High Gain Amplified Telephones

Performance Requirements, Test Methods, and Test Procedures

Release R0
March 30, 2011

Revision History

Date	Revision	Author	Description
3/24/2011	Draft R1	AST (Bress / McKinnon)	Release coinciding with availability of testing services at AST for amplified telephones
3/30/2011	Release R0	AST (Bress / McKinnon)	Official release version. Ringer acoustics updated.

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1 INTRODUCTION

This document presents performance requirements, measurement methods, and test procedures to test the acoustic performance of high gain amplified telephones. High gain amplified telephones sold in the United States must currently only meet minimum standards that apply to normal (unamplified) telephones as specified in TIA−968−B, FCC parts 15 and 68, and UL 60950. These standards do not address telephone receiver performance beyond the FCC minimum required 12 dB volume control gain requirements or describe telephone audio and acoustics performance for telephones intended to be used by individuals with hearing loss.

The purpose of this document is to establish a measurement specification that enables comparing two different high gain amplified telephones in a meaningful way and to provide useful information for end users with hearing loss who depend on such devices to enable acquiring such a device with greater confidence.

High gain amplified telephones may be either corded or cordless and are used specifically by people with hearing loss. High gain amplified telephones are designed with control over critical characteristics such as level (loudness), frequency response, distortion, signal to noise ratio, acoustic stability (no howling), and other audio parameters. This document specifies measurement techniques and parameters to address these and other performance requirements.

This specification does not currently address cellular or mobile phones, as they are measured in a different manner due to the complexities of the RF interface to the cellular base station. However, the acoustic characteristics specified in this document for hearing loss would still be applicable.

2 OVERVIEW

2.1 Scope

This specification establishes handset audio performance requirements, measurement methods, and test procedures for telephones with high receive gain and control of the receive frequency spectrum. This specification addresses audio performance in narrow band telephony frequencies using scientific methods and techniques derived or adapted from current telephone measurement standards. Narrow band is defined as the frequency range between 300 and 3400 Hz.

The current revision of this document addresses analog interface telephones designed for connection to the PSTN (Public Switched Telephone Network). PSTN connected telephones have a narrow band frequency range. Future revisions of this standard may address VoIP and other digital interface telephones including wide band telephony.

2.2 Measurement Requirements

The test measurement methods in this document reference procedures in IEEE and TIA Standards and ITU-T recommendations. Although this document may reference specific procedures or test equipment, other measurement procedures and equipment that can generate an equivalent result will be considered valid. However, it is the responsibility of the tester to insure equivalence.

2.3 Other Telephony Performance Considerations

This document does not specify the complete analog telephone performance requirements (e.g. Network Dialing, Resistance and Impedance, Caller-ID, etc. are not included). The complete list of analog interface telephone related performance requirements can be found in TIA−470.000−D.

It is expected that a high gain amplified telephone will meet the TIA−470.000−D list of requirements for normal telephone operation. Limited acoustic testing for normal acoustic performance is specified in this document to establish the baseline performance.

2.4 Safety Performance Considerations

This document does not contain acoustic safety requirements. Measurements for long term acoustic output, which is a safety requirement, is included in this specification but only for the purposes of verifying the measured receive gain levels are obtained without exceeding maximum sound pressure level limits which have been established for safety.

2.5 Environmental Considerations

This document does not contain environmental related requirements. Environmental related requirements for telephones can be found in ANSI/TIA−571−B and ANSI/TIA−-631−A.

3 REFERENCES

3.1 Standards References

The following standards contain provisions, which through reference in this text, constitute provisions of this document. At the time of publication of this document, the editions indicated were valid. All standards are subject to revision, and testers using this specification are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

1. **IEEE Std 269-2010** – *Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets, Handsets and Headsets*
2. **IEEE Standard 1652-2008** – *IEEE Standard for the Application of Free Field Acoustic Reference to Telephony Measurements*
3. **47 CFR Part 68** – *Code of Federal Regulations (CFR), Title 47, FCC Part 68, Connection of Terminal Equipment to the Telephone Network.*
4. **ITU-T Recommendation P.57 (2008)** – *Artificial Ears*
5. **ITU-T Recommendation P.58 (1996) and P.58 Note (2008)** – *Head and torso simulator for telephonometry*
6. **ITU-T Recommendation P.79 (1999)** – *Calculation of Loudness Ratings for Telephone Sets*
7. **ANSI/TIA−470.110−C-2004** *Telecommunications – Telephone Terminal Equipment – Handset Acoustics Performance Requirements for Analog Telephones*
8. **ANSI/TIA−470.220−C-2004** *Telecommunications – Telephone Terminal Equipment – Alerter Acoustic Output Performance Requirements for Analog Telephones*

3.2 Other References

1. *Report on Selection of Standard Audiograms for the ISMADHA Measurement Procedure*, Nikolai Bisgaard, EHIMA Technical Committee, August 2007-08-06

4 ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

4.1 Abbreviations and Acronyms

For the purposes of this standard, the following abbreviations and acronyms apply.

DRP Drum Reference Point

DUT Device Under Test

ERP Ear Reference Point

FF Free-Field

HATS Head And Torso Simulator

HFE High Frequency Emphasis

MRP Mouth Reference Point

PSTN Public Switched Telephone Network

RTP Recommended Test Position

SLR Send Loudness Rating

SPL Sound Pressure Level

STMR Sidetone Masking Rating

4.2 Definitions

For the purposes of this standard, the following definitions apply.

Conversational Gain: The level of an acoustic output signal relative to 70 dBSPL for handsets or single ear headsets, and 64 dBSPL for dual ear headsets and speakerphones.

Handsets and single-ear headsets
Conversational Gain = (Measured dBSPL Level – 70 dBSPL) dB

Dual-ear headsets and speakerphones

Conversational Gain = (Measured dBSPL Level – 64 dBSPL) dB

dBm: Power level in decibels, relative to a power of 1 mW (milliwatt).

dBmp: Power level in decibels, relative to a power of 1 mW, using psophometric weighting.

dBV: Voltage level in decibels, relative to 1 volt rms.

dBPa: The logarithmic measure of the measured sound pressure relative to a reference pressure:

Lp = 20 Log10 (Prms/Pref) dBPa

Where

Pref = 1 Pascal = $1N/m^2$

dBSPL: The logarithmic measure of the effective sound pressure of a sound relative to a reference value, measured in decibels (dB) above a standard reference level.

Lp = 20 Log10 (Prms/Pref) dBSPL

Where

Pref = $2 \times 10^{-5} N/m^2$

The relationship of dBPa to dBSPL is:

0 dBPa – 94 dBSPL

dBA: Sound pressure level in decibels (dBSPL), relative to 2×10^{-5} Pa, using A-weighting specified in ANSI S1.4.

Mouth Reference Point (MRP):
A point on the axis of the mouth simulator, 25 mm in front of the center of the equivalent lip plane.

Nominal Tone Control Setting:
The tone control setting which results in the receive frequency response being closest to the middle of the “desired” receive frequency response mask in TIA-470.110-C.

Nominal Volume Control Setting:
The volume control setting that results in a Conversational Gain closest to 6 dB.

Ringer Gain: The calculated average sound pressure level of the ringer acoustic output signal relative to 75 dBSPL.

Ringer Gain = (Measured average SPL (dBSPL) – 75 dBSPL) dB

Usable Gain: Conversational Gain plus the level of the input signal used for testing relative to -28 dBV.

<u>Handsets and single-ear headsets</u>
Usable Gain = (Measured dBSPL Level – 70 dBSPL) + (–28 dBV – Input Signal Level) dB

<u>Dual-ear headsets and speakerphones</u>

Usable Gain = (Measured dBSPL Level – 64 dBSPL) + (–28 dBV – Input Signal Level) dB

5 PERFORMANCE REQUIREMENTS

The performance requirements, for high gain amplified analog interface telephones with a handset, are summarized in this section.

1. Measurement of Maximum Usable Receiver Gain
2. Measurement of Maximum Ringer Acoustic Level
3. Performance requirements specified for three hearing loss categories:
   a. Receiver Conversational Gain and High Frequency Emphasis (HFE)
   b. Ringer gain

Hearing Loss Category	**Hearing Loss (HL) Range**	**Hearing Loss Frequency Response Slope Type**	**Required Telephone Receiver HFE** **Tolerance: (+/- 4 dB)**	**Required Telephone Receiver Gain** **(Reference= 70 dBSPL)** **Tolerance: (+/- 4 dB)**	**Required Telephone Ringer Gain** **(Reference= 75 dBSPL)** **Tolerance: (+/- 4 dB)**
Mild	20 dB to 40 dB	Slight Slope	9 dB	16 dB	13 dB
		Steep Slope	14 dB		
Moderate	40 dB to 70 dB	Slight Slope	9 dB	31 dB	26 dB
		Steep Slope	25 dB		
Severe	70 dB to 90 dB	Slight Slope	9 dB	41 dB	33 dB
		Steep Slope	21 dB		

   c. Ringer frequency spectrum requirements:
      - f1 >=400Hz, <= 800 Hz
      - f2 <= 1000 Hz
      - f2 is at least 1.25 times f1 (i.e., $f2 \geq 1.25*f1$)
      - f1 and f2 are not harmonically related
      - f1 level
      - f2 level
      - f1 level - f2 level difference <= 10 dB.

4. Other Acoustic Performance Requirements
    a. Maximum long duration SPL ≤ 125 dBA
    b. Send Frequency response and SLR meets TIA-470.110-C requirements for all volume control and tone control settings tested.
    c. Stability meets TIA−470.110−C requirements for all volume control and tone control settings tested.
5. Normal Mode Acoustics Performance Requirements
    - The telephone must include settings for “normal” send, receive, and sidetone frequency response and loudness acoustics performance which are specified in TIA−470.110−C.

    Note: TIA−470.110−C specifies using a 10N force of the handset against the HATS ear when testing.
6. Acoustic Hearing Aid Compatibility Performance Requirements
    - The telephone must include settings for “normal” send, receive, and sidetone frequency response and loudness acoustics performance which are specified in TIA−470.110−C that can be met when two Newtons (2N) of force are used when testing with the HATS.

    Note: A 2N force simulates usage of the telephone handset by a person using a hearing aid.
7. Cordless Telephone Magnetic Hearing Aid Compatibility Performance Requirements
    - The telephone must pass TIA−1083−A for magnetic signal output performance.
8. Regulatory and Safety
    a. FCC Part 68.316 and 68.317 including Volume Control and Hearing Aid Compatibility. The product must bear an FCC Part-68 registration number.
    b. FCC Part 15. The product must bear an FCC Part-15 registration number.
    c. UL60950 for safety. The product must bear a registered safety mark – UL, ETL, WH, etc.

6 GENERAL TESTING METHODS INFORMATION

The following information provides insight into the basic principles used for performing testing per this specification. See ANNEX-A: Requirements and Measurements Rationale for further information regarding the rationale for establishing the performance requirements and other information regarding testing methods.

6.1 Conversational Gain

Acoustical gain measurements for this specification are based on measurements described in IEEE-269 and proposals which are being reviewed (and provisionally accepted) by TIA and the FCC to use the concept of "Conversational Gain". Conversational Gain is based on the well accepted fact that when two people are talking to each other at about 1 meter apart, the acoustic level at the listener's ear is 64 dBSPL (average listening level). If only one ear were used (for example in the case of a telephone handset or a single ear headset) then the level in the one ear needs to increase by approximately 6 dB to be perceived as an equivalent level to a two-ear listening at 64 dBSPL. Therefore, the reference handset listening level is established as 70 dBSPL and Conversational Gain for handset measurements are referenced to the 70 dBSPL level.

- **Conversational Gain (handset, single-ear headset) =**
  Measured dBSPL – 70 dBSPL (dB)

6.2 Maximum Usable Gain

The concept of Conversational Gain does not account for additional gain a telephone may provide when the received signal level is lower than an average receive level (e.g., -28 dBV). Traditionally designed telephones were designed with a linear response to received signal level changes (i.e., when the received signal goes up or down X dB the acoustic output level also goes up or down X dB). A telephone that can provide additional gain when the received signal level is lower provides additional useful functionality, especially for a hearing impaired person whose dynamic range of hearing is usually less than that of a person with normal hearing.

- The Usable Gain for a telephone is calculated based on the 70 dBSPL reference level and the -28 dBV reference test signal input level. The formula for Usable Gain of a handset or single-ear headset is:
  - Usable Gain =
    (Measured dBSPL – 70 dBSPL) + (-28 dBV – test signal input level) (dB)

  For example, if a test signal level of -43 dBV yielded an acoustic output level of 110 dBSPL then:
    - Usable Gain = (110 – 70) + (-28 – (-43)) = 40 + 15 = 55 dB

Because the lowest test signal level specified is -43 dBV, the "Maximum Usable Gain" of a telephone is therefore defined in terms of gain as described above when tested with a -43 dBV test signal level. -43 dBV is the lowest level test signal to be used to measure Maximum Usable Gain.

- **Maximum Usable Gain = Measured dBSPL – 55 dB**
  (tested with a -43 dBV test signal level)

6.3 Nominal Volume Control Setting

The Nominal Volume Control Setting is the setting that yields a Conversational Gain of 6 dB when tested with the -28 dBV test signal level and the tone control set to nominal. It is well accepted within the telephone industry that an original design AT&T 2500 (or 500) telephone will produce about 76 dBSPL when a signal level of -28 dBV is received when the telephone volume control is set to provide nominal ROLR (i.e., the middle of the receiver loudness tolerance established in TIA-470). The original telephone design therefore had 6 dB of Conversational Gain (76 dBSPL – 70 dBSPL) for average input signal level conditions. This original design compromise was made to account for the fact that actual received signal levels will have a wide dynamic range.

6.4 Nominal Tone Control Setting

The Nominal Tone Control Setting is the setting that yields a frequency response that is as close as possible to the middle of the "desired" receiver frequency response mask as specified in TIA−470.110−C with the Nominal Volume Control Setting.

6.5 High Frequency Emphasis (HFE)

Tone control is measured by establishing a parameter called "HFE" (High Frequency Emphasis). HFE is calculated by measuring the band energy of the acoustic signal:

1. HFE-Low- band: Three 1/3 octave bands below 1KHz
2. HFE-Mid-band: Three 1/3 octave bands with 1 KHz near the center of the bands
3. HFE-High-band: Three 1/3 octave bands above 1 KHz.

The calculated HFE is the HFE-High-band (dB) average minus the HFE-Low-band (dB) average. Negative HFE indicates that the telephone receive design has a frequency response with more gain in the lower frequency bands.

In addition to comparing the HFE-High-band dB average to the HFE-Low-band dB average, additional requirements are:

1. The HFE-Mid-Band dB average must be higher than the HFE-Low-band dB average
    - HFE-Mid-band dB average > HFE-Low-band average
2. The HFE-Mid-Band dB average must not be more than 3 dB higher than the HFE-High-band dB average
    - HFE-Mid-band dB average < HFE-High-band average + 3 dB

The HFE-Mid-band requirements are included to ensure the frequency response is generally a controlled response with slope that has increasing gain for increasing frequency without a significant attenuation or gain in the mid-band frequencies around 1 KHz.

Frequency response measurements produce dB vs. frequency data. In this case the dB values are actually dBSPL / dBV which is only meaningful as a unit-less dB value for frequency response. Nonetheless, HFE is calculated by using the frequency response dB values as if they were dBSPL values and measuring 1/3 octave band energy. Mathematically, HFE is calculated from 1/3 octave band energy measurements:

- HFE-Low-band = (315 Hz FR + 400 Hz FR + 500 Hz FR) / 3
- HFE-Mid-band = (800 Hz FR + 1000 Hz FR + 1250 Hz FR) / 3
- HFE-High-band = (2000 Hz FR + 2500 Hz FR + 3150 Hz FR) / 3
- **HFE = HFE-High-band - HFE-Low-band (dB)**
- **Verify:**
  - **HFE-Mid-band > HFE-Low-band**
  - **HFE-Mid-band < HFE-High-band + 3 dB**

Where "FR" denotes the value is the frequency response value for each 1/3 octave band.

NOTE 1: Although the general desire is to have an upward sloping frequency response, the 3 dB allowance for the HFE-Mid-band to exceed the HFE-High-band was included as a practical matter (compromise) due to the fact that some telephones exhibit higher mid-band frequency response (called a "haystack" effect).

NOTE 2: The HFE-Low band 1/3 octave band frequencies do not include the lowest frequency band (250 Hz) as stated in IEEE-269. This change was made because the analog telephone network is designed to carry frequencies limited to the 300 Hz to 3400 Hz range.

6.6 Hearing Loss Categories

This specification establishes three categories of hearing loss: Mild, Moderate, and Severe. The concept of defining Mild, Moderate and Severe categories related to gain and tone control is in response to the fact that the design of different telephones will provide multiple combinations of volume control and tone control settings. If an attempt were made to test and report all combinations of settings the amount of testing and test data could be overwhelming and as such may make the use of the data for comparison of products impractical.

Instead, each category of hearing loss defined (Mild, Moderate, and Severe) is defined with a specified receiver gain range and a specified HFE (High Frequency Emphasis) range. In addition acoustic ringer gain and frequency spectrum are included in the hearing loss category requirements. For a telephone to pass the requirements for the Mild, Moderate, or Severe category, the telephone must be able to be set within the ranges for volume control gain and tone control HFE, and ringer gain and frequency spectrum, as specified for each respective hearing loss category.

Telephones will receive audio signals with a range of amplitudes due primarily to variations in far-end talker levels and audio signal attenuation in the telephone transmission network. It is important for telephones designed to be used by persons with hearing impairment that the appropriate acoustical output level is able to be generated regardless of the level of the received signal. The requirements are stated such that for a telephone to be deemed to provide the necessary gain and tone control for a specific hearing loss category, the specified Conversational Gain and HFE must be obtainable (i.e., settable) when the received signal is anywhere within the expected dynamic range for received signal level (i.e., the lowest expected receive signal level to the highest expected receive signal level). For testing purposes, three levels of receive test signal are used for analog interface telephones. These levels are specified in IEEE-269.

- Minimum (-43 dBV)
- Average (-28 dBV)
- Maximum (-13 dBV)

6.7 "Pre-Qualified" Receive Signals for Distortion and Noise

All receiver gain measurements reported for this specification must be "pre-qualified" such that the acoustic receive signal meets minimum receive distortion and receive noise requirements. The test procedures in this document specify that if a volume control and tone control setting combination tested produce a signal which fails either the receive distortion or receive noise requirement, then the volume control or tone control must be adjusted to obtain a signal which meets the receive distortion and receive noise requirements.

6.7.1 Receive Distortion

Receive distortion testing using traditional "tone based" distortion measurements may be inaccurate when testing devices with a significantly "non-flat" frequency response (e.g., high frequency emphasis). Therefore, receive distortion testing shall be performed first using the "1/3 octave pulsed noise" test signal and methods specified in IEEE-269. In addition, receive distortion measurements often do not reflect the psycho-acoustic effects of distortion and noise that may be mixed with the intended signal.

It is generally accepted that if the objective (i.e., measured with equipment) distortion test passes, then the subjectively assessed distortion will also be acceptable (i.e., "false positives" for failing distortion are not expected to occur). Because the same is not true for "false negatives" regarding distortion tests (i.e., a distortion test may yield a failing result but subjectively, the distortion is deemed to be acceptable) there exists a need to allow a "subjective override" if an objectively measured receive distortion fails the requirements.

Given distortion measurements may not accurately affect the psycho-acoustic assessment of distortion, in the event a receive distortion measurement fails, before it is deemed a failed test, testing will be performed subjectively to identify any "significant clipping". "Significant clipping" is the standard stated in FCC Part-68.317 for volume control performance. The specified IEEE 12 second male real speech signal shall be used for subjective receive distortion testing.

6.7.2 Receive Noise

TIA−470.110−C specifies a maximum allowable receive noise level of 40 dBA which is based on volume control settings set for nominal RLR. If the receive noise was at the maximum allowable 40 dBA, then with a receive signal level = 76 dBSPL a 36 dB SNR exists, and if the receive signal level were 15 dB lower (=61 dBSPL) then a 21 dB SNR exists. This specification uses SNR to evaluate the noise level rather than an absolute maximum noise level. SNR is used to account for the fact that if a person has hearing impairment and needs gain (Conversational Gain) to hear the intended signal, lower noise levels will also not be audible without gain applied. This specification uses 26 dB as the minimum allowable SNR when tested with a specified test signal level.

Noise measurements are A-weighted and referenced to the free-field (FF). The signal level used for SNR calculations is the FF SPL measured for each of the combinations of volume control and tone control specified.

Due to the fact that Voice Activity Detectors (VAD) and/or voice path switching features may be used, noise measurements are made by applying a 3 second test speech signal and then measuring the quiescent noise (i.e., noise when no receive signal is applied) just after the receive speech signal ends.

6.8 Send, Sidetone, Maximum SPL, Stability

In addition to receiver acoustics testing, send, sidetone, maximum sound pressure level, and stability must meet regular industry standards (TIA−470.110−C, and UL 60950) for the range of settings tested for a telephone. It is important that settings for receive volume control and tone control settings do not negatively affect other transmission parameters.

6.9 Acoustic Hearing Aid Compatibility

Telephones shall pass the requirements for normal receiver acoustics specified in TIA−470.110−C for the 2.7 km loop test when tested using a 2 Newton (2N) force against the HATS ear rather than the 10 Newton (10N) force specified in TIA−470.110−C. A force of 2N is typical usage of a handset for people using a hearing aid. It is assumed that for a person with a hearing aid, the hearing aid provides the desired amplification, so this requirement ensures that when the telephone is used with a hearing aid, the receiver acoustics will provide normal acoustic signals.

6.10 Magnetic Hearing Aid Compatibility (HAC) for Cordless Telephones

Cordless telephone handsets must be tested to TIA−1083−A to verify the receiver's magnetic audio signal output meets the requirements for amplitude, frequency response, SNR, and noise.

6.11 Ringer (Alerter) Maximum Sound Pressure Level

The telephone's default ringer tone acoustic ringer level and frequency spectrum is measured per the requirements in TIA−470.220−C (A-weighted) using the maximum ringer volume setting.

TIA−470.220−C includes the following requirements which are **not** included in this specification.

1. Ring signal detection with variations of the DC voltage with the ringing signal.
2. Ring signal detection with variations of the ringing signal frequency or amplitude.
3. Ringer "no response" for various signals which may be received on a telephone line (e.g. line maintenance signals) that should not cause the telephone to generate an acoustic ringing signal.
4. Ringer on/off timing vs. ring signal timing.

6.12 Ringer (Alerter) Hearing Loss Categories

The telephone's default ringer tone acoustic ringer level and frequency spectrum is measured per the requirements in this document. Differences from TIA−470.220−C are:

1. Uses a 20Hz, 40Vrms ring signal.
2. Does not utilize the A-weighting curve.
3. f1 minimum frequency of 400 Hz vs. 500 Hz.
4. f1 maximum frequency of 800 Hz vs. 1600 Hz.
5. f2 maximum frequency of 1000 Hz vs. 3000 Hz
6. The plotted spectrum and frequency content are from the compiled average sound pressure of the 6 positions vs. using the 0 degree position.

6.13 Regulatory and Safety

All telephones must have labeling showing the required regulatory compliance and safety listings for:

1. FCC Part-68
2. FCC Part-15
3. Safety Listing (e.g., UL)

7 *TESTING AND MEASUREMENT METHODS*

This section includes methods to be used when performing measurements as described in the testing procedures in section 8.

7.1 Handset Receive Performance Testing Methods

7.1.1 Receive Frequency Response

Receive frequency response is the measurement used to graphically display the acoustic output of the telephone relative to the electrical input signal. Receive frequency response is measured by applying the electrical test signal (specified level in dBV) to the telephone and capturing the frequency spectrum of the receiver's acoustic output signal (measured as dBPa). The measurement is made using real-time analysis with 1/3 octave or smaller bands averaged over the entire duration of the test signal. If bands smaller than 1/3 octave are used then the frequency response shall be band averaged to 1/3 octave (see IEEE 269) before being presented in terms of dBPa/V.

7.1.2 Receive Level

The receive acoustic level is the measurement used to calculate receive Conversational Gain and Usable Gain values. The receive level is measured by:

1. Applying the test signal (dBV) and capturing the frequency spectrum of the telephone's acoustic output signal (dBPa) using real-time analysis with 1/12 octave bands averaged over the entire duration of the test signal from 100 Hz to 8000 Hz.
2. The DRP data is translated to the FF by applying the DRP-FF transfer function (See IEEE 1652).
3. The 1/12 octave band measurements included in the 1/3 octave bands between 315 Hz to 3150 Hz are power summed and the result expressed in terms of dBSPL for the receive level measurement.

7.1.3 Receive High Frequency Emphasis (HFE)

The receive HFE is calculated from the receive frequency response 1/3 octave data. The following are examples of HFE calculations for a negative, flat and positive HFE. HFE bands are calculated by averaging "dB-wise" the dB level of the three 1/3 octave bands that are defined for the HFE-Low-band, HFE-Mid-band, and HFE-High-band respectively.

HFE Type	**Frequency Response Data (dB)**													
	200 Hz	250 Hz	**HFE Low Band**			630 Hz	**HFE Mid Band**			1600 Hz	**HFE High Band**			4000 Hz
			315 Hz	**400 Hz**	**500 Hz**		**800 Hz**	**1000 Hz**	**1250 Hz**		**2000 Hz**	**2500 Hz**	**3150 Hz**	
Negative	46	53	56	62	64	63	61	60	59	57	55	53	51	22
Flat	43	38	45	49	52	53	50	49	48	48	50	55	51	38
Positive	32	39	44	50	55	56	58	60	63	65	67	67	68	42

	HFE Low Band Average (315 Hz + 400 Hz + 500 Hz) (dB)	HFE Mid Band Average (800 Hz + 1000 Hz + 1250Hz) (dB)	HFE High Band Average (2000 Hz + 2500 Hz + 3150Hz) (dB)	HFE (High band – Low band) (dB)	HFE Mid Band Requirements Met (Yes / No)
Negative	60.7	60.0	53.0	-7.7	NO
Flat	48.7	49.0	52.0	0.7	NO
Positive	49.7	60.3	67.3	17.6	YES

7.1.4 Receive Distortion

Receive distortion testing shall be performed using the 1/3 octave pulsed noise SDNR measurement specified in IEEE-269-2010. The following testing parameters shall be used:

1. -15 dBV test signal level
2. Test Frequencies:
    a. 400 Hz
    b. 1000 HZ
    c. 2000 Hz

- **The SDNR measurement must be greater than or equal to 20 dB (i.e., less than or equal to 10%).**

Subjectively Determined Override

In some cases objectively measured distortion does not reflect what is subjectively considered objectionable. Due to these questions regarding receive distortion tests, if the SDNR test fails, the tester shall use subjective listening methods to evaluate if the receive signal has "significant clipping" or other sound that is unacceptable. If the subjective testing shows the receive signal is acceptable, then the measured distortion level shall be reported but "waived subjectively" shall be stated to show the outcome of the subjective testing.

Note: To implement a subjective test for receive distortion the ear simulator measurement microphone output signal shall be routed (bridged) to a separate amplifier and speaker that the tester can listen to.

7.1.5 Receive Noise

Receive noise testing is performed by first applying a 3 second speech signal and then measuring the quiescent noise after the speech signal has ended. The initial speech signal is applied so the receive signal path is active in the case when a Voice Activity Detector (VAD), or other features which may switch the gain of the receive signal, are present. The following testing parameters and methods are used:

1. The first 3 seconds of the IEEE male test speech shall be used with a 50 ms silence appended to the end of the speech signal.
2. The test signal level shall be the same as the level used to measure the receive level for a given test scenario.
3. The noise measurement shall be started no later than 50 ms after the end of the test signal (3 second speech+50 ms silence) and the noise shall be measured for 500 ms.
4. The measurement may be performed directly with an A-weighting filter, or may be calculated from the FFT spectrum or real-time spectrum analysis measurement and post-processing using an A-weighting filter (See TIA−470.110−C Annex A).
5. The DRP data is translated to the FF by applying the DRP-FF transfer function (See IEEE 1652).
6. The noise is calculated using the 100 Hz to 8000 Hz band and the result expressed in terms of dBA.
7. During the measurement the handset microphone shall be isolated from sound input and mechanical disturbances. A microphone mute feature shall not be used.
8. The background noise level shall be less than 29 dBA.

Receive noise shall be evaluated as a Signal-to-Noise-Ratio (SNR). The SNR shall be calculated as:

- Receive SNR = Receive Level (dBSPL) – Receive Noise (dBA)
- **The receive SNR shall be greater than 26 dB.**

7.2 Handset Send Performance Testing Methods

7.2.1 Send Frequency Response

The telephone’s send frequency response is the measurement used to graphically display the electrical output of the telephone relative to the acoustic input signal.

1. Apply the acoustic test signal (dBPa) to the handset microphone and capture the frequency spectrum of the telephone’s electrical output signal (dBV).
2. The measurement is made using real-time analysis with 1/3 octave or smaller bands averaged over the entire duration of the test signal. If bands smaller than 1/3 octave are used then the frequency response shall be band averaged to 1/3 octave (see IEEE 269) before being presented in terms of dBV/Pa.
3. The electrical output frequency spectrum is then divided by the frequency spectrum of the acoustic input signal to obtain the frequency response data.
4. The send testing may be performed using the ITU Male P.50 test signal rather than the IEEE 12 sec real speech test signal.

7.2.2 Send Loudness

The telephone’s send loudness is calculated from the transmit frequency response data presented in terms of SLR (per TIA−470.110−C) using ITU-T P.79.

7.3 Handset Sidetone Performance Testing Methods

7.3.1 Sidetone Frequency Response

The telephone's sidetone frequency response is the measurement used to graphically display the acoustic output of the telephone receiver relative to the microphone acoustic input signal.

1. Apply the acoustic test signal (dBPa) to the handset microphone and capture the frequency spectrum of the receiver acoustic output signal (dBPa).
2. The measurement is made using real-time analysis with 1/3 octave or smaller bands averaged over the entire duration of the test signal. If bands smaller than 1/3 octave are used then the frequency response shall be band averaged to 1/3 octave (see IEEE 269) before being presented in terms of dBPa/Pa.
3. The acoustic output frequency spectrum is then divided by the frequency spectrum of the acoustic input signal to obtain the frequency response data.
4. The telephone's sidetone testing may be performed using the ITU Male P.50 test signal rather than the IEEE 12 sec real speech test signal.

7.3.2 Sidetone Loudness

The telephone's sidetone loudness is calculated from the sidetone frequency response data presented in terms of STMR per (TIA−470.110−C) using ITU-T P.79.

7.4 Handset Maximum Receiver Sound Pressure Level (SPL) Testing Methods

The maximum receiver SPL measurement is performed to determine the maximum acoustic output when a large electrical signal is applied to the telephone.

1. Apply a +15 dBV, 100 Hz to 8500 Hz, square wave electrical test signal to the telephone using a slow logarithmic sine sweep (at least 90 seconds duration) that does not provide an underestimation of the receiver acoustic output.
2. The receiver acoustic output is measured using real-time analysis with 1/12 octave bands using rms fast averaging (250ms effective averaging time) and peak hold over the entire duration of the test signal.
3. The measurement may be performed directly with the A-weighting filter, or may be calculated by post-processing with application of the A-weighting filter (See TIA−470.110−C Annex A). The spectrum result is expressed in terms of dBA.

NOTE: The test signal used for this test may be 100 Hz to 8000 Hz.

- **<u>No frequency component from 100 Hz to 8000 Hz shall exceed 127 dBSPL.</u>**

  NOTE: 125 dB is the UL maximum but for this specification 2 dB higher (127 dBSPL) is accepted to allow for variations in lab test equipment and the specific unit tested. This test is performed to confirm that the unit does in fact conform but only for the purposes of not overstating the telephone's receive acoustic gain.

7.5 Handset Stability Testing Methods

Stability testing is performed using the reference corner (Figure 1) as specified in TIA−470.110−C and tested with the following handset test orientations:

1. Per Figure 2, place the handset face-down on the Base plane 25cm from the reference corner, equal distant from each side plane. Slowly lift the handset vertically approximately 25cm and then return to the Base plane surface.
2. Per Figure 3, place the handset on its side facing parallel to Side A, 25cm from the Side A plane and equal distance from the Side B plane and the end of the Base plane. Slowly move the handset to the side plane surface, maintaining parallel orientation and then return to the starting point.

- **<u>No howling or loud sounds shall be audible from the handset receiver during the entire stability testing procedure.</u>**

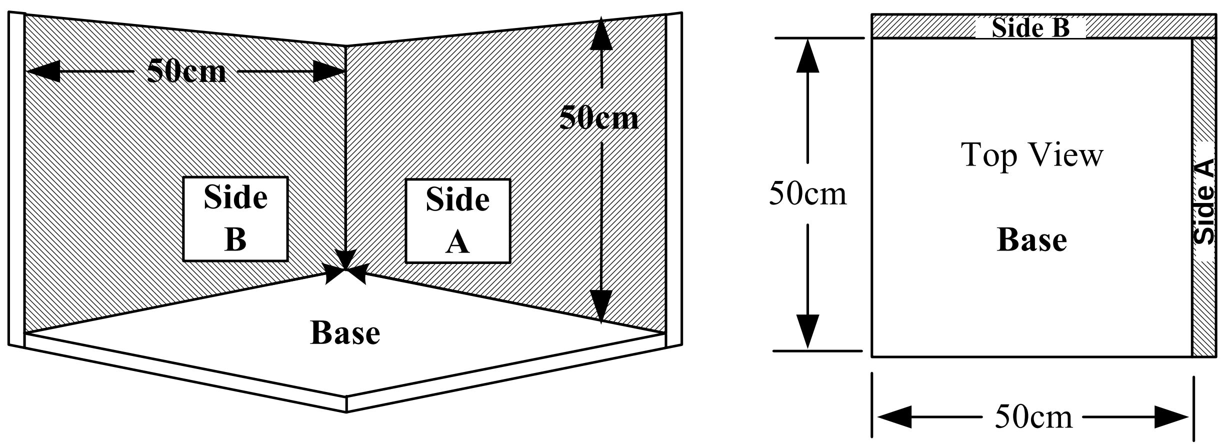


Figure 1 – Reference Corner

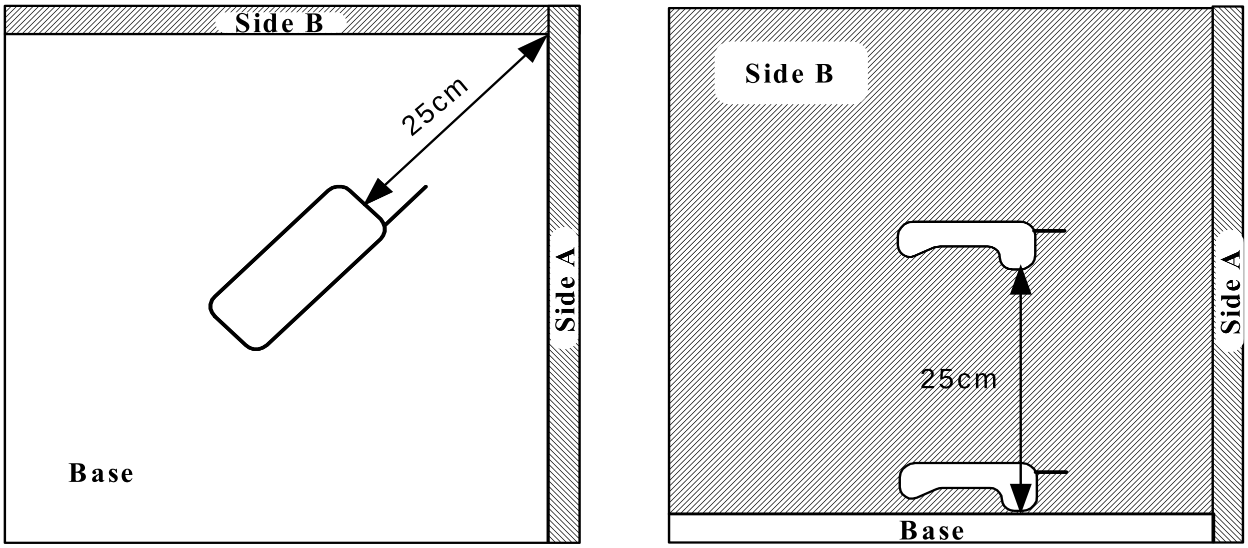


Figure 2 – Stability Face Down Orientation - Test #1

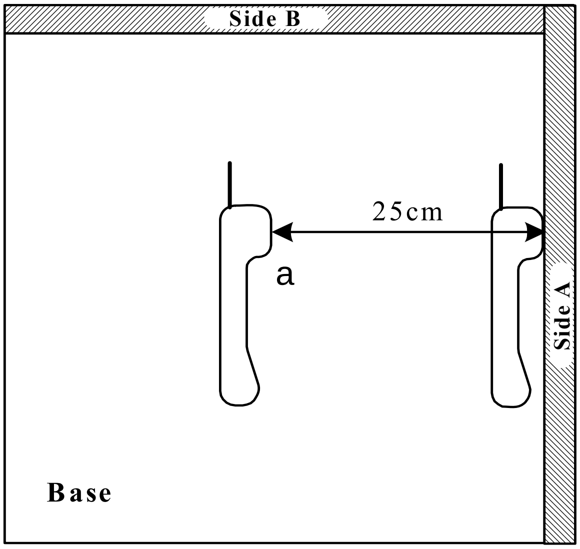


Figure 3 – Stability On Side Orientation – Test #2

7.6 Ringer (Alerter) Maximum Sound Pressure Level Testing Methods

The telephone's default ringer tone acoustic ringer level and frequency spectrum is measured per the requirements in TIA−470.220−C (A-weighted) using the maximum ringer volume setting.

7.7 Ringer (Alerter) HL Performance Testing Methods

Ringer HL acoustic sound pressure level output and frequency content are measured as specified below. The ringer shall be tested with a 20 Hz, 40 Vrms power ringing signal and without any spectral weighting. Figure 4 below from TIA−470.220−C shows the test position set-up used.

1. Connect the telephone to the ringer generator test circuit and position the telephone at the 0-degree microphone position.
2. Apply a 2 second on,4 second off, 20 Hz, 40 Vrms ringing signal and for period the acoustic alerter is on measure with a maximum resolution of 5 Hz and Flat-Top windowing:
   a. The 100 Hz to 8000 Hz frequency spectrum.
   b. The sound pressure level for the 100 Hz to 8000 Hz frequency spectrum.
3. Repeat frequency spectrum and sound pressure level measurements for the remaining five microphone positions (60, 120, 180, 240 and 300-degrees).
   Note: The microphone can be moved or the telephone rotated (microphone stationary) to achieve the test positions.

4. The ringer's average sound pressure level shall be calculated according to the following formula:

$$Lp = 10 \log_{10} \left[\tfrac{1}{6} \sum_{i=1}^{6} 10^{(Lpi/10)} \right] \text{dBSPL}$$

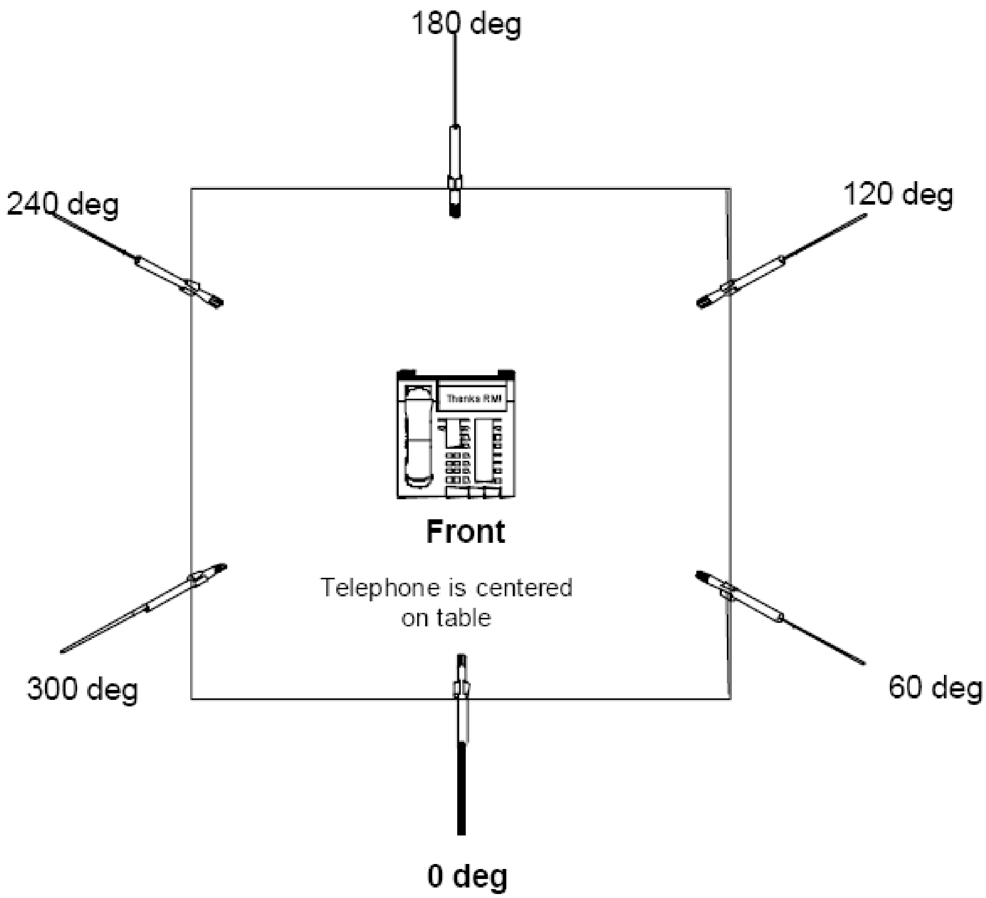
Where:
Lp = the average alerter sound pressure, in dBSPL.
Lpi = the 100 Hz to 8000 Hz sound pressure level, in dBSPL, for each microphone position. (0 deg, 60 deg, 120 deg, 180 deg, 240 deg, 300 deg)

5. The ringer's average sound pressure spectrum shall be calculated for each frequency point from 100 Hz to 8000 Hz according to the following formula:

$$Lf_{(100\ \text{to}\ 8000\text{Hz})} = 10 \log_{10} \left[\tfrac{1}{6} \sum_{i=1}^{6} 10^{(Lfi/10)} \right] \text{dBSPL}$$

Where:
$Lf_{(100\ \text{to}\ 8000\text{Hz})}$ = the average alerter sound pressure, in dBSPL, for each frequency point from 100 Hz to 8000 Hz.
Lfi = the sound pressure, in dBSPL, for the frequency point at each microphone position (100 Hz 0 deg, 60 deg, 120 deg, 180 deg, 240 deg, 300 deg, up to 8000 Hz 0 deg, 60 deg, 120 deg, 180 deg, 240 deg, 300 deg)

6. Determine the f1, f2 frequencies and levels from the average sound pressure spectrum ($Lf_{(100\ \text{to}\ 8000\text{Hz})}$).
7. Determine the Ringer gain by subtracting 75 from the average sound pressure level (Lp)



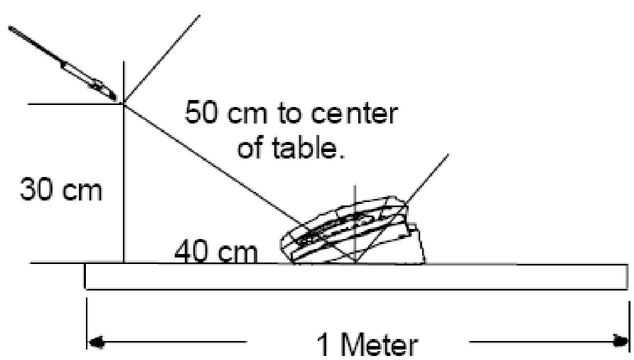


Figure 4 – Ringer Sound Pressure Level Testing per TIA−470.220−C

7.8 Test Equipment

7.8.1 Artificial Ear Couplers and Test Position

Artificial ear coupler calibration, usage and handset positioning shall be performed according to IEEE-269. A Type-3.3 ear simulator used with a Head And Torso Simulator (HATS), as specified in ITU P.57 and ITU P.58 respectively, shall be used for testing.

- The handset shall be positioned in the Standard Test Position (STP) with the receiver contacting the pinna with a force of 10N.
- If the handset contacts the HATS with the STP and 10N force, the rotation (angle) shall be adjusted to remove the contact before testing is performed.
- The handset contact region shall be adjusted to allow an air space between the handset and HATS of 2-5 mm.
- The new positioning is referred to as the Recommended Test Position (RTP). The mounting force (10N) remains the same with the RTP.
- The positioning used for testing shall be recorded.

7.8.2 DC Feed Circuit

The dc feed circuit must supply the power and interface such that the required parameters may be measured without introducing any significant error. The dc feed shall provide the following:

- 50 Vdc (+/- 2Vdc) in series with 400 ohms (± 1%).
- Less than 0.1 dB insertion loss over the 100 Hz to 10 kHz range (See IEEE Std 269)
- A resistive AC load of 900 ohms (± 1%) termination impedance.
- An AC source impedance of 900 ohms (± 1%)
- Loop resistance simulations to change the DC loop current:
    - 1600 ohms (long loop resistance)
    - 700 ohms (medium loop resistance)
    - 200 ohms (short loop resistance).

Note: The loop resistance simulation is in series with the 400 ohms and are not AC signal loop simulators (i.e. not in series with AC signals).

7.8.3 Ringer Test Circuit

The ringer test circuit must supply the DC Voltage and ring signals. See TIA−470−220−C for example of a ringer test circuit.

7.9 Test Signals

- The test signal used for receiver acoustics testing shall be the IEEE Std 269 12 second male composite real speech test signal.
- The ITU P.50 male 2 second test signal (concatenated) may be used instead of the IEEE-269 12 second male speech test signal for send and sidetone measurements.
- Three different test signal levels are specified for testing. Each test signal level also has an associated simulated loop resistance which will only affect the loop current and not the level of the applied test signal. Test signals are calibrated into a 900 ohm load when transmitted from the feeding bridge with a 900 ohm source impedance.
    1. -43 dBV test signal with the loop resistance simulation set to 1600 ohms.
    2. -28 dBV test signal with the loop resistance simulation set to 700 ohms.
    3. -13 dBV test signal with the loop resistance simulation set to 200 ohms.

  These test signals will be referenced in this specification as:
    1. "the -43 dBV test signal"
    2. "the -28 dBV test signal
    3. "the -13 dBV test signal"
- The maximum SPL tests shall use the test signal procedures as specified in IEEE-269 section 7.10.1 for *Maximum acoustic pressure (long duration)*. The test signal is summarized as:
    - 100 Hz to 8500 Hz square wave sweep of at least 90 seconds.
    - The test signal level is +15 dBV

  NOTE: The test signal used for testing to this specification may be 100 Hz to 8000 Hz.

8 HANDSET TESTING PROCEDURES

This section provides a sequence of steps a tester will follow to obtain the required test data using the previously specified measurement methods. In some cases, this specification includes specific parameters for Pass / Fail to meet the specified requirement. In other cases, the test procedure is performed to obtain test data with no specified Pass / Fail criteria.

8.1 Usable Gain

Usable Gain testing is performed to find the Maximum Usable Gain when tested with the lowest test signal level and the maximum receiver acoustic output level (dBSPL) when tested with higher test signal levels. Usable gain measurements are performed with tone control set to nominal (flat frequency response).

8.1.1 Test Set-up

1. Connect the telephone to the dc feed circuit and mount the handset on the HATS.
2. Set the volume control to the nominal setting.
3. Set the tone control to the nominal setting that has:
    a. Non-negative HFE
    b. HFE-Low-band < HFE-Mid-band < HFE-High-band + 3 dB

8.1.2 Test Procedure

1. Perform the tests specified below for each of the following test signal levels:
    a. -43 dBV test signal with the loop resistance simulation set to 1600 ohms
    b. -28 dBV test signal with the loop resistance simulation set to 700 ohms
    c. -13 dBV test signal with the loop resistance simulation set to 200 ohms
2. Set the volume control to the maximum volume control setting.
3. Measure the receive frequency response, receive spectrum, and receive level (SPL).
4. Calculate the Conversational Gain and the Usable Gain.
5. HFE Calculations:
    a. Calculate the HFE-Low-band, HFE-Mid-band, and the HFE-High-band
    b. Calculate the HFE
    c. Verify: HFE-Low-band < HFE-Mid-band < HFE-High-band + 3 dB
6. Measure the Usable Gain with other tone control settings which have a non-negative HFE and the required HFE-Mid-band value to find the tone control setting that produces the highest Usable Gain value.
7. Measure receive distortion and noise
    a. Evaluate the receive distortion.
    b. Evaluate the receive noise.
    c. If distortion or noise fails, adjust the volume control and/or tone control then iterate testing to find the volume control and tone control settings that produce passing distortion and noise.

8. When the volume control and tone control settings to be used for each test signal level are determined measure the following:
    a. Maximum SPL
    b. Send frequency response
    c. Send loudness
    d. Sidetone loudness
    e. Stability

8.1.3 Data to be Reported

	Usable Gain Testing		
Test Signal Level (dBV)	**-43**	**-28**	**-13**
Rx Frequency Response	(Plot)	(Plot)	(Plot)
Rx Level	dBSPL	dBSPL	dBSPL
Rx Conversational Gain	dB	dB	dB
Rx Usable Gain	dB	dB	dB
Rx HFE-High-Band	(dB)	(dB)	(dB)
Rx HFE-Mid-Band	(dB)	(dB)	(dB)
Rx HFE-Low-Band	(dB)	(dB)	(dB)
Rx HFE (High– Low)	(dB)	(dB)	(dB)
Rx HFE Mid-Band Acceptable?	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)
Rx Distortion (SDNR)	(dB)	(dB)	(dB)
Rx Noise (absolute)	dBA	dBA	dBA
Rx Noise (relative SNR)	dB	dB	dB
Volume Control Settings (record)	text desc.	text desc.	text desc.
Tone Control Settings (record)	text desc.	text desc.	text desc.
Maximum SPL (long duration)	dBSPL	dBSPL	dBSPL
Send Frequency Response.	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)
Send Loudness (SLR)	(value)	(value)	(value)
Sidetone (STMR)	(value)	(value)	(value)
Stability	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)

NOTE: Receive (Rx) Usable Gain is calculated as follows for each test signal level tested:

- Usable Gain (-43 dBV test signal) = Measured SPL – 55 (dB) (**Maximum Usable Gain**)
- Usable Gain (-28 dBV test signal) = Measured SPL – 70 (dB)
- Usable Gain (-13 dBV test signal) = Measured SPL – 85 (dB)

8.2 Maximum Acoustic Ringer Level

The audible ringer acoustic sound pressure level shall be measured as specified in TIA−470.220−C (A−weighted). The ringer's acoustic output must meet the frequency content requirements stated in TIA−470.220−C.

8.2.1 Test Set-up

1. Set the telephone up in the specified testing configuration.
2. Set the ringer tone to the default ringer setting.
3. Set the ringer volume control to maximum.

8.2.2 Test Procedure

1. Per TIA−470.220−C , measure the ringer's A weighted frequency spectrum and levels for all 6 positions and include the plot of the frequency vs. level for the 0 degree position in the product's test report. Verify:
    a. Average sound pressure level (dBA)
    b. f1 >=500Hz, <= 1600 Hz
    c. f2 <= 3000 Hz
    d. f2 is at least 1.25 times f1 (i.e., $f2 \geq 1.25*f1$)
    e. f1 and f2 are not harmonically related
    f. f1 level (dBA)
    g. f2 level (dBA)
    h. f1 level - f2 level difference
2. For cordless telephones use the following procedures to measure ringer acoustic output:
    a. Measure the handset in the base or charging cradle with both the base and cordless handset ringers set to default and maximum ringer volume.
    b. Measure the cordless handset alone (per the measurement methods in section 7.7) without the base and with the handset standing up, lying face-up, or lying face-down whichever yields the highest output level. Include this data in the test report.
    c. Measure the base alone (per the measurement methods in section 7.7) without the cordless handset. Include this data in the test report.

8.2.3 Data to be Reported

Parameter	Test Result Base for Corded Or Cordless Handset + Base	Test Result Handset of a Cordless Telephone	Test Result Base of a Cordless Telephone
Acoustic Ringer Frequency Spectrum (A-wgt) (0 Degree 100 to 8000 Hz)	(Plot)	(Plot)	(Plot)
Ringer Level (Average SPL for all positions)	__ (dBA)	__ (dBA)	__ (dBA)
Ringer Low Tone (f1) (Hz) (500 Hz to 1600 Hz)	__ (Hz)	__ (Hz)	__ (Hz)
Ringer High Tone (f2) (Hz) (>= f1 * 1.25, <=3 kHz, f1 non-harmonic)	__ (Hz)	__ (Hz)	__ (Hz)
f1 Frequency Level	__ (dBA)	__ (dBA)	__ (dBA)
f2 Frequency Level	__ (dBA)	__ (dBA)	__ (dBA)
f1 Level – f2 Level (<= 10 dB)	__ (dB)	__ (dB)	__ (dB)

8.3 Hearing Loss Categories

Each category of hearing loss specifies an acceptable range of Conversational Gain and HFE, and acoustic ringer gain to be considered meeting the requirements of each specified hearing loss category. Testing for each hearing loss category is performed by setting the volume control and tone control settings to obtain the Conversational Gain and HFE as specified for each category and repeating this test for each specified test signal level. The default ring tone is then tested to verify the required acoustic ring signal gain and frequency spectrum for each hearing loss category.

8.3.1 Test Set-up

1. Receiver Testing
   a. Connect the telephone to dc feed circuit and mount the handset on the HATS.
   b. Set the volume control and tone control to the nominal setting.
2. Ringer Testing
   a. Set the ring tone to the default ring tone.
   b. Set the ringer volume to the maximum setting.

8.3.2 Test Procedure

Mild, Moderate, Severe Hearing Loss Category Settings

Testing for hearing loss categories is performed by adjusting the volume control and tone control to produce Conversational Gain and HFE values within the defined ranges for each hearing loss category and for each test signal level tested. Then the ringer gain, individual tone levels and frequency spectrum is tested.

Hearing Loss Category	Hearing Loss (HL) Range	Hearing Loss Frequency Response Slope Type	Required Telephone Receiver HFE Tolerance: (+/- 4 dB)	Required Telephone Receiver Gain (Reference= 70 dBSPL) Tolerance: (+/- 4 dB)	Required Telephone Ringer Gain (Reference= 75 dBSPL) Tolerance: (+/- 4 dB)
Mild	20 dB to 40 dB	Slight Slope	9 dB	16 dB	13 dB
		Steep Slope	14 dB		
Moderate	40 dB to 70 dB	Slight Slope	9 dB	31 dB	26 dB
		Steep Slope	25 dB		
Severe	70 dB to 90 dB	Slight Slope	9 dB	41 dB	33 dB
		Steep Slope	21 dB		

NOTE: 18 dB to 24 dB Conversational Gain is the volume control gain expected to be available for compliance to FCC Part-68.317.

8.3.2.1 Receiver Testing

1. Perform the testing steps below for each defined hearing loss category and HFE slope.
    a. Mild Slight Slope
    b. Mild Steep Slope
    c. Moderate Slight Slope
    d. Moderate Steep Slope
    e. Severe Slight Slope
    f. Severe Steep Slope
2. Perform the tests specified below for each of the following test signal levels:
    a. -43 dBV test signal with the loop resistance simulation set to 1600 ohms
    b. -28 dBV test signal with the loop resistance simulation set to 700 ohms
    c. -13 dBV test signal with the loop resistance simulation set to 200 ohms

3. Set the volume control to provide an estimated Conversational Gain equal to the target for the category being tested.
4. Set the tone control to provide an estimated HFE Gain equal to the target for the category being tested.
5. Measure the receive frequency response and receive level (SPL).
6. Calculate the Conversational Gain and the Usable Gain.
7. HFE Calculations:
    a. Calculate the HFE-Low-band, HFE-Mid-band, and the HFE-High-band
    b. Calculate the HFE
    c. Verify: HFE-Low-band < HFE-Mid-band < HFE-High-band + 3 dB
8. Adjust the volume control and/or tone control to obtain as close as possible to the target values for the category being tested while keeping the Conversational Gain and the HFE within the specified ranges for the category and repeat the measurements and calculations.
    a. Repeat this step until the closest values possible to the target values are set.
    b. If more than one combination of volume control and tone control settings meet the required ranges for Conversational Gain and HFE, then select the settings which are (first criteria) highest for gain and (second criteria) highest for HFE.
    c. If no combination of volume control and tone control settings can be found that meet the required ranges for Conversational Gain and HFE, then enter the values measured which are closest to the specified ranges.
9. Measure receive distortion and noise
    a. Evaluate the receive distortion.
    b. Evaluate the receive noise.
    c. If distortion or noise fails, adjust the volume control and/or tone control then iterate testing to find the volume control and tone control settings that produce passing distortion and noise.
    d. If no settings can be found that pass distortion and noise for a given hearing loss category and test signal level, record the Conversational Gain and HFE meeting the requirements for the category tested which have the highest SDNR and lowest noise measurements.
10. When the volume control and tone control settings to be used for each hearing loss category and each test signal level are determined measure the following:
    a. Maximum SPL
    b. Send frequency response
    c. Send loudness
    d. Sidetone loudness
    e. Stability

8.3.2.2 Ringer Gain and Frequency Spectrum Testing

1. Perform the testing steps below for each defined hearing loss category.
    a. Mild
    b. Moderate
    c. Severe
2. Measure the ringer sound pressure level and frequency contents as specified in section 7.7. Adjust the ringer level to find a level that meets the requirements for the hearing loss category being tested.
3. Measure the ringer's frequency spectrum and levels for all 6 positions and include the plot of the frequency vs. level average SPL spectrum in the product's test report. Verify:
    a. Average sound pressure
    b. f1 >=400Hz, <= 800 Hz
    c. f2 <= 1000 Hz
    d. f2 is at least 1.25 times f1 (i.e., $f2 \geq 1.25*f1$)
    e. f1 and f2 are not harmonically related
    f. f1 level
    g. f2 level
    h. f1 level - f2 level difference
4. For cordless telephones use the following procedures to measure ringer acoustic output:
    a. Measure the handset in the base or charging cradle with both the base and cordless handset ringers set to default and maximum ringer volume.
    b. Measure the cordless handset alone (per the measurement methods in section 7.7) without the base and with the handset standing up, lying face-up, or lying face-down whichever yields the highest output level. Include this data in the test report.
    c. Measure the base alone (per the measurement methods in section 7.7) without the cordless handset. Include this data in the test report.
    d. A cordless telephone is deemed to pass if it meets the gain and frequency spectrum requirements for the specified hearing loss category for the measurements of either the base alone, the handset alone, or the combination of the base and handset..

8.3.3 Data to be Reported

	Settings for Mild Hearing Loss *(Sight Slope)*			**Settings for Moderate Hearing Loss *(Sight Slope)***			**Settings for Severe Hearing Loss *(Sight Slope)***		
Test Signal Level (dBV)	-43	-28	-13	-43	-28	-13	-43	-28	-13
Rx Frequency Response	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)
Rx Level	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL
Rx Conversational Gain	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB
Rx Usable Gain	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB
Rx HFE-High-Band	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)
Rx HFE-Mid-Band	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)
Rx HFE-Low-Band	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)
Rx HFE (High– Low)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)
Rx HFE Mid-Band Acceptable?	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)
Rx Distortion (SDNR)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)
Rx Noise (absolute)	__ dBA	__ dBA	__ dBA	__ dBA	__ dBA	__ dBA	__ dBA	__ dBA	__ dBA
Rx Noise (relative SNR)	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB	__ dB
Volume Control Settings (record)	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.
Tone Control Settings (record)	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.
Maximum SPL (long duration)	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL	__ dBSPL
Send Frequency Response.	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)
Send Loudness (SLR)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)
Sidetone (STMR)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)	__ (value)
Stability	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)

	Settings for Mild Hearing Loss *(Steep Slope)*			**Settings for Moderate Hearing Loss *(Steep Slope)***			**Settings for Severe Hearing Loss *(Steep Slope)***		
Test Signal Level (dBV)	-43	-28	-13	-43	-28	-13	-43	-28	-13
Rx Frequency Response	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)
Rx Level	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL
Rx Conversational Gain	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB
Rx Usable Gain	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB
Rx HFE- High-Band	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)
Rx HFE- Mid-Band	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)
Rx HFE- Low-Band	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)
Rx HFE (High– Low)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)
Rx HFE Mid-Band Acceptable?	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)
Rx Distortion (SDNR)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)	___ (dB)
Rx Noise (absolute)	___ dBA	___ dBA	___ dBA	___ dBA	___ dBA	___ dBA	___ dBA	___ dBA	___ dBA
Rx Noise (relative SNR)	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB	___ dB
Volume Control Settings (record)	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.
Tone Control Settings (record)	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.	text desc.
Maximum SPL (long duration)	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL	___ dBSPL
Send Frequency Response.	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)
Send Loudness (SLR)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)
Sidetone (STMR)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)	___ (value)
Stability	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)	(Pass / Fail)

Parameter	Test Result Base For Corded or Cordless Handset + Base			Test Result Handset of a Cordless Telephone			Test Result Base of a Cordless Telephone		
	Mild	**Moderate**	**Severe**	**Mild**	**Moderate**	**Severe**	**Mild**	**Moderate**	**Severe**
Acoustic Ringer Frequency Spectrum (Average SPL for all positions 100 to 8000 Hz)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)	(Plot)
Ringer Level (Average SPL for all positions)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)
Ringer Gain (Average SPL - 75 dBSPL)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)
Ringer Low Tone (f1) (Hz) (400 Hz to 800 Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)
Ringer High Tone (f2) (Hz) (>= f1 * 1.25, <=1kHz, f1 non-harmonic)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)	__ (Hz)
f1 Frequency Level	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)
f2 Frequency Level	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)	__ (dBSPL)
f1 Level – f2 Level (<= 10 dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)	__ (dB)

8.4 Normal Telephone Acoustics

The settings for normal telephone acoustic parameters based on TIA−470.110−C must be verified.

8.4.1 Test Set-up

1. Connect the telephone to the HATS.
2. Set the volume control and tone control to the nominal setting.

8.4.2 Test Procedure

Using a 2.7 km loop simulation perform the following tests as specified in TIA−470.110−C:

1. Set the volume control and tone control to nominal settings for gain and frequency response.
2. Measure the receive loudness (RLR) and the receive frequency response.
3. Measure the send loudness (SLR) and the send frequency response.
4. Measure the sidetone loudness (STMR) and the sidetone frequency response.
5. Measure the maximum (long duration) sound pressure level (Max SPL).
6. Measure the acoustic stability.

8.4.3 Data to be Reported

Parameter	Test Result
Test Loop:	**2.7 Km Loop Simulation**
Receive Frequency Response	(Plot)
Receive Loudness (RLR)	__ (value)
Send Frequency Response	(Plot)
Send Loudness (SLR)	__ (value)
Sidetone Frequency Response	(Plot)
Sidetone Loudness (STMR)	__ (value)
Maximum SPL	__ dBSPL
Stability	(Pass / Fail)

8.5 Acoustic Hearing Aid Compatibility Performance

The settings for normal telephone acoustic parameters based on TIA−470.110−C must be verified when tested with a 2 Newton (2N) force using the HATS.

8.5.1 Test Set-up

1. Connect the telephone to the HATS using a 2N force rather than the 10N force specified in TIA−470.110−C.
2. Set the volume control and tone control to the nominal setting.

8.5.2 Test Procedure

Using a 2.7 km loop simulation perform the following tests as specified in TIA−470.110−C:

1. Set the volume control and tone control to nominal settings for gain and frequency response.
2. Measure the receive loudness (RLR) and the receive frequency response.
3. Measure the send loudness (SLR) and the send frequency response.
4. Measure the sidetone loudness (STMR) and the sidetone frequency response.
5. Measure the maximum (long duration) sound pressure level (Max SPL).
6. Measure the acoustic stability.

8.5.3 Data to be Reported

Parameter	**Test Result (2N Test)**
Test Loop:	**2.7 Km Loop Simulation**
Receive Frequency Response	(Plot)
Receive Loudness (RLR)	__ (value)
Send Frequency Response	(Plot)
Send Loudness (SLR)	__ (value)
Sidetone Frequency Response	(Plot)
Sidetone Loudness (STMR)	__ (value)
Maximum SPL	__ dBSPL
Stability	(Pass / Fail)

8.6 TIA−1083−A Hearing Aid Compatibility (HAC) Performance

- **Pass / Fail (See separate test report)**

8.7 Regulatory Labels and Safety Listing

Product Parameter	Test Results Required
FCC Part-68 Verify registration number is on product	Registration Number on Product
FCC Part-15 Verify registration number is on product	Registration Number on Product
Safety Listing Verify listing mark is on product	Listing Number on Product

9 ANNEX-A: REQUIREMENTS AND MEASUREMENTS RATIONALE

This section includes a summary of the rationale and justification for the measurements performed and the parameters selected for Hearing Loss Categories.

9.1 Telephone Handset Measurement Equipment

Telephone handset acoustics used to be measured using the ITU P.57 Type-1 ear simulator when telephones met specific design requirements for the physical design of the handset and the electrical design of the acoustic transducer (the handset receiver/speaker). Following is an excerpt from ITU P.57 which is the standard defining the Type-1 ear coupler.

From ITU-P.57-2005 (underlining and bold added by specification document author):

> 5 Artificial ear types
>
> The fundamental purpose of an artificial ear is to test a receiver under conditions that most closely approximate actual use by real persons. The recommendations that follow are based upon the manner in which the receivers are intended to be used. **Modifications to an artificial ear or test procedure shall not be made. To avoid alteration of the specified concha volume and/or leak, flexible sealing material, such as putty, shall not be used. Of the artificial ears defined below, the artificial ears with a flexible pinna are intended to most closely resemble the manner in which the receivers are intended to be used.**
>
> 5.1 Type 1 – IEC 60318 The Type 1 artificial ear is specified in IEC 60318-1 [1]. **It is recommended that the Type 1 artificial ear should only be used as a legacy ear simulator for measurements on large, supra-aural or supra-concha, hard-cap, conically symmetrical receivers, which naturally seal to the simulator rim, intended for narrow-band telephony applications (100 Hz to 4 kHz). The Type 1 artificial ear should not be used for receivers not meeting these specifications.**
>
> NOTE 1 – **The Type 1 artificial ear is not suitable for measuring low acoustic-impedance earphones.**
>
> NOTE 2 – The Type 1 artificial ear is defined for simulating the acoustic load of the human ear under no leakage conditions. For receive loudness rating calculations according to ITU-T Rec. P.79, it is recommended that measured data be corrected using the real ear loss correction LE provided in Table 2/P.79.
>
> NOTE 3 – It is recommended to use an application force between 5 N and 10 N for placing earcaps against Type 1 artificial ears. The force applied in measurements shall always be reported.

The loudness and frequency response requirements specified in TIA−470−B (and previous revisions of TIA−470) were based on using the Type-1 ear simulator. Use of the Type-1 ear simulator was started many years ago when Bell Labs engineers developed the testing interface to measure the frequency response, loudness, noise, and distortion of telephones. In those days, telephones were all designed similarly with the same handset ear cup shape and similar electronics. The telephones tested were already known to be acceptable from subjective testing and then the measurements made on the Type-1 ear simulator were correlated with acceptable performance. **The Type-1 ear simulator does not produce test results which correlate with what someone actually hears.**

Due to the need to make more realistic measurements of telephone handsets, the Head and Torso Simulator (HATS) and the Type-3.3 ear simulator were developed and standardized. The Type-3.3 ear simulator is more like a real ear and the HATS allows for positioning the handset the same as a real user would. Thus, measurements made on a HATS do indicate what a person using the handset will actually hear.

Establishing specifications for gain and tone control makes use of the knowledge of hearing loss as measured for real people. Therefore, the gain and tone control specifications and measurements must be performed with equipment that indicates what a user will actually hear. **In addition, some telephone handsets cannot be measured using a Type-1 ear simulator because these handsets do not properly couple to a Type-1 ear simulator.**

Therefore, the only practical solution for establishing a universal specification for high gain amplified telephone's acoustics performance measurements is to use a HATS and a Type-3.3 ear simulator. Use of the HATS and the Type-3.3 ear simulator has been specified in TIA−470.110−C since 2004.

9.2 Test Signal Levels

- IEEE-269 establishes the range of speech signals for the analog telephone network to be a maximum level = -13 dBm, an average level = -28 dBm, and a minimum level = -43 dBm.
- The speech level range values provided in various studies were specified in terms of dBm because they were measured during live calls with telephones having an average 600 ohm input impedance. Telephone testing specified in TIA standards is performed by calibrating signal levels into a 900 ohm load (using a signal generator with a 900 ohm source impedance) and the test signal levels are specified in dBV rather than dBm.
- Signal levels specified in this specification are in terms of dBV when calibrated into a 900 ohm load with a signal generator having a 900 ohm source impedance. During testing, the 900 ohm test load impedance is removed and the telephone is connected to the test equipment. Signal levels are therefore converted from the dBm referenced values to dBV.
    - The conversion of dBV from dBm values is dBV = dBm – 2.2 dB.
    - When converting from a 900 reference to a 600ohm reference the conversion is X dB(900) = X dB(600) +1.8 dB.
    - Therefore when converting dBm values referenced to 600 ohms to dBV values referenced to 900 ohms the conversion is dBV(900) = dBm(600) -0.4 dB. For the purposes of testing specification simplicity, the 0.4 dB difference is neglected and the testing signal levels used are -13.0 dBV, -28.0 dBV, and -43.0 dBV.

9.3 Hearing Loss Categories Rationale

The concept of defining Mild, Moderate, and Severe categories related to gain and tone control for this specification is in response to the fact that the design of different telephones will provide multiple combinations of volume control and tone control settings for the received telephone signals, and settings for acoustic ringer level. If an attempt were made to test and report all combinations of settings the amount of testing and test data could be overwhelming and may make the use of the test data impractical for comparison of products.

Instead, each category of hearing loss (Mild, Moderate, and Severe) is defined with a specified gain range and a specified HFE (High Frequency Emphasis) range for the frequency spectrum of the acoustic signal generated by the telephone and ringer gain range and frequency spectrum requirements.

For the purposes of this specification, it is accepted that the largest majority of persons with hearing impairment require more emphasis (more gain) on higher frequencies. It is recognized that other types of tone control may also be useful for some people with hearing impairment (for example, mid-band emphasis, different frequency response) but high frequency emphasis was selected as the "minimum performance criteria" to meet the specified requirements.

For a telephone to be considered to pass the requirements for the Mild, Moderate, or Severe category, the telephone must be able to be set within the range for volume control gain and tone control HFE, as specified for each respective category. Related to HFE,, the frequency response must be such that the mid-band frequencies (between 800 Hz and 1250 Hz) level are higher than the low-band frequencies (between 315 Hz and 500 Hz) level and not more than 3 dB higher than the high-band frequencies (between 2000 Hz and 3150 Hz) level.

In addition, for a telephone to be considered to pass the requirements for the Mild, Moderate, or Severe category, the telephone must be able to be set within the range of ringer gain as specified for each respective category and meet the frequency requirements.

9.3.1 Volume Control and Gain

The following table shows industry accepted dB ranges and the associated classification for hearing loss (HL). There are other categories used within the audiology industry and other specifications of the HL for each category. The table below was derived from reviewing several hearing loss classifications from various sources. Some of the variability in the industry is caused because HL levels are often different at different frequencies so one may have a mild hearing loss below 1 KHz but a moderate hearing loss above 2 KHz.

Classification	**Hearing Loss (dBHL)**
Normal Hearing	0 – 20
Mild Hearing Loss	20 – 40
Moderate Hearing Loss	40 – 70
Severe Hearing Loss	70 – 90

The gain specified for meeting the need of each category is derived from the one-half gain rule[1] that is commonly used for fitting hearing aids in the audiology industry. The one-half gain rule states that the appropriate gain setting of the device is approximately one-half of the user's total hearing loss. Some may argue that a one-third gain rule should be used. There is some debate within the audiology industry regarding which is more appropriate (one-third or one-half gain rule). The reality is there is not one correct answer because the gain needed will vary depending on the specific characteristics of an individual's hearing loss. For this specification, the one-half gain rule was selected because it will lead to the telephone receiver having a higher sound pressure level for which it is assumed the volume control will have enough range to make the receiver level lower if necessary. Also, the gain rule used for hearing aids is for continuous use, but because a telephone is normally used non-continuously, then higher levels should be tolerable, and likely desirable, for the telephone user.

The gain range specified to meet each category was selected such that the gain nearer to the higher end of the hearing loss category gain requirement is specified. This was done assuming the volume control will allow for setting the volume to a lower level if necessary and acknowledging the user can normally adjust the handset position to obtain a lower level, but it is more difficult to use handset positioning to obtain a higher level.

Following is the hearing loss categories with the gain setting required for meeting the need for each category. The gain setting for each category has a target value with a +/-4 dB tolerance for products to meet the gain requirement.

Hearing Loss Category	**Hearing Loss (dBHL)**	**½ Gain Rule Gain Range (dB)**	**Gain Required (dB) (+/-4 dB Tolerance)**
Mild	20 – 40	10 – 20	16
Moderate	40 – 70	20 – 35	31
Severe	70 - 90	35 - 45	41

9.3.2 Hearing Loss Frequency Response

The tone control required to meet the needs of all types of hearing impairment has a wide range from a flat frequency response, to a large high frequency emphasis, to mid-band frequency emphasis, etc. There are many types of hearing loss which can be described with an audiogram measurement showing a person's hearing loss at various frequencies.

9.3.2.1 High Frequency Hearing Loss

The largest majority of people with hearing loss have a larger hearing loss at higher frequencies than low frequencies which is due to age and long term exposure to environmental sounds (loud music, gun shots, machinery, etc.). This is called "high frequency hearing loss".

[1] Berger, K.W., E. N. Hagberg, and R. L. Rane, 1980, "A Reexamination of the One-Half Gain Rule," *Ear and Hearing* 1, no. 4, The Williams and Wilkins Co, USA.

9.3.2.2 "Cookie-Bite" Type Hearing Loss

Most audiogram measurements are performed to 8 KHz. A hearing loss type often referred to as "cookie bite" hearing loss is characterized by a higher hearing loss level between approximately 1000 Hz to 3500 Hz and then the hearing loss improves (i.e., the level of hearing loss decreases) for frequencies from about 3500 Hz to 8 KHz. The usable frequency range for analog telephones connect to the PSTN (Public Switched Telephone Network) is 300 Hz to 3300 Hz. Because the analog telephone frequency range only goes to 3300 Hz, it is evident that most "cookie-bite" type hearing loss is actually just "high frequency" loss within the usable analog telephone frequency range.

9.3.3 Hearing Loss Data

An extensive hearing loss study was performed by the European Hearing Instrument Manufacturers Association (EHIMA) and a report was published in 2007. The goal of the EHIMA study was to establish "standard audiograms" that could be used to enable efficient fitting of hearing aids. Overview information regarding the EHIMA study follows:

9.3.3.1 EHIMA Study Data Source

Pure tone thresholds from 28244 ears were collected from a database at the Department of Audiology at Stockholm South Hospital

9.3.3.2 EHIMA Study Tested Subjects

All audiograms from the patients who visited the Department of Audiology at Stockholm South Hospital during the 44 months period 2001-01-01 to 2004-08-31 were collected.

9.3.3.3 EHIMA Study Audiogram Measurements

The audiograms were measured in standard audiometry booths. About 19500 audiograms were recorded during the 44 months period. Because a number of patients were measured multiple times, only the first measurement for each patient was selected. After removing empty and obviously erroneous measurements, the number of measurements used for the study was 28244 ears measured.

9.3.3.4 EHIMA Study Data Summary

The EHIMA study describes the significant statistical analysis that was performed to derive standard audiograms. An important finding in the analysis of the data was that a "bi-modal" distribution existed related to the slope of the hearing loss measured (high frequency hearing loss compared to the level of the low frequency hearing loss). The EHIMA study described seven standard audiograms for slightly sloping hearing loss from "very mild" to "profound and three standard audiograms for steeply sloping hearing loss from "mild" to "moderate/severe".

9.3.4 Tone Control and Hearing Loss: High Frequency Emphasis (HFE)

The quantity established for measuring a telephone's high frequency gain was developed for this specification using the IEEE-269 specified measurement of "tonal balance" as a guideline.

The quantity is called "HFE" (High Frequency Emphasis). Included in the specifications for HFE, is the requirement that the frequency response must be such that the mid-band frequencies (between 800 Hz and 1250 Hz) level are higher than the low-band frequencies (between 315 Hz and 500 Hz) level and not more than 3 dB higher than the high-band frequencies (between 2000 Hz and 3150 Hz) level. Specifying a requirement for the mid-band frequencies will ensure the telephone has a frequency response which is controlled and does not over-emphasize or under-emphasize the mid-band frequencies. Although mid-band frequency emphasis, or de-emphasis, may be desirable for some specific hearing loss characteristics, this specification is focused on high frequency emphasis only being settable as the minimum requirement.

The data from the EHIMA study was used to derive two standard audiograms (slightly sloping and steeply sloping) for each of three hearing loss categories (Mild, Moderate, and Severe). These standard audiograms were then used to derive the required HFE an amplified telephone should provide to meet the needs of each of the standard audiograms. The table below summarizes the standard audiogram slope data used for each hearing loss category with the corresponding HFE required from the telephone to meet the needs of each hearing loss category. The slope of the audiograms was evaluated from 500 Hz to 2500 Hz which is the mid-point of the HFE low-band and HFE high-band respectively.

Hearing Loss Category	**Hearing Loss Frequency Response Slope Type (from EHIMA Study)**	**Hearing Loss Slope Value (500 Hz to 2500 Hz) (from EHIMA Study)**	**Required Telephone Receiver HFE (1/2 Gain Rule) Tolerance: (+/- 4 dB)**
Mild	Slight Slope	18 dB	9 dB
	Steep Slope	28 dB	14 dB
Moderate	Slight Slope	18 dB	9 dB
	Steep Slope	50 dB	25 dB
Severe	Slight Slope	18 dB	9 dB
	Steep Slope	42 dB	21 dB

9.3.5 Ringer Acoustics

The acoustic ringer of an amplified telephone needs to be loud enough to compensate for a person's hearing loss. The compensation required is a combination of increased level (louder ringer) and having lower frequencies for the acoustic ringer signal than allowed by TIA−470.220−C. Lower frequency ringing signals will require less gain than higher frequencies due to the high frequency hearing loss experienced by most people with hearing loss.

Similar to the handset acoustics, the ringer acoustics are specified using a quantity of gain above a normal level. TIA−470.220−C specifies a normal acoustic ringer level to be 75 dBSPL.

This amplified telephone specification deviates from the specifications in TIA−470.220−C by requiring lower frequency spectrum components for the acoustic ring signal.

The default ringer tone will be the only ringer tone measured for this specification.

9.3.5.1 Ringer Gain

The acoustic ringer is specified to be measured per the methods in TIA−470.220−C. The ringer level specified in TIA−470.220−C (75 dBSPL) is for normal hearing so any ringer level above 75 dBSPL is considered to be "ringer gain".

9.3.5.2 Ringer Acoustic Spectrum

The frequency content of the default acoustic ringer must meet the following frequency spectrum requirements:

1. The ringing signal shall contain at least two frequency components, designated f1 and f2 in the range of 400 to 1000 Hz.
2. The component designated f1 shall be between 400 Hz to 800 Hz.
3. The component designated f2 shall be at least 1.25 times f1 (i.e., $f2 \geq 1.25\ f1$) but must be less than or equal to 1000 Hz.
4. The component designated f2 shall not be a harmonic of f1.
5. The alerter shall alternate between the frequencies so that f1 and f2 do not appear simultaneously.

Requiring frequency components to be below 1000 Hz ensures a very high frequency ringer is not used which could be inaudible to a person with significant high frequency hearing loss.

9.3.6 Ringer Acoustics and Hearing Loss

Using the EHIMA study data, it is seen that the difference between 1600 Hz (the highest frequency allowed for f1 in TIA−470.220−C) and 800 Hz (the highest frequency allowed for f1 in this amplified telephone specification) can be characterized as shown in the following table for each hearing loss category. Also shown in the table is the corresponding reduction in gain required for each hearing loss category due to the requirement for the ringer to have lower frequency components. The method used was to use the average of the level change for the slight and steep slope and then use the one-half gain rule to adjust the amount of gain required for each category.

Hearing Loss Category	Gain Required For Category (dB)	Hearing Loss Frequency Response Slope Type (from EHIMA Study)	Difference From 800 Hz to 1600 Hz (from EHIMA Study)	Required Ringer Gain (One-half Gain Rule)
Mild	12 – 20	Slight Slope	-10 dB	9 – 17
		Steep Slope	0 dB	
Moderate	27 – 35	Slight Slope	-6 dB	22 – 30
		Steep Slope	-12 dB	
Severe	37 - 45	Slight Slope	-8 dB	29 - 37
		Steep Slope	-22 dB	