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TIA STANDARD

Land Mobile FM or PM Communications Equipment Measurement and Performance Standards

TIA-603-E
(Revision of TIA-603-D)

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TR-8.0 wishes to dedicate TIA-603 to the memory of Charles Willyard, who provided the requisite leadership during the formative stages of this effort. Charlie's standards contributions extended well beyond this document, encompassing its predecessors and other worldwide activities throughout most of his working and retirement years. Charlie's standards statesmanship merits emulation and his experience, expertise, and perspective will be missed.

Foreword

This foreword is not part of this document.

TIA-603-E is a Recommended Standard developed and maintained by the TR-8 Committee on Private Radio Systems and its subcommittees under the sponsorship of the Telecommunications Industry Association. This Standard represents the consensus of the formulating subcommittees at the time of publication.

This Standard replaces TIA-603-D, which was originally published in June 2010. Technical updates include changes to reflect the latest frequency assignments by the FCC and NTIA.

There are two Annexes in the document. Both Annex A and Annex B are informative, and are not considered part of this Standard.

Contents

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1 INTRODUCTION

1.1 Scope

This standard provides definition, methods of measurement and performance standards for radio equipment used in the Private (Dispatch) Land Mobile Services that employ FM or PM modulation, for transmission of voice or data using analog or digital techniques, with a frequency of 1 GHz or less.

This standard may be applicable to services other than those listed above. Use of this standard is encouraged for any application of similar equipment. However, the user should review the required standards needed for the specific application.

Standards for equipment employing digital C4FM or CQPSK modulation may be found in TIA-102.CAAA-C and TIA-102.CAAB-C.

This standard is promulgated to apply to land-mobile equipment licensed under Federal Communications Commission (FCC Part 90) in the Public Safety, Special Emergency, and Industrial Radio Services. This standard also has applicability for equipment used by the federal government services that fall under National Telecommunication and Information Administration (NTIA) rules.

The measurement procedures of this standard are also applicable to the General Mobile Radio Service (GMRS) (25 kHz spaced channels only) in the 450 to 470 MHz band (FCC Part 95), as well as Remote Broadcast Pickup (voice quality only) (FCC Part 74). Certain sections of this standard are applicable to the VHF Marine Radio Service (FCC Part 80) and the Common Carrier Radio Service (FCC Part 22). However, technical standards may vary depending on FCC rules for those services.

1.2 Object

The object of this standard is to standardize parameter titles, definitions, the test conditions, and the methods of measurement used to ascertain the performance of equipment within the scope of this standard, and to make possible a meaningful comparison of the results of measurements made by different observers and on different equipment.

This standard has the further objective of providing separate performance standards for base stations, mobiles, and portable equipment, while retaining common definitions and methods of measurement for parameters that are common to these pieces of equipment.

1.2.1 Required Performance Standards

For those parameters where the FCC has specified limits, these limits are listed as the required standards. However, where there are recommendations that are more stringent than the FCC requirement they will also be noted and listed as the recommended standard.

1.2.2 Performance Standards

For all other parameters, the standard values are listed. The standard values have been determined by TIA to be the current value or range of values conducive to promoting the maximum or effective use of the spectrum with the practical aspect of equipment cost and equipment application carefully considered. Two performance levels are given. Class B performance levels are recommended minimum performance for Private Land Mobile Radio transceivers. Class A performance levels are recommended performance for Private Land Mobile transceivers with enhanced interference protection characteristics.

1.3 Standard Definitions

1.3.1 Definitions of Physical Values

Standard definitions of terms can be found in IEEE Standard Dictionary of Electrical and Electronics Terms, IEEE Std 100-2000.

1.3.2 Common Definitions

This section details common definitions for the characteristics and measurements of FM or PM private land mobile equipment in vehicular (mobile), fixed (base station), or handheld (portable) installations.

1.3.2.1 Standard Continuous Duty Cycle for Mobile and Base Equipment

Transmitter continuous operation denotes operation of the transmitter at rated power output into the manufacturer's specified load continuously for 24 hours.

Receiver continuous operation denotes operation of the receiver at rated audio frequency output power into the manufacturer's specified load continuously for 24 hours.

1.3.2.2 Standard Intermittent Duty Cycle for Mobile and Base Equipment

The standard duty cycle for intermittent operation is 4 minutes receive at rated audio output power followed by 1 minute transmit at rated transmitter output power, both under the manufacturer's specified load, for a period of 8 hours, followed immediately by three cycles of 15 minutes receive and 5 minutes transmit, both at rated power.

1.3.2.3 Standard Duty Cycle for Portable Equipment

The standard duty cycle, measured under manufacturer's specified load, for portable equipment may be one of the following:

a) 10-10-80: 6 seconds transmit at rated power output, 6 seconds receive at rated audio output power, and 48 seconds standby.

b) 5-5-90: 3 seconds transmit at rated power output, 3 seconds receive at rated audio output power, and 54 seconds standby.

c) 5-45-50: 3 seconds transmit at rated power output, 27 seconds receive at rated audio output power, and 30 seconds standby.

If the equipment does not contain either a transmitter or a receiver, the corresponding part of the duty cycle shall be replaced by the equivalent additional seconds of standby. The standard duty cycle shall be performed over the hours specified by the manufacturer for equipment with a battery life of less than 16 hours, and for 8 hours followed by a 16 hour rest for equipment with a battery life of over 16 hours. The 8 hour test and 16 hour rest cycle is continued until the specified life of the battery is reached.

1.3.3 Definitions for Receivers

This section details definitions for the characteristics and measurements of FM or PM private land mobile receivers in vehicular (mobile), fixed (base station), or handheld (portable) installations.

1.3.3.1 Input Signal Level for Testing Receivers With Suitable Antenna Terminals

The nominal radio frequency impedance (R_n) is that value stated by the manufacturer at the port for which the equipment performance will be measured.

The input signal level for receivers will be expressed as a power, in dBm, delivered to an impedance having a value of R_n. This level may also be expressed in μV across R_n, with the value of R_n noted.

NOTE: When the signal source is not in close proximity to the receiver input terminals, the transmission line loss must be taken into account, in addition to the loss of any impedance matching networks.

1.3.3.2 Standard Input Signal

Standard input signal is defined as a radio frequency signal at standard input signal level, with standard input signal frequency, at the standard modulation of the input signal.

1.3.3.3 Standard Input Signal Level

Standard input signal level is -47 dBm (1000 μV into 50 Ω).

1.3.3.4 Standard Input Signal Frequency

Standard input signal frequency for all tests is the nominal specified receiver frequency.

1.3.3.5 Standard Modulation of an Input Signal

Standard modulation of an input signal is the modulation due to an input signal of 1000 Hz at a level to produce 60% of the maximum permissible frequency (or phase) deviation.

1.3.3.6 De-emphasis

Standard de-emphasis reference is a 6 dB per octave decreasing slope from 300 Hz to 3000 Hz. De-emphasis should be operative for all tests, unless otherwise noted.

1.3.3.7 Squelch Condition

The squelch control should be adjusted for the unsquelched condition unless otherwise specified.

NOTE: The term squelch is synonymous with mute.

1.3.3.8 User Accessible Squelch

User accessible squelch is a squelch control that has threshold level adjustment accessible to the operator during normal operation of the radio equipment.

1.3.3.9 Rated Audio Frequency Output Power

The rated audio frequency output power is the power specified by the manufacturer which, under standard conditions, is available at the receiver output terminals when the latter are connected to a specified load.

When measuring equipment under nonstandard environmental conditions, the rated audio frequency output power may be degraded by no more than 3 dB from the value specified at standard conditions.

1.3.3.10 Audio Frequency Output Load

For equipment with an integral audio frequency output transducer, the load is the output transducer.

NOTE: The manufacturer shall specify the method of connection and state the impedance (and tolerance) of the output transducer at 1000 Hz. It is desirable also to state the impedance at specified upper and lower audio frequency band limits.

An audio frequency output test load is an impedance network that replaces the load to which the receiver is connected under normal operating conditions. It simulates the impedance of the normal load and any cables with which it is normally used. The network is specified by the manufacturer, and usually consists of a pure resistance.

1.3.3.11 Signal-to-Noise Ratio (SINAD)

The signal-to-noise ratio (SINAD) is:

$$SINAD(dB) = 20\log_{10}\left(\frac{Signal + Noise + Distortion}{Noise + Distortion}\right)$$

where:

Signal = Wanted audio frequency signal voltage due to standard test modulation.

Noise = Noise voltage with standard test modulation.

Distortion = Distortion voltage with standard test modulation.

1.3.3.12 Standard Signal-to-Noise Ratio (SINAD)

The value of the standard signal-to-noise ratio is 12 dB. The standard signal-to-noise ratio (SINAD) allows comparison between different equipment when the standard test modulation is used.

NOTE: Other values of SINAD may be used in this document.

1.3.4 Definitions for Transmitters

This section details definitions for the characteristics and measurements of FM or PM private land mobile transmitters in vehicular (mobile), fixed (base station), or handheld (portable) installations.

1.3.4.1 Standard Transmitter Load

The Standard Transmitter Load shall consist of one of the following:

For transmitters with non-integral antennas:
A nonradiating resistive attenuator (see 1.5.12) with a 50 Ω input impedance (unless otherwise specified by the manufacturer) and an output impedance matched to the test equipment.

For transmitters with integral antennas:
The transmitter load shall be the antenna supplied by the manufacturer. The manufacturer shall specify the coupling or matching circuit from the integral antenna to the test equipment.

1.3.4.2 Standard Test Modulation

Standard test modulation is a 1000 Hz input signal at a level that produces 60% of full rated system deviation.

1.3.4.3 Pre-emphasis

Standard pre-emphasis reference is a 6 dB per octave increasing slope from 300 Hz to 3000 Hz. Pre-emphasis should be operative for all tests, unless otherwise noted.

1.3.4.4 Rated System Deviations, Authorized Bandwidths and Test Bandwidths

Authorized Bandwidths and Test Bandwidths, which are derived from 47 CFR 90.209 and 90.210 (where it applies), are defined in Table 1.

Table 1
Rated System Deviation, Authorized Bandwidths, and Test Bandwidths

Frequency Range (MHz)	Channel Bandwidth (kHz)	Rated System Deviation for F3E Emission[1] (kHz)	Maximum Authorized Bandwidth (kHz)	Test Bandwidth (kHz)
25 - 88	20	±5	20	±50
138 - 174	25 & 30	±5	20	±50
	12.5 & 15	±2.5	11.25	±55.625
	12.5(NTIA)	±2.5	11	±55.5
380-399.9	12.5(NTIA)	±2.5	11	±55.5
406 - 512	25	±5	20	±50
	12.5(FCC)	±2.5	11.25	±55.625
	12.5(NTIA)	±2.5	11	±55.5
769-775	12.5	±2.5	11.25	757-805 MHz
799-805	12.5	±2.5	11.25	769-817 MHz
806 - 809	25/12.5	±4	20	±50
809 - 824	25	±5	20	±50
851 - 854	25/12.5	±4	20	±50
854 - 869	25	±5	20	±50
896 - 901	12.5	±2.5	13.6	±15
935 - 940	12.5	±2.5	13.6	±15

Test Bandwidth is centered about the assigned transmitter frequency and is the measurement frequency range used for transmitter sideband spectrum measurements.

Note 1: Test Bandwidth for 700 MHz bands is defined in 47 CFR 27.53 and 90.543 for non-spurious measurements.

Note 2: Per revisions in FCC 95-255, 47 CFR 90 rules and regulations, maximum deviation limits for voice or other modulations are no longer specified. The maximum rated system deviation limits for analog voice operation (F3E emission) are recommended to maintain compatibility with existing equipment.

1.3.5 Definitions for Subaudible Signaling

1.3.5.1 Subaudible Signaling Systems

The term "Continuous Tone Controlled Squelch System" (herein referred to as CTCSS) and "Continuous Digital Controlled Squelch System" (herein referred to as CDCSS) shall define a system where the radio receiver(s) are equipped with tone or data responsive devices that allow audio signals to appear at the receiver audio output, select voice processing such as scrambling, select between voice or data, or control repeater functions, only when a carrier modulated with a specific tone or data pattern is received. The tone or data pattern must be continuously present for continuous audio output. The transmitter emitting the carrier shall be modulated with a continuous tone as in a CTCSS system, whose frequency is the same as the tone required to operate the tone-responsive CTCSS device at the receiver output. In a CDCSS system, the transmitter emitting the carrier shall in a similar manner be modulated with a continuous NRZ FSK data stream having the correct pattern to operate the data sensitive detector at the receiver output. The purpose of the defined system is to minimize the annoyance of hearing communications directed to others sharing the same carrier frequency or channel. By using a specific tone or data stream, each user may code his carrier to prevent the reception of audio signals by any uncoded or differently coded carriers.

Both CTCSS and CDCSS are considered primarily as a means for group calling as distinguished from individual calling.

Since the CTCSS or CDCSS receiver is equipped to prevent hearing non-coded or differently coded carriers, the transmitter operator may cause interference if he does not monitor the channel prior to his own transmission. To minimize this problem, all CTCSS or CDCSS receivers must be provided with a means for monitoring all signals on the receiver channel. Either of three pre-transmission monitoring systems may be used:

> Means shall be provided in such a manner that the receiving channel can be monitored prior to transmission without requiring the operator to perform any additional function other than that normally performed in preparing to energize his transmitter such as lifting his microphone from its hang-up mechanism.
>
> or

A switch means shall be provided such that the operator can monitor the channel manually before each transmission or at any time deemed necessary in the course of operation.

or

A controller within the equipment shall not allow transmission on a receiving channel that has a signal present.

1.3.5.2 CTCSS Code Frequencies

The CTCSS Code Frequency is the assigned tone frequency. The standard frequencies available for assignment are given in Table 2.

Table 2 - CTCSS Code Frequencies

Freq (Hz)	Freq (Hz)	Freq (Hz)	Freq (Hz)
67.0	94.8	131.8	186.2
69.3	97.4	136.5	192.8
71.9	100.0	141.3	203.5
74.4	103.5	146.2	210.7
77.0	107.2	151.4	218.1
79.7	110.9	156.7	225.7
82.5	114.8	162.2	233.6
85.4	118.8	167.9	241.8
88.5	123.0	173.8	250.3
91.5	127.3	179.9	

1.3.5.3 Standard CTCSS Modulation

Standard CTCSS Modulation of an input signal is the modulation due to an input of a tone on any CTCSS Code Frequency to produce a level of frequency (phase) deviation shown in Table 3. This modulation is different from the Standard Test Modulation.

Table 3 - Standard CTCSS Modulation

Rated System Deviation (kHz)	Standard CTCSS Modulation (Hz)
±2.5	350
±4.0	400
±5.0	500

1.3.5.4 CTCSS Reverse Burst

CTCSS Reverse Burst is a squelch tail or noise elimination method. CTCSS Reverse Burst changes the phase of the subaudible tone prior to the removal of the RF carrier. This serves to discharge the energy stored in the narrowband CTCSS filters at the receiver, causing the receiver audio to turn off. Thus, the CTCSS reverse burst reduces or eliminates the noise burst heard in the receiver after the end of a transmission. There are currently two formats in use. One format advances the phase of the tone forward 120 degrees for 180 milliseconds at the end of the transmission prior to turning off the RF carrier. The other format advances the tone phase forward 180 degrees for 150 milliseconds.

1.3.5.5 CDCSS Data Rate

The CDCSS data rate is the assigned bit rate frequency for the NRZ data stream. The CDCSS data rate is 134.4 ±0.4 bps.

1.3.5.6 CDCSS Audio Turn Off Code

The CDCSS audio turn off code is the waveform necessary to disable the audio output of the receiver prior to the RF carrier removal. This serves as a squelch tail or noise eliminator. To accomplish this, the CDCSS encoder shall transmit a 134.4 ±0.5 Hz tone for 150 to 200 milliseconds.

1.3.5.7 CDCSS Code Words

The CDCSS code word consists of twenty-three bits of NRZ data that are continuously transmitted as long as the receiver audio is to be enabled. The eighty three code patterns are given in Table 4.

Table 4 - CDCSS Code Words

Octal Code	Bit Pattern MSB LSB	Octal Code	Bit Pattern MSB LSB
023	11101100011100000010011	162	11010111100100001110010
025	11010110111100000010101	165	01100011101100001110101
026	11001011101100000010110	172	00001011111100001111010
031	10100011111100000011001	174	00110001011100001111100
032	10111110101100000011010	205	11011101001100010000101
043	10110110110100000100011	223	11010001110100010010011
047	00011111101100000100111	226	11110110000100010010110
051	11111001010100000101001	243	10001011011100010100011
054	11011110100100000101100	244	00111111010100010100100
065	10111010001100000110101	245	10110001111100010100101
071	11001111001100000111001	251	11000100111100010101001
072	11010010011100000111010	261	00101110111100010110001
073	01011100110100000111011	263	10111101000100010110011
074	11101000111100000111100	265	10000111100100010110101
114	01101011110100001001100	271	11110010100100010111001
115	11100101011100001001101	306	00011001111100011000110
116	11111000001100001001110	311	01110001101100011001001
125	00001111011100001010101	315	11011000110100011001101
131	01111010011100001011001	331	01000111110100011011001
132	01100111001100001011010	343	01010010111100011100011
134	01011101101100001011100	346	01110101001100011100110
143	01101111010100001100011	351	00011101011100011101001
152	00111101100100001101010	364	11010000101100011110100
155	10001001101100001101101	365	01011110000100011110101
156	10010100111100001101110	371	00101011000100011111001

CDCSS Code words (continued):

Octal Code	Bit Pattern MSB LSB	Octal Code	Bit Pattern MSB LSB
411	11101110110100100001001	606	10111011001100110000110
412	11110011100100100001010	612	11001110001100110001010
413	01111101001100100001011	624	00011110101100110010100
423	10010111001100100010011	627	00000011111100110010111
431	11011000101100100011001	631	11100101000100110011001
432	11000101111100100011010	632	11111000010100110011010
445	11110111000100100100101	654	10011000011100110101100
464	01001111110100100110100	662	01001000111100110110010
465	11000001011100100110101	664	01110010011100110110100
466	11011100001100100110110	703	01000101011100111000011
503	01111000110100101000011	712	00010111101100111001010
506	01011111000100101000110	723	01110011000100111010011
516	10000001101110010100111 0	731	00111100100100111011001
532	00011100011100101011010	732	00100001110100111011010
546	00110011110100101100110	734	00011011010100111011100
565	00011000111100101110101	743	00101001101100111100011
		754	01000001111100111101100

LSB is transmitted first.

1.3.5.8 Standard CDCSS Modulation

Standard CDCSS Modulation of an input signal is the modulation due to an input of a NRZ Data Code Word to produce a level of frequency (phase) deviation shown in Table 5. This modulation is different from the Standard Test Modulation.

Table 5 - Standard CDCSS Modulation

Rated System Deviation (kHz)	Standard CDCSS Modulation (Hz)
±2.5	350
±4.0	400
±5.0	500

1.3.5.9 CDCSS Modulation Sense

CDCSS Modulation, being an NRZ baseband FSK modulation system is sensitive to the polarity of the frequency change the transmitter exhibits for a data bit of a one or zero. For the data bits shown in 1.3.5.7, the transmitter shall have the characteristics shown in Table 6.

Table 6 - CDCSS Modulation Sense

Modulation Type	Data Bit	Frequency Change
A	0 1	Minus frequency shift Plus frequency shift
B	0 1	Plus frequency shift Minus frequency shift

1.3.6 Definitions for Environmental Testing

1.3.6.1 Degradation From Standard (DFS)

DFS is degradation from the TIA standard or the manufacturer's specification, whichever is more stringent. This is not a degradation from measured value.

1.4 Standard Test Conditions

1.4.1 Basic Equipment Under Test

The equipment shall be assembled and any necessary adjustments shall be made in accordance with the manufacturer's instructions for the mode of operation being tested. When alternate modes of operation are available, the equipment shall be assembled and adjusted for these modes, as instructed by the manufacturer. A complete series of measurements shall be made for each mode of operation.

1.4.2 Associated Equipment

Tests are to be made with associated equipment that is normally used with the unit under test installed.

In mobile or portable equipment, the receiver, transmitter, control unit, and power supply unit shall be included and functional in the housing(s) supplied with the equipment, where applicable.

In fixed equipment, the normal power supply unit and other units that might affect the operation shall be included and operational in the cabinet(s) supplied with the equipment, where applicable.

1.4.3 Special Function Subsystems

In cases where the equipment is provided with special function subsystems, such as continuous tone or digital coded squelch, selective calling, receiver noise blankers, etc. the subsystems shall be disabled unless the method of measurement calls for these subsystems to be enabled.

1.4.4 Standard Conditions for the Power Supply

1.4.4.1 General

The standard test voltage shall be specified by the manufacturer, and shall, unless otherwise specified, refer to the voltage at the power cable input of the equipment when the equipment is in operation. The voltage shall not deviate from the stated value by more than ±2% during the measurement of any one parameter, on any one unit under test, unless otherwise stated. If the manufacturer does not specify the standard test voltage, then the default value shall be used as given in Table 7.

1.4.4.2 Default Standard Test Voltages for Battery Chemistry Types

Equipment measurements are typically conducted on battery powered equipment using a battery eliminator. Since each battery chemistry cell type has a unique voltage characteristic, it is appropriate to conduct measurements with the value based on the cell type and the number of cells utilized in the battery pack. Table 7 lists commonly available battery chemistry cell types. The values listed as Standard Test Voltages in Table 7 are to be used in combination with the number of cells in the battery to calculate the standard test voltage to be applied to the equipment by the battery eliminator for standard test conditions.

Table 7
Secondary Cell Voltages for Common Battery Chemistry Types

Cell Chemistry	Nominal Voltage (V/Cell)	Default Standard Test Voltage (V/Cell)
Lead Acid	2.0	Per Table 8
Nickel-Cadmium with incorporated gas-venting	1.2	1.40
Nickel-Cadmium of the sealed type	1.2	1.25
Nickel-Metal-Hydride	1.2	1.25
Lithium Ion	3.6	3.75

1.4.4.3 Standard Test Voltage for Equipment Powered by Integral Batteries

For equipment powered by batteries integral to the equipment the standard test voltage shall be specified by the manufacturer or be equal to the default standard test voltage of Table 7, multiplied by the number of cells in the battery to be used. The standard test voltage shall not exceed the voltage measured at the battery at any time after 10% of rated battery capacity has been used.

For equipment with integral batteries, the battery may be disconnected and/or removed, and an external source connected through leads that are shielded and filtered. When making radiated measurements, the batteries may be disconnected, but not removed, to prevent altering the radiation or reception pattern of the unit.

Integral batteries are defined as battery packs that are required for a primary mode of operation and mounted integrally to the equipment. The battery pack or individual cells may be detachable or removable for the purpose of replacement by the user.

1.4.4.4 Standard Test Voltage for Equipment Powered by External Batteries

For vehicular equipment powered by batteries external to the equipment, the standard test voltage shall be specified by the manufacturer, or be equal to the default standard test voltage of Table 8, based on the equipment current drain.

Table 8
Vehicular 12 Volt Battery Default Standard Test Voltages

Operating Current (A)	Test Voltage (V)
Less than 6	13.8
6 to 16	13.6
16 to 36	13.4
36 to 50	13.2
Greater than 50	13.0

1.4.4.5 Other Power Sources

For operation from other power supplies or types of batteries, the manufacturer shall specify the nominal and extreme test voltages.

1.4.4.6 Standard AC Voltage and Frequency

The standard ac test voltage shall be equal to the nominal ac mains voltage to be applied to the equipment. If equipment is provided with different input voltage taps, the one designated nominal should be used. The standard test frequency shall be equal to the nominal ac mains frequency. During the measurements, the test frequency, and the test voltage shall not deviate more than ±2% from the value at the beginning of each test.

For power supplies that are specified as wide input range or universal input, the nominal ac mains voltage to be applied to the equipment shall be used under nominal test conditions. For extreme conditions testing, the upper and lower mains voltage, and frequency test values shall be calculated using the nominal ac mains values applied to the equipment.

Alternatively, the manufacturer shall specify the extreme conditions voltage and frequency values.

1.4.5 Standard Atmospheric Conditions

The standard atmospheric condition is a temperature of 25 °C at an atmospheric pressure of 1013 hPa (1013 mbar). Measurements, however, may be carried out at any combination of temperature, pressure, and relative humidity within the following limits:

Temperature: 20 °C to 35 °C
Relative Humidity: 45% to 75%
Atmospheric Pressure: 860 hPa to 1060 hPa (860 mbar to 1060 mbar)

During any series of tests, the temperature should be held to within ±1 °C.

If the quantities to be measured depend on temperature, humidity, or atmospheric pressure, and the law of dependence is known, the values obtained shall be corrected by calculation to the standard atmospheric condition. If the quantities to be measured depend on temperature, humidity, or atmospheric pressure, and the law of dependence is not known, the atmospheric conditions prevailing during the tests shall be recorded.

1.5 Characteristics of Test Equipment

Test equipment to be used is left to the manufacturer's discretion. All test equipment used shall be in current calibration. The following parameters are provided as a guide for selecting the test equipment.

1.5.1 Distortion, SINAD, and Audio Frequency Level Meter

For the measurement of signal-to-noise ratio (SINAD) and audio level, the indicating meter shall be a true rms voltmeter. The meter shall have the following characteristics:

a) Input impedance of at least 50 kΩ.

b) Measurement accuracy of ±3% over the frequency range from 20 Hz to 20 kHz.

c) Accurately measure nonsinusoidal signals with a peak to rms ratio of at least a 3:1.

d) An optional low pass filter may be used for measurement of receivers employing Class-D audio amplifiers. If used, the corner frequency shall be ≥ 15 kHz.

The rms meter may be a separate device or it may be included within a distortion factor meter.

The distortion factor meter shall incorporate a band rejection filter to attenuate the fundamental component of the demodulated signal. The filter shall have the following characteristics:

a) The relative attenuation of the fundamental frequency shall be at least 40 dB.

b) The relative attenuation at 1/2 or twice the fundamental frequency shall not exceed 0.6 dB.

c) In the presence of a noise signal, the filter shall not cause more than 1 dB of relative attenuation of the total noise output power of a 300 Hz to 3000 Hz bandwidth flat noise source.

d) Provide an output signal of the waveform after it has been processed by the notch.

1.5.2 RF Signal Generators

The RF signal generator shall have the following characteristics:

a) 50 Ω output impedance with a VSWR of ≤1.2:1.

b) Calibrated variable output with a level accuracy of ≤ ±2 dB.

c) Single sideband phase noise in a 1 Hz bandwidth of 135 dB below the carrier at 25 kHz offset from the carrier for frequencies of 500 MHz and lower. For frequencies above 500 MHz, the phase noise shall be less than 130 dB below the carrier at a frequency offset of 25 kHz from the carrier.

   NOTE: The measurement of certain characteristics, for example adjacent channel rejection, can be erroneous when a signal generator having a high spectral noise content is used. At frequencies below 200 MHz, a crystal filter having at least 20 dB rejection at the adjacent channel can be connected at the output of the signal generator under test as a means of assessing whether a result is influenced by signal generator noise.

d) Variable frequency deviation with an accuracy of at least 5%.

e) The intermodulation in the signal generators and the combining network may be tested, when performing the receiver intermodulation rejection test, using the following procedure:

1) Insert a variable attenuator between the combining network and the receiver under test.

2) Increase the attenuation in steps of 1 dB and increase the output voltage of the generators by the same amounts, thus maintaining the original signal level input to the receiver.

3) Since the intermodulation products in the output should remain constant, any increase is caused by intermodulation in the signal generators or combining network. Therefore, more isolation between the signal generators or an improved combining network is required.

1.5.3 Digital Multimeter

The digital multimeter (DMM) shall have the following characteristics:

a) ac/dc voltage-measurement accuracy of $\leq \pm 2\%$ of reading.

b) ac/dc current-measurement accuracy of $\leq \pm 2\%$ of reading.

c) Input impedance of ≥ 1 MΩ.

1.5.4 RF Power Meter

The RF power meter shall have the following characteristics:

a) Measurement accuracy of $\leq \pm 0.2$ dB

b) Input VSWR of $\leq 1.2:1$.

1.5.5 Spectrum Analyzer

The spectrum analyzer shall have the following characteristics:

a) A resolution bandwidth range of ≤ 100 Hz to 1 MHz in a 1, 3, 10 sequence by decade. The resolution bandwidth filter shape factor (ratio of 60 dB bandwidth to 3 dB bandwidth) should be ≥ 10 and ≤ 15.

b) A video bandwidth range of ≤ 100 Hz to 3 MHz in a 1, 3, 10 sequence by decade.

c) Log fidelity error of ≤2 dB over a 70 dB range.

d) A spurious free dynamic range of ≥80 dB.

e) Ability to measure relative levels of input-signal components with an accuracy of ≤ ±1 dB.

f) A quasi peak detector that meets the requirements of CISPR Publication 11, and a peak detector (as required in the method of measurement).

g) Be capable of digitizing an input spectrum for adjacent channel power measurements.

1.5.6 Audio Spectrum Analyzer

The audio spectrum analyzer shall have the following characteristics:

a) Ability to measure frequencies from 100 Hz to 50 kHz.

b) A dynamic range of ≥60 dB.

c) Input attenuator capable of ≥40 dB in ≤10 dB steps.

d) Input impedance of ≥500 kΩ.

e) Ability to measure relative levels of input signal components with an accuracy of ≤ ±2 dB

1.5.7 Test Receiver

The test receiver shall consist of test equipment configured to comply with the following requirements:

a) Tunable over the transmitter's frequency range.

b) Measure peak positive, peak negative, and rms deviations up to ±30 kHz, with a calibrated accuracy of ≤ ±1%.

c) Measure instantaneous and steady-state deviation.

d) Include a switchable de-emphasis network whose audio response does not vary more that ±1 dB from a 750 microsecond characteristic between 50 Hz and 3000 Hz.

e) Have a nominal 3 dB audio band pass from ≤50 Hz to ≥15,000 Hz with a frequency response variation not exceeding ±0.5 dB from 300 Hz to 3000 Hz.

f) Have a selectable 3 dB bandwidth of ≤0.25 Hz to ≥15,000 Hz.

g) Include a switchable 3 dB bandwidth of 300 Hz to 3000 Hz. The maximum number of poles at the high and low pass corners should not exceed five.

h) Include a switchable 3 dB bandwidth of 50 Hz to 3000 Hz. The maximum number of poles at the high and low pass corners should not exceed five.

i) Have an unsquelched hum and noise ratio of at least 10 dB better (when measured in a bandwidth equal to that to be used to measure the device under test) than the level to be measured.

j) Have signal processing distortion of ≤1%.

k) Provide a demodulated signal that can be analyzed by the distortion level meter.

l) The capture effect of the Demodulator Output Port (DOP) should be less than 10 dB when two RF signals at the same tuned frequency are applied to the RF input. Performance test is a follows:

Connect two RF generators to the input of the test receiver via a RF combiner. Modulate one RF signal with 1000 Hz tone at ±25 kHz deviation and the other RF signal is not modulated, adjust the modulated signal level to -40 dB below the test receiver's maximum input level and set the unmodulated signal at approximately -100 dBm. The demodulated output should be a continuous 1000 Hz tone due to the modulated signal capturing the demodulator. Then increase the unmodulated signal in magnitude until the 1000 Hz demodulated signal at the DOP is suppressed. The unmodulated RF level must be 10 dB or less above the level of the modulated RF signal at the input to the test receiver when the 1000 Hz tone is suppressed.

m) Have a delay time of ≤10 msec from the time an RF signal is applied until the demodulated output signal is stable.

1.5.8 Adjacent Channel Power Measuring Receiver

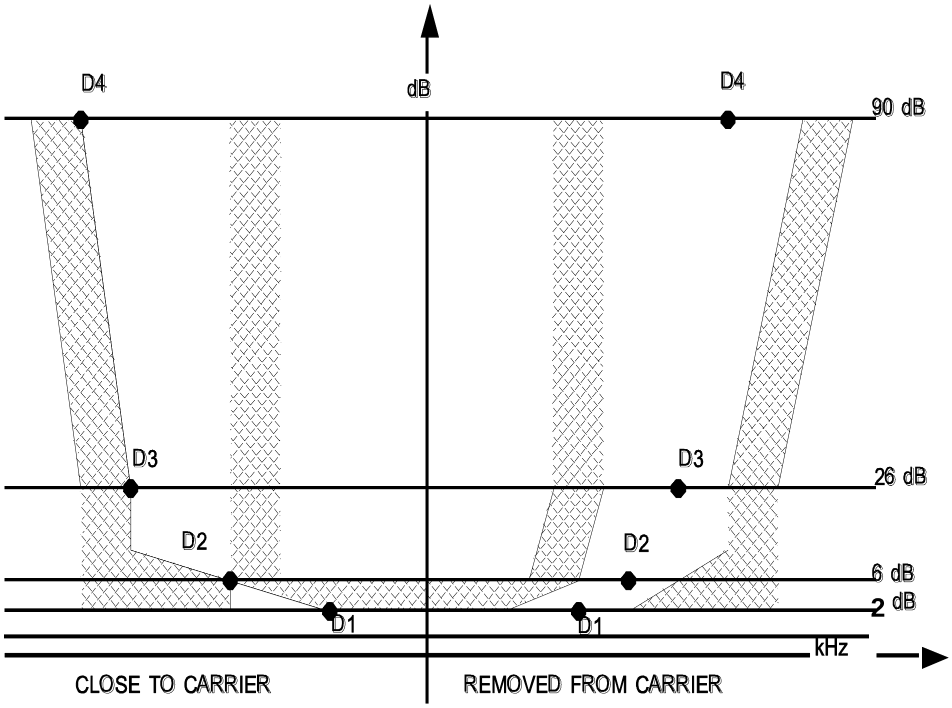
The adjacent channel power measuring receiver shall consist of a mixer, IF filter, oscillator, amplifier, variable attenuator, and an rms indicator. Instead of the variable attenuator with the rms indicator, it is also possible to use an rms voltmeter calibrated in dB as the rms indicator. The adjacent channel measuring receiver shall meet the following characteristics:

a) The frequency tuning shall be adjusted away from the carrier such that the -6 dB response nearest to the transmitter's carrier frequency is located at a displacement from the nominal carrier frequency as given in Table 9.

Table 9 -
Adjacent Channel Power Measuring Receiver Tuning

Channel Separation (kHz)	Displacement from the -6 dB point (kHz)
12.5	8.25
20	13
25 & 30	17

b) The IF filter shall be within the limits of the following selectivity curves:



IF Filter Selectivity Curves

c) The selectivity characteristics shall keep the frequency separation from the nominal center frequency as given in Table 10.

Table 10
Adjacent Channel Power Measuring Receiver Frequency Separation

Channel Separation (kHz)	Frequency separation of filter curve from nominal center frequency of adjacent channel (kHz)			
	D1	D2	D3	D4
12.5	3.0	4.25	5.5	9.5
20	4.0	7.0	8.25	12.25
25 & 30	5.0	8.0	9.25	13.25

d) The attenuation shall not exceed the tolerances for the points closest to the carrier as given in Table 11.

Table 11
Adjacent Channel Power Measuring Receiver Tolerance

Channel Separation (kHz)	Tolerance range (kHz)			
	D1	D2	D3	D4
12.5	+1.35	±0.1	-1.35	-5.35
20	+3.1	±0.1	-1.35	-5.35
25 & 30	+3.1	±0.1	-1.35	-5.35

e) The attenuation shall not exceed the tolerances for the points removed from to the carrier as given in Table 12.

Table 12
Adjacent Channel Power Measuring Receiver Tolerance

Channel Separation (kHz)	Tolerance range (kHz)			
	D1	D2	D3	D4
12.5	±2.0	±2.0	±2.0	+2.0 -6.0
20	±3.0	±3.0	±3.0	+3.0 -7.0
25 & 30	±3.5	±3.5	±3.5	+3.5 -7.5

f) The variable attenuator shall have a minimum range of 80 dB and a resolution of 1 dB.

g) The instrument shall accurately indicate nonsinusoidal signals in a ratio of up to 10:1 between peak values and rms values.

h) The oscillator and the amplifier shall be designed in a way that the measurement of the adjacent channel power on a low-noise unmodulated transmitter, whose self-noise has a negligible influence on the measurement result, yields a measurement value of ≤ -90 dB for channel separations of 20 kHz, 25 kHz, and 30 kHz and ≤ -80 dB for a channel separation of 12.5 kHz, referenced to the carrier of the oscillator.

1.5.9 Audio Frequency Load

An audio frequency output test load is an impedance network that replaces the load to which the receiver is connected under normal operating conditions. It simulates the impedance of the normal load and any cables with which it is normally used. The network is specified by the manufacturer, and usually consists of a pure resistance. It must have the capability to dissipate the receiver audio output power without generating a temperature rise that would change its operating impedance.

1.5.10 RF Counter

The RF counter shall measure the transmitter unmodulated radio frequency with the following accuracy:

a) Time drift of ≤1 x 10^{-9} parts per day.

b) Resolution ≤30 Hz.

c) Calibrated to an absolute frequency accuracy 10 times better than the desired measurement accuracy.

1.5.11 Oscilloscope

The oscilloscope shall have the following characteristics:

a) Measure time intervals with an accuracy of ≤ ±2%.

b) Measure peak voltage with an accuracy of ≤ ±1%.

c) An external trigger input or dual channel with trigger capability on one of the channels.

d) A digital storage scope capable of viewing trace information that occurs at 10 milliseconds before the trigger.

e) Horizontal sweep control for 1 microsecond to 100 milliseconds per division.

f) Vertical sensitivity of 5 mV to 5 V per division.

g) Bandwidth of at least 10 MHz.

1.5.12 RF Attenuator

The RF attenuator is a two-port resistive device that couples a portion of the transmitter output power to the test equipment. The attenuated power has the same waveform as the transmitter output power. The attenuator shall have the following characteristics:

a) RF frequency range of 10 times the transmitter assigned frequency.

b) Attenuation that will reduce the transmitter output power to the optimum range of the test equipment.

c) Attenuation over the range indicated in a) shall be flat within ±1 dB.

d) Power rating of ≥2 times the output power of the transmitter under test.

e) VSWR over the range indicated in a) shall be ≤1.2:1.

1.5.13 Audio Frequency Signal Generator

The audio frequency signal generator shall have the following characteristics:

a) Audio frequency range of 50 Hz to 20,000 Hz.

b) Output level sufficient to supply the transmitter's microphone input with 20 dB above 60% of rated system deviation.

c) Distortion of ≤1%.

d) Output level flatness of ≤0.2 dB over the range indicated in a).

1.5.14 Sound Level Meter

The sound level meter shall conform to the IEC 651 standard. It shall have an accuracy of IEC Type 2 or better.

1.5.15 RF Detector

The RF detector shall have the following characteristics at the assigned transmitter frequency:

a) Provide a linear response from RF input to detected output voltage.

b) Time constant of ≤0.5 ms.

c) RF frequency range sufficient to detect the transmitter's output power.

d) Input VSWR of ≤1.2:1.

1.5.16 Directional Coupler

The directional coupler shall have the following characteristics:

a) Insertion loss of ≤1 dB at the RF frequency of the transmitter ±500 kHz.

b) Directivity of ≥20 dB.

c) VSWR for all ports of ≤1.2:1.

1.5.17 50 Ohm Termination

The 50 Ω terminations are used to terminate unused directional coupler and combining network ports in their characteristic impedances. The 50 Ω termination shall have the following characteristics:

a) VSWR of ≤1.01:1.

b) Frequency range and power rating as required by the test.

1.5.18 TX Key Control

The transmitter key control switch is defined as a device or circuit that supplies the power necessary to change the transmitter state from standby to transmit and supplies the oscilloscope with a simultaneous trigger signal. For example, a TX key control switch may be a relay contact or a saturated transistor that supplies a voltage to the oscilloscope trigger input and the Push To Talk (PTT) input of the transmitter.

1.5.19 RF Switch

An RF switch is used to apply an RF signal to the receiver or transmitter and apply a signal to trigger an oscilloscope. The RF switch shall have the following characteristics at the assigned frequency:

a) VSWR of ≤2:1 at the RF ports when the other port(s) is(are) terminated into 50 Ω.

b) RF isolation for the RF ports of ≥30 dB when the ports are not engaged.

c) The multi-pole switch should engage/disengage and all contact bouncing should be completed by 10 msec.

1.5.20 Dummy Microphone

The dummy microphone circuit shall be specified by the manufacturer. Its purpose is to provide a frequency response characteristic that can replace the microphone during testing. It shall have a constant input impedance over the frequency range of 300 Hz to 30,000 Hz.

1.5.21 RF Combining Network

An RF combining network is used to couple two or more RF signals together for making measurements. The RF combining network shall have the following characteristics:

a) No more than 0.5 dB imbalance in attenuation between any input port and the output port.

b) VSWR of ≤1.3:1 at any port, with all other ports terminated with a 50 Ω termination.

1.5.22 Impulse Generator

An impulse generator shall have the following characteristics:

a) Variable amplitude pulse output.

b) Output impedance of 50 Ω with a VSWR of ≤1.3:1.

c) Capable of generating 10 nanosecond wide pulses at a 10 kHz repetition rate.

d) The pulses shall have a rise and fall time of less than 5 nanosecond.

1.5.23 CTCSS/CDCSS Signal Generator

For the measurement of subaudible signaling sections of receivers, the CTCSS/CDCSS signal generator shall provide a selection of all CTCSS code frequencies and CDCSS code patterns defined in this document. The generator shall have the following additional characteristics:

a) Generate a sinewave or filtered NRZ data stream.

b) The generated sinewave shall have a distortion of ≤ 1%.

c) The sinewave shall have an output flatness of ≤0.2 dB across the CTCSS code frequency range.

d) The output level shall be sufficient to provide at least ±2 kHz of deviation when used with the RF signal generator.

e) The sinewave frequency shall be accurate to within 0.05%.

f) The sinewave frequency shall be adjustable in at least 0.1 Hz steps.

g) The NRZ data stream shall be at a bit rate of 134.4 bps ±0.5 bps.

h) Generate a CDCSS turn off code at the end of the NRZ data stream. This code shall be a 134.4 Hz sinewave for a period of 180 to 200 ms.

i) The power of the NRZ data stream above 300 Hz shall be less than 1% of the total power.

j) Generate a CTCSS reverse burst appropriate to the system being tested.

1.5.24 Notch Filter

The notch filter shall have the following characteristics:

a) Attenuation of ≥30 dB at the transmitter assigned frequency.

b) Attenuation of ≤2 dB at frequencies ≥2 times the transmitter's assigned frequency.

c) An input and output VSWR of ≤1.2:1.

1.5.25 Lumped Constant Line Stretcher (LCLS)

a) A typical LCLS may consist of the following circuit with the values from the following table.

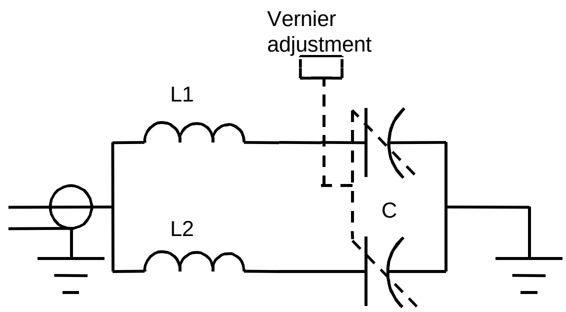


Table 13 - Lumped Constant Line Stretcher

Frequency (MHz)	L1 (nH)	L2 (nH)	C (pF)
25-33	0.113	0.554	10-365 Dual Gang Variable Capacitor
33-42	0.69	0.410	
42-50	0.44	0.290	
130-150	0.33	0.123	5.9-50 Butterfly Capacitor
150-175	0.25	0.83	

b) The minimum VSWR of the LCLS box should be ≥10 times that of the test VSWR.

Note: The rotor portion of the capacitor should be grounded to prevent an RF potential from being exposed.

1.5.26 Constant Impedance Line Stretcher (CILS)

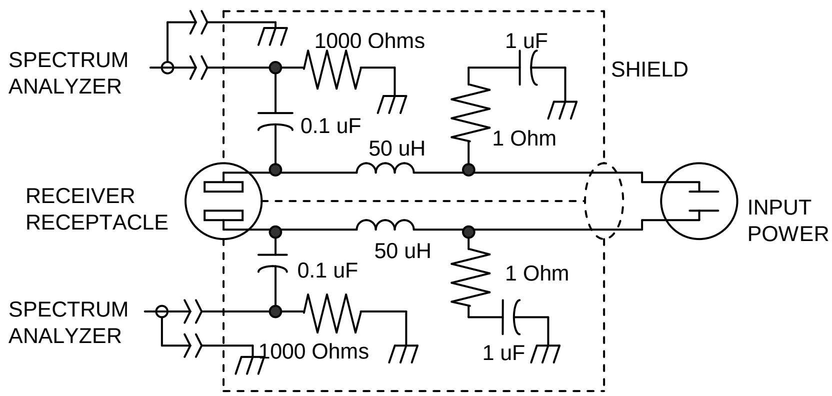
The constant impedance line stretcher shall have the following characteristics:

a) Insertion loss ≤0.1 dB at the RF frequency of the transmitter ±500 kHz.

b) Phase rotation of 360 degrees at RF frequencies >175 MHz.

1.5.27 Line Impedance Stabilization Network (LISN)

a) The LISN shall consist of the following circuit:



1.5.28 Variable dc Power Supply

The variable dc power supply shall have the following characteristics:

a) Variable dc voltage over a range of standard test voltage -20% to standard test voltage +20%.

b) Maximum current sufficient to supply the transmitter when keyed.

c) Ripple and noise of ≤10 mV rms.

d) Operate in the constant voltage mode.

1.5.29 Variable ac Power Supply

The variable ac power supply shall have the following characteristics:

a) Variable ac voltage over a range of standard test voltage -20% to standard test voltage +20%.

b) Maximum current sufficient to supply the equipment under test when the transmitter is keyed and under full load and power output conditions.

c) Capable of operating in a constant voltage mode.

d) Shall produce a line frequency of ±1% of the assigned line frequency.

1.5.30 Standard Radiation Test Site (3 meter)

The test site shall be on a level surface that is of uniform electrical characteristics. The site shall be clear of metal objects, overhead wires, etc., and shall be as free as possible from undesired signals such as ignition noise, other carriers, etc. The distance from the unit under test or the test antenna to reflecting objects shall not be less than 3 m. At the transmitter or receiver end, a turntable essentially flush with the ground, should be provided that can be remotely controlled. A platform 80 cm high shall be provided on this turntable to hold the receiver or transmitter under test. A conductive ground plane consisting of not greater than 1.3 cm square soldered mesh wire shall extend to or beyond the two 3 m radius circles described above. If desired, radome shelters may be provided for the equipment and personnel at both ends of the test site. All such construction shall be of wood, plastic, or nonmetallic material. All power, telephone, or control circuits to the site shall be placed below the conductive ground plane.

Measurements of radiated signals shall be made at a point 3 m from the center of the turntable. A nonconductive pole with a movable horizontal boom shall be arranged so that the center of the test antenna can be raised and lowered from 1 m to 6 m. The test antenna shall be mounted on the end of the boom with its cable lying horizontally on the boom back to the supporting mast. A spectrum analyzer is connected to this cable at the foot of the mast.

The transmitter or receiver to be tested shall be placed on the platform on the turntable. (Rack type equipment may be placed directly on the turntable.) The power cable shall extend downward to a maximum of 0.1 m above the ground plane. Any excess cable shall be coiled on the turntable. For receiver tests, a vertical whip antenna, adjusted to 1/4 wavelength at the standard input signal frequency, mounted 3 m above the ground plane over the center of the turntable, having a ground system of at least four ground radials 1/4 wavelength long, shall be connected to the receiver antenna terminal. A minimum length of low loss cable shall be used to make this connection.

1.5.31 Standard Radiation Test Site (30 meter)

The test site shall be on level ground that is of uniform electrical characteristics. The site shall be clear of metal objects, overhead wires, etc., and shall be as free as possible from undesired signals such as ignition noise, other carriers, etc. The distance from the unit under test or the test antenna to reflecting objects such as rain gutters, house plumbing, etc. shall not be less than 90 m. At the transmitter or receiver end, a turntable essentially flush with the ground, should be provided that can be remotely controlled. A platform 80 cm high shall be provided on this turntable to hold the receiver or transmitter under test. If desired, radome shelters may be provided for the equipment and personnel at both ends of the test site. All such construction shall be of wood, plastic, or nonmetallic material. All power, telephone, or control circuits to the site shall be buried at least 0.3 m deep.

Measurements of radiated signals shall be made at a point 30 m from the center of the turntable. A nonconductive pole with a movable horizontal boom shall be arranged so that the center of the test antenna can be raised and lowered from 1 m to 6 m. The test antenna shall be mounted on the end of the boom with its cable lying horizontally on the boom back to the supporting mast. A spectrum analyzer is connected to this cable at the foot of the mast.

The transmitter or receiver to be tested shall be placed on the platform on the turntable. (Rack type equipment may be placed directly on the turntable.) The power cable shall extend downward to a maximum of 0.1 m above the ground plane. Any excess cable shall be coiled on the turntable. For receiver tests, a vertical whip antenna, adjusted to 1/4 wavelength at the standard input signal frequency, mounted 3 m above the ground plane over the center of the turntable, having a ground system of at least four ground radials 1/4 wavelength long, shall be connected to the receiver antenna terminal. A minimum length of low loss cable shall be used to make this connection.

NOTE: This site is recommend when making measurements below 88 MHz. If the 3 meter site is used for these measurements the results will be worse than the actual values.

1.5.32 Acoustic Chamber

The acoustic chamber shall be constructed using ISO 3745 annex A as a guide.

When performing acoustic measurements, the nonreflectivity of the environment can be checked by observing a 6 dB change on the sound level meter for a l:2 change in distance to the acoustic transducer.

1.5.33 Adjacent Channel Power Analyzer

This instrument shall be similar to the spectrum analyzer previously described except it shall also be capable of:

a) Directly measuring (in linear power units) and displaying in average power density (not video averaging) in three channels as a function of swept frequency over user defined channels by digital computation.

b) Making the measurement using a resolution bandwidth in the range from

0.5% to 2% of the measurement bandwidth.

c) Adjustable band edge settings (-6 dB point) with at least 100 Hz resolution.

d) Having optional band edge markers simultaneously visible for a center channel and both adjacent channels.

e) Displaying the power in the center channel (in dBm), and the ratio of the power in each adjacent channel (in dB) relative to the center channel.

f) Having a frequency span display range of 100 kHz, 50 kHz, and 30 kHz.

g) Providing an output signal to generate a print, plot, or file of the display and readings.

1.5.34 Modulation Domain Analyzer

The modulation domain analyzer shall have the following characteristics:

a) Measure frequency with a resolution of 1 kHz or less over the frequency range of interest.

b) An external trigger input or multiple channels with RF envelope detector trigger capability on one of the channels.

c) Horizontal sweep control for 1 μs to 100 ms per division.

d) Ability to assign a time stamp to the occurrence of the trigger signal and display time-of-measurement.

e) Have time markers and frequency markers to allow set-up of a mask for the resultant waveform display.

1.5.35 Signal Preamplifier

The signal preamplifier shall have the following characteristics:

a) Gain of at least 25 dB from 30 to 5000 MHz.

b) Noise figure of ≤7 dB.

c) 1dB gain compression or less at +20 dBm output.

1.5.36 Gigahertz Transverse Electromagnetic Cell (GTEM)

The GTEM cell consists of a section of gently flared rectangular coaxial transmission line terminated with a matched load. The end termination of the cell is a wall with absorbing material. At low frequencies it operates as a circuit element 50 Ohm load. At higher frequencies absorbers attenuate the incident waves as in an anechoic chamber. The GTEM cell shall have the following characteristics:

a) Radiated frequency range from 9 kHz to 5 GHz.

b) Input impedance (Z_c) 50Ω.

c) VSWR of ≤1.65:1.

d) Shielding effectiveness of 80dB.

e) Field uniformity ±3dB below 1GHz and ±4dB above 1 GHz.

f) Maximum continuous wave (CW) input power of 1 kW.

g) Antenna factor $E = e_0 \sqrt{P} = e_0 V_{out} / \sqrt{50}$

where:

$e_0 = \sqrt{Z_c} / h$
E is the electrical field strength in the test volume
h is the height of the septum in the test volume
e_0 is the output voltage from the septum

h) The equipment under test manipulator reflections should not affect accuracy by more than ±2 dB.

i) Signal processor software: IEC 60481-1 compliant 3 axis (or greater) correlation algorithm that converts maximum individual dBμV field strength, including provisions to utilize correlation factors obtained via measurements at an open air test site.

1.5.37 RF Anechoic Chamber

A RF anechoic chamber is one in which all interior surfaces are covered by electromagnetic absorption material that suppresses reflections to simulate free-space conditions. A free-space environment is assured by the chamber providing a square law site attenuation characteristic. Both the equipment to be tested and the measurement antenna are located in the chamber interior. The chamber must be sufficiently large to assure that their separation assures far-field test conditions at the lowest frequency of measurement. Like an open-air test site (OATS), these may be custom designs in contrast to being off-the-shelf available. The chamber may be constructed of shielding material to exclude external disturbing influences.

An example RF anechoic chamber with the dimensions 5-m x 5-m x 10-m has the following performance characteristics:

Table 14 - RF Anechoic Chamber Characteristics

Characteristic	**Performance**
Useful Frequency Range	100 MHz to above 1 GHz
Useful Measuring Distance	3-m to 5-m
Nominal Site Attenuation	26 dB (5-m separation at 100 MHz)
Nominal Site Attenuation	46 dB (5-m separation at 1 GHz)
Minimum Shielding Attenuation	60 dB
Minimum Return Loss of Absorbers	10 dB
Maximum Equipment Size	1-m

2 METHODS OF MEASUREMENT

2.1 Methods of Measurement for Receivers

This section details test definitions and methods of measurement of the characteristics of FM or PM private land mobile receivers in vehicular (mobile), fixed (base station), or handheld (portable) installations employing voice modulation.

When the receivers are equipped with special function subsystems, such as continuous tone coded squelch or selective signaling, the subsystems shall be disabled. This section does not cover testing of receivers that include subsystems that cannot be disabled or bypassed.

The standards for each receiver method of measurement can be found in sections 3.1.X, where X is the last digit of the method of measurement being performed.

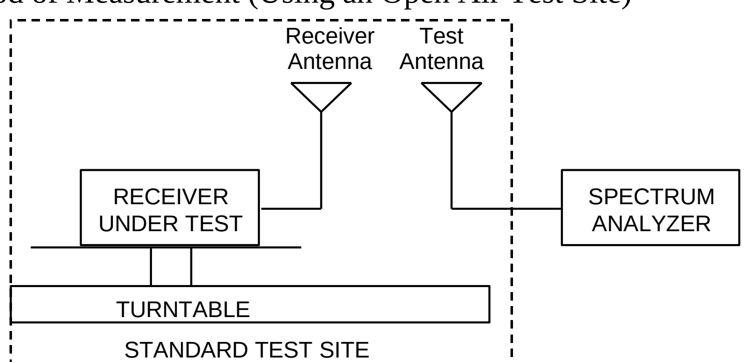
An example measurement uncertainty calculation for each receiver method of measurement can be found in Annex B1.X (informative), where X is the last digit of the method of measurement being performed.

2.1.1 Radiated Spurious Output Power

2.1.1.1 Definition

The radiated spurious output power is the electromagnetic power generated or amplified in a receiver and radiated from the receiver or by the antenna, or by all control, audio, and power leads.

2.1.1.2 Method of Measurement (Using an Open Air Test Site)



a) Adjust the equipment in accordance with the manufacturer's tuning procedure. Measurements are to be done at a standard radiation test site, or an FCC listed test site compliant with ANSI C63.4-2001 clause 5.4 using a spectrum analyzer with a quasi peak detector meeting the requirements of IEC CISPR Publication 16.

b) For each spurious frequency of measurement, adjust the test antenna for the correct length. This length may be determined from a calibration ruler that is supplied with the equipment. For a superheterodyne receiver not controlled by a digital device, these measurements shall be made from 30 MHz to 1000 MHz, or 2 times the highest local oscillator frequency generated in the receiver, whichever is higher. For a superheterodyne receiver controlled by a digital device, the upper limit test frequency shall be the greater of the requirement for a receiver not controlled by a digital device, or an upper limit frequency per table 15:

Table 15 - Test Frequency Limit

Highest Internally Generated Digital Device Operating Frequency (MHz)	Upper Limit Test Frequency (MHz)
Below 108	1000
108 to 500	2000
500 to 1000	5000
Above 1000	5th Harmonic of highest internally generated digital device operating frequency

c) For each frequency, raise and lower the test antenna to obtain the maximum reading on the spectrum analyzer with the test antenna at a horizontal polarity.

d) Rotate the turntable for a maximum reading on the spectrum analyzer.

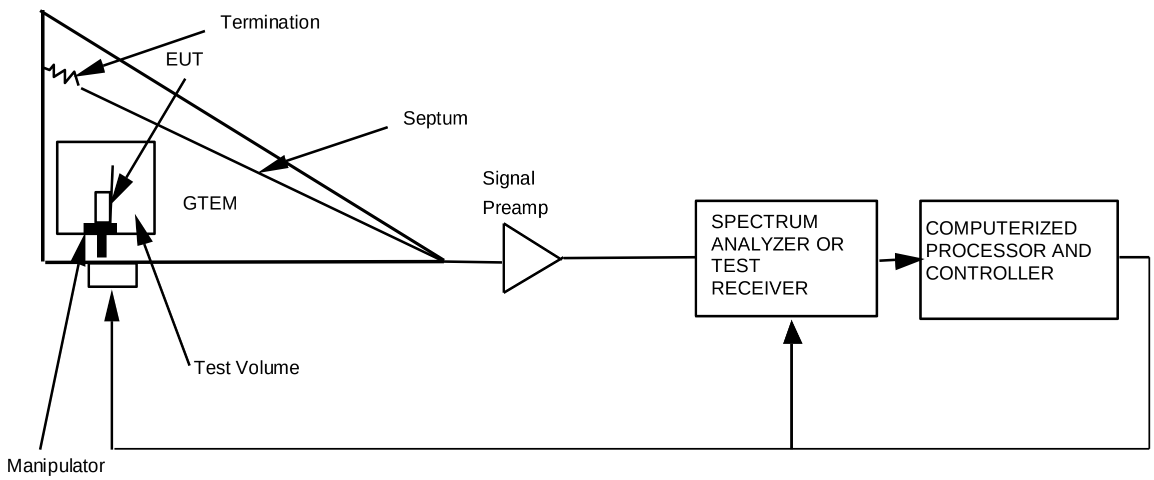
e) Repeat steps c) and d) to obtain a maximum reading. Record this power level.

f) Repeat steps c) and d) with the antenna vertically polarized. Record this power level. (When the test antenna length does not permit lowering the boom to 1 m, adjust the minimum height for 0.3 m ground clearance.)

g) Compute the field intensity in μV/m of the larger of the readings obtained in steps e) and f) for each frequency, using the information supplied with the test antenna to make this conversion, accounting for cable loss.

h) The radiated spurious output power at each frequency of measurement is the value obtained in step g) at the frequency of measurement. It is not necessary to record levels that are more than 20 dB below the specified limit.

2.1.1.3 Alternate Method of Measurement (Using a GTEM Cell)



a) Position the equipment under test in the GTEM cell test volume. The initial orientation shall be designated as the X orientation. Designate additional orthogonal orientations Y and Z.

b) Set the spectrum analyzer or test receiver to use an IEC CISPR 16 quasi-peak detector for signals below 1 GHz, or an average detector above 1 GHz. Sweep or scan the appropriate frequency range and record the voltage from the GTEM at each spurious radiation frequency observed.

c) Repeat step b) for the Y and Z orientations.

d) Use the GTEM calibration software to determine the maximum field intensity in dB μV/m at each spurious frequency.

e) The radiated spurious output power at each frequency is the value obtained in step d).

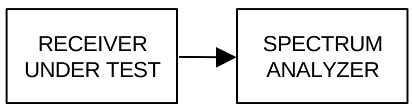
Note: For purposes for receiver FCC Certification per Part 15 rules, it is required that that the GTEM be calibrated to an open air test site using the method in 2.1.1.2 and inputting the appropriate correlation factors into the signal processing software.

2.1.2 Conducted Spurious Output Power

2.1.2.1 Definition

The conducted spurious output power is power that is generated or amplified in a receiver and appears at the receiver's antenna terminals.

2.1.2.2 Method of Measurement



a) Connect a spectrum analyzer, using a quasi peak detector, meeting the requirements of IEC CISPR Publication 16, (through a resistive matching network if required to match the receiver input impedance Rn to the spectrum analyzer) to the receiver antenna terminals.

b) Tune the spectrum analyzer to search for spurious outputs. For a superheterodyne receiver not controlled by a digital device, these measurements shall be made from 30 MHz to 1000 MHz, or 2 times the highest local oscillator frequency generated in the receiver, whichever is higher. For a superheterodyne receiver controlled by a digital device, the upper limit test frequency shall be the greater of the requirement for a receiver not controlled by a digital device, or an upper limit frequency per table 16:

Table 16 - Test Frequency Limits

Highest Internally Generated Digital Device Operating Frequency (MHz)	Upper Limit Test Frequency (MHz)
Below 108	1000
108 to 500	2000
500 to 1000	5000
Above 1000	5th Harmonic of highest internally generated digital device operating frequency

Record all spurious outputs found that are in excess of 20 dB below the specified limit.

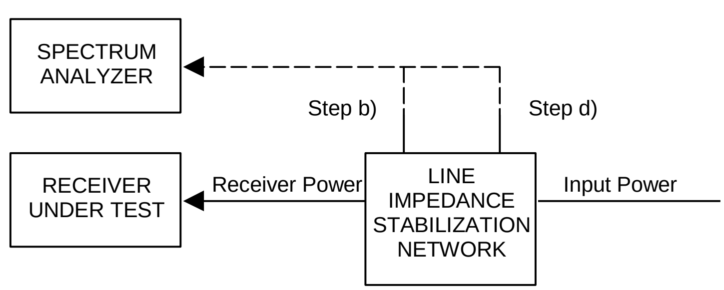
c) The conducted spurious output power is the largest reading obtained in step b) (corrected for any matching network loss, if used).

2.1.3 Power Line Conducted Spurious Output Voltage

2.1.3.1 Definition

The power line conducted spurious output voltage is the voltage that is generated or amplified in a receiver and appears between each power line terminal that connects to a public utility line and ground.

2.1.3.2 Method of Measurement



a) Connect the receiver to the power line through a line impedance stabilization network as illustrated.

b) Connect a spectrum analyzer, using a quasi peak detector meeting the requirements of IEC CISPR Publication 16, of nominal 50 Ω impedance to one terminal of the line impedance stabilization network.

c) Tune the spectrum analyzer to search for spurious outputs from 150 kHz to 30 MHz. Record all spurious outputs found.

d) Connect the spectrum analyzer to the other terminal of the line impedance stabilization network and repeat step c).

e) Repeat step c) using the spectrum analyzer in an average responding mode.

f) Repeat step d) using the spectrum analyzer in an average responding mode.

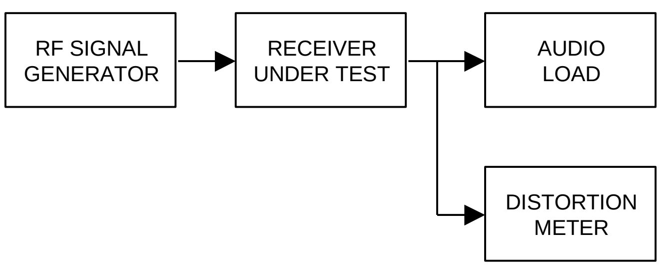
g) The power line conducted spurious output voltage at each frequency is reading obtained in steps c), d), e), and f).

2.1.4 Reference Sensitivity

2.1.4.1 Definition

The reference sensitivity is the level of receiver input signal at a specified frequency with specified modulation that will result in the standard SINAD at the output of the receiver.

2.1.4.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver input terminals.

c) Adjust the receiver volume control to obtain rated output power.

d) Adjust the receiver input signal level to produce the standard SINAD. Record this level.

e) If the output power obtained in step d) is more than 3 dB below the level obtained in step c), the input signal level at which the output has fallen by 3 dB should be recorded.

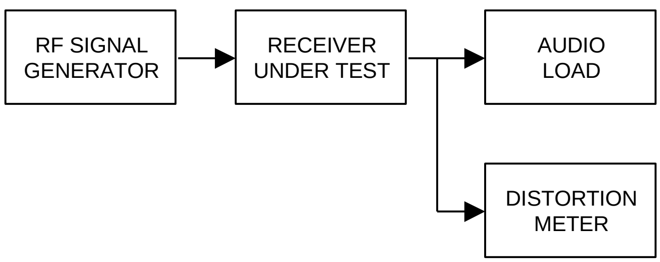
f) The reference sensitivity is the larger of the input signal levels that were obtained in steps d) and e).

2.1.5 Signal Displacement Bandwidth

2.1.5.1 Definition

The signal displacement bandwidth is the input signal frequency displacement that reduces the SINAD produced by a signal 6 dB in excess of the reference sensitivity, to the standard SINAD.

2.1.5.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal and adjust its level to a value that produces reference sensitivity.

c) Increase the signal level by 6 dB.

d) Increase the input signal frequency until the standard SINAD is obtained. Record this frequency as F_H .

e) Decrease the input signal frequency until the standard SINAD is obtained. Record this frequency as F_L .

f) Calculate the frequency differences by the following:

$$F_{DIFF\ 1} = F_H - \textit{nominal frequency}$$

$$F_{DIFF\ 2} = \textit{nominal frequency} - F_L$$

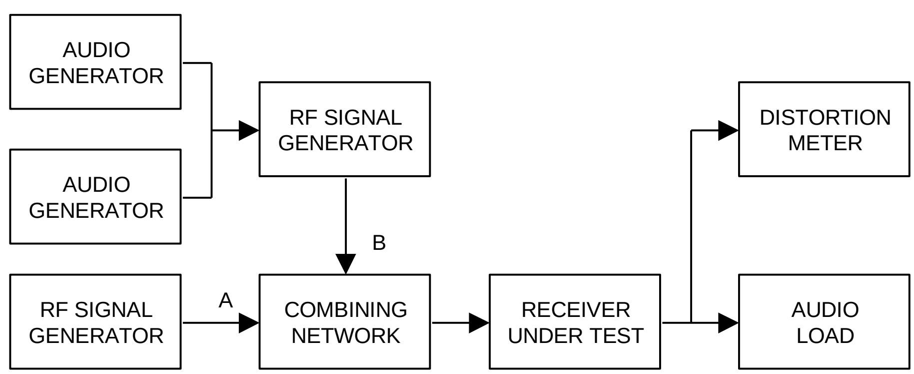
The smaller of $F_{DIFF\,1}$ or $F_{DIFF\,2}$ is the signal displacement bandwidth.

2.1.6 Adjacent Channel Rejection

2.1.6.1 Definition

The adjacent channel rejection is the ratio of the level of an unwanted adjacent channel input signal to the reference sensitivity. The unwanted signal is of an amplitude that causes the SINAD produced by a signal 3 dB in excess of the reference sensitivity to be degraded to the standard SINAD.

2.1.6.2 Method of Measurement



a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network. Reduce its level to obtain reference sensitivity. Record this level P_{REF} .

c) Increase the level of the wanted input signal by 3 dB.

d) Apply an unwanted input signal, modulated simultaneously with two tones, one at 650 Hz at a deviation of 50% of the maximum permissible frequency deviation, and another at 2200 Hz at a deviation of 50% of the maximum permissible frequency deviation. The level of each of the two signals should be set to 50% of the RF signal generator modulator specified input level. The deviation of the RF signal generator should be set to 100% of the maximum permissible frequency deviation.

e) Adjust the unwanted signal frequency to the adjacent channel above and below the wanted signal frequency and adjust its level each time so as to reestablish the standard SINAD. Record these levels P_{HIGH} and P_{LOW}.

f) Calculate the adjacent channel rejection by the following:

$$adjacent\ channel\ rejection\ high = P_{HIGH} - P_{REF}$$

$$adjacent\ channel\ rejection\ low = P_{LOW} - P_{REF}$$

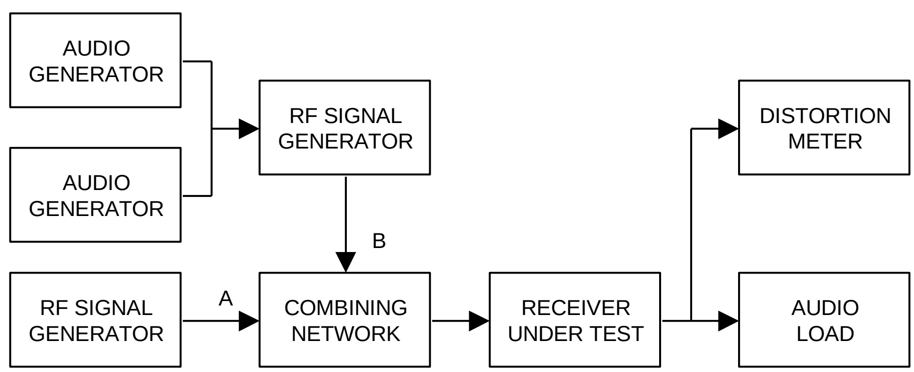
The smaller of the above is the adjacent channel rejection.

2.1.7 Offset Channel Selectivity

2.1.7.1 Definition

The offset channel selectivity is the ratio of the level of an unwanted signal at an offset channel frequency to the reference sensitivity. The unwanted signal is of an amplitude that causes the SINAD produced by a signal 3 dB in excess of the reference sensitivity to be degraded to the standard SINAD.

2.1.7.2 Method of Measurement



a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network. Reduce its level to obtain reference sensitivity. Record this level P_{REF} .

c) Increase the level of the wanted input signal by 3 dB.

d) Apply an unwanted input signal, modulated simultaneously with two tones, one at 650 Hz at a deviation of 50% of the maximum permissible frequency deviation, and another at 2200 Hz at a deviation of 50% of the maximum permissible frequency deviation. The level of each of the two signals should be set to 50% of the RF signal generator modulator specified input level. The deviation of the RF signal generator should be set to 100% of the maximum permissible frequency deviation.

e) Adjust the unwanted signal frequency to one half of the adjacent channel above and below the wanted signal frequency and adjust its level each time so as to reestablish the standard SINAD. Record these levels P_{HIGH} and P_{LOW}.

f) Calculate the offset channel selectivity by the following:

$$\textit{offset channel selectivity high} = P_{HIGH} - P_{REF}$$

$$\textit{offset channel selectivity low} = P_{LOW} - P_{REF}$$

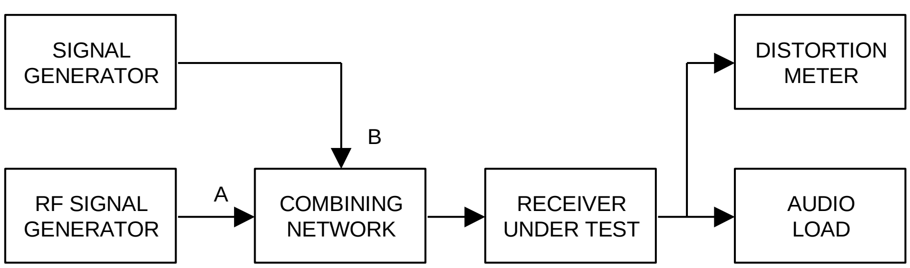
The smaller of the above is the offset channel selectivity.

2.1.8 Spurious Response Rejection

2.1.8.1 Definition

The spurious response rejection is the ability of a receiver to prevent single unwanted signals from causing a degradation to the reception of a desired signal. It is expressed as the ratio of the level of a single unwanted input signal to the reference sensitivity. The unwanted signal is of an amplitude that causes the SINAD produced by a wanted signal 3 dB in excess of the reference sensitivity to be degraded to the standard SINAD.

2.1.8.2 Method of Measurement



a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network. Reduce its level to obtain reference sensitivity. Record this level as P_{REF} .

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted input signal, modulated with 400 Hz at 60% of the maximum permissible frequency deviation, to terminal B of the combining network. The level of this generator shall be adjusted according to the following:

$$P_U = P_{REF} + SRR + 6 \text{ dB}$$

where:

P_U is the level of the unwanted signal generator in dBm.

P_{REF} is the level of reference sensitivity in dBm.

SRR is the manufacturer specified limit for spurious response rejection in dB.

e) Vary the unwanted signal frequency over a range from one half of the lowest IF frequency in the receiver to twice the receiver frequency or 1000 MHz, whichever is greater, to search for degradation of the SINAD. Exclude the frequency band that is within ±100 kHz of the receiver frequency. When a response is found, adjust the frequency of the unwanted signal to maximize the degradation.

f) At the frequency of each spurious response, change the level of the unwanted input signal until the standard SINAD is obtained. Record the frequency of the unwanted signal and record its level as P_{SPUR} .

g) Calculate the spurious response rejection for each frequency concerned as follows:

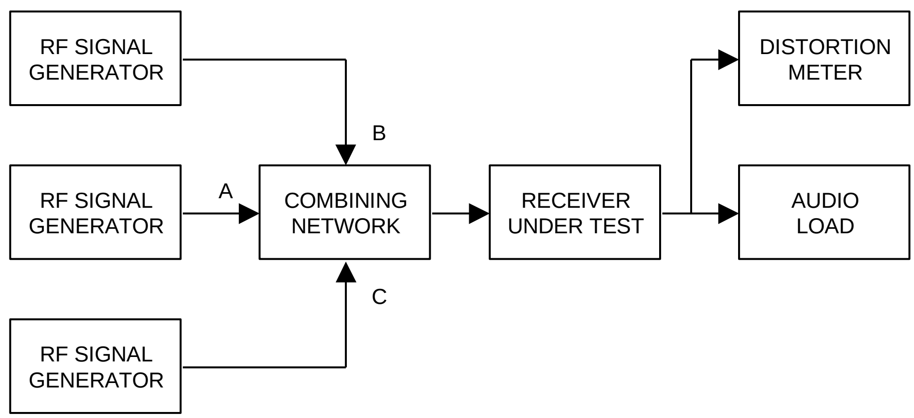
$$\textit{spurious response rejection} = P_{SPUR} - P_{REF}$$

2.1.9 Intermodulation Rejection

2.1.9.1 Definition

The intermodulation rejection is the ability of a receiver to prevent two unwanted input signals, with a specific frequency relation to the wanted signal frequency, from causing degradation to the reception of a desired signal. It is expressed as the ratio of the level of two equal level unwanted signals to the reference sensitivity. The unwanted signals are of an amplitude that cause the SINAD produced by the wanted signal 3 dB in excess of the reference sensitivity to be degraded to the standard SINAD.

2.1.9.2 Method of Measurement



a) Connect the equipment as illustrated. Connect two additional signal generators (unwanted signal sources) to terminals B and C of an appropriate matching or combining network.

b) In the absence of the unwanted signals, apply the standard input signal at terminal A of the combining network and reduce its level to obtain reference sensitivity. Record the level P_{REF} .

c) Increase the level of the wanted input signal by 3 dB.

d) Apply an unwanted, unmodulated input signal from the generator connected to terminal B. Adjust this generator frequency to the wanted frequency plus 50 kHz.

e) Apply an unwanted input signal modulated with 400 Hz at 60% rated system deviation from the generator connected to terminal C. Adjust this generator frequency to the wanted frequency plus 100 kHz.

f) Simultaneously increase the levels of the two unwanted signals until the SINAD is degraded.

g) Adjust the levels of the unwanted signals to be equal and to produce standard SINAD. Record this level as P_{HIGH}.

h) Repeat the above steps adjusting the frequency of the signal generator connected to terminal B to the wanted frequency minus 50 kHz, and the frequency of the signal generator connected to terminal C to the wanted frequency minus 100 kHz. Record this level as P_{LOW}.

i) Calculate the intermodulation rejection as follows:

intermodulation rejection high = $P_{HIGH} - P_{REF}$

intermodulation rejection low = $P_{LOW} - P_{REF}$

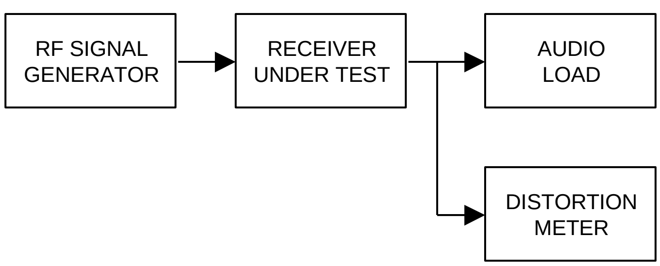
The smaller of the above is the intermodulation rejection.

2.1.10 Audio Frequency Response

2.1.10.1 Definition

The audio frequency response denotes the degree of closeness to which the audio output of a receiver follows a 6 dB per octave de-emphasis curve with constant frequency deviation over a given continuous frequency range.

2.1.10.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver input terminals.

c) Adjust the receiver volume control for 50% of the rated audio output power.

d) Reduce the generator modulation to 20% of the maximum rated system deviation.

e) Record the audio output level as V_{REF} .

f) Vary the modulation frequency from 300 Hz to 3000 Hz.

g) When the modulation frequency is varied record the audio output level as V_{FREQ} .

h) Calculate the audio frequency response at the frequency of interest by the following:

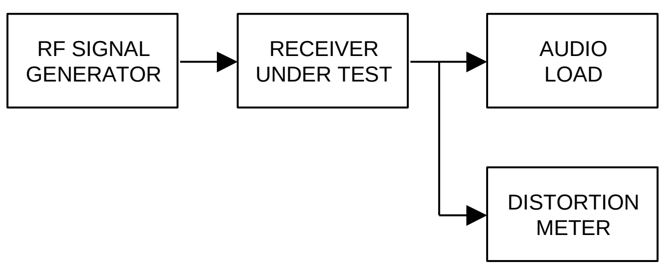
$$audio\ \ frequency\ response = 20\log_{10}\left(\frac{V_{FREQ}}{V_{REF}}\right)$$

2.1.11 Hum and Noise Ratio

2.1.11.1 Definition

The hum and noise ratio is the ratio of the rated output power to the residual output power in the absence of modulation, both measured at standard input signal level.

2.1.11.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver.

c) Operate the receiver at rated output power and record the audio output level as V_{REF} .

d) Remove the modulation and record the audio output level as $V_{NOISE\ 1}$.

e) The unsquelched hum and noise ratio, in dB, is calculated as follows:

$$unsquelched\ hum\ and\ noise\ ratio = 20\log_{10}\left(\frac{V_{REF}}{V_{NOISE1}}\right)$$

f) Remove the RF signal generator and adjust the receiver's squelch, if necessary, to mute the receiver. Record the audio output level as $V_{NOISE\ 2}$.

g) The squelched hum and noise ratio, in dBW, is calculated as follows:

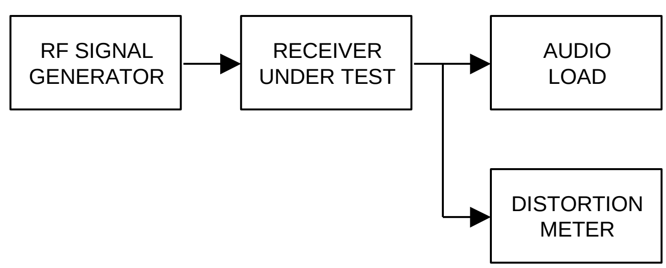
$$squelched\ hum\ and\ noise\ ratio = 10\log_{10}\left(\frac{(V_{NOISE2})^2}{Audio\ load\ impedance}\right)$$

2.1.12 Audio Distortion

2.1.12.1 Definition

The audio distortion is the voltage ratio, usually expressed as a percentage of the rms value of the undesired signal to the rms value of the complete signal at the output of the receiver.

2.1.12.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver input terminals.

c) Operate the receiver at rated output power.

d) Measure the audio distortion factor at the audio frequency load.

e) Repeat step d) at an audio level 17 dB below rated output power.

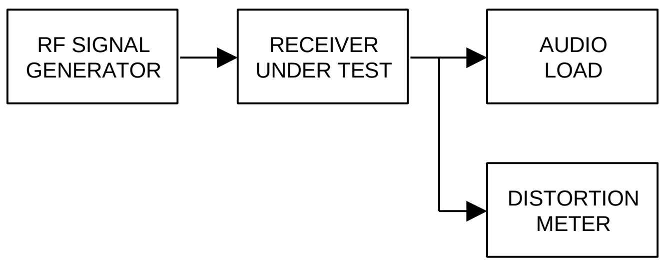
f) The values recorded in steps d) and e) are the audio distortions for the respective power outputs.

2.1.13 Audio Squelch Sensitivity

2.1.13.1 Definition

The audio squelch sensitivity of a receiver is the minimum signal level from a standard input signal source, which when modulated at standard test modulation, will open the receiver squelch.

2.1.13.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal to the receiver input terminals.

c) Adjust the receiver volume to obtain rated output power.

d) Remove the input signal.

e) Adjust the squelch control from the unmuted condition to the position where the audio output is just continuously muted. (If no external squelch control is provided, the squelch should be adjusted as specified by the manufacturer.)

f) Increase the input signal to the minimum level that produces a continuous audio output not lower than 10 dB below the rated audio output for a period of at least 10 seconds. Record the input signal level and the resulting SINAD.

g) Remove the input signal. The audio must again be muted. If the audio is not muted, readjust the squelch control to a position that again mutes the audio output and repeat step f).

h) The threshold squelch sensitivity is the level recorded in step f).

i) Set the input signal level to the level recorded in step f).

j) Reduce the input signal level until the audio is continuously muted for a period of at least 10 seconds. Record the input signal level.

k) The threshold squelch hysteresis is the difference in dB between the levels recorded in steps f) and j).

l) If the receiver has a user accessible squelch control, adjust the squelch control to the position that requires the largest input signal level to give an unmuted audio output.

m) Remove the input signal.

n) Increase the input signal level to the minimum level that produces a continuous audio output no lower than 10 dB below the rated output power for a period of at least 10 seconds. Record this level and the resulting SINAD.

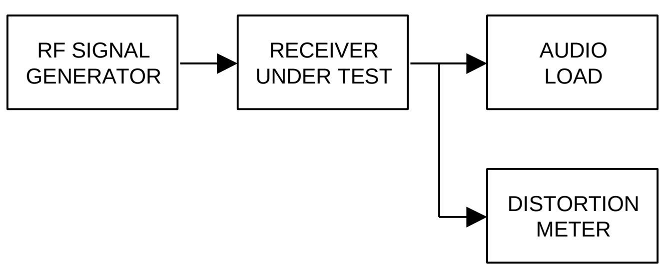
o) The level recorded in step n) is the tight squelch sensitivity.

2.1.14 Squelch Blocking

2.1.14.1 Definition

Squelch blocking is the tendency of the receiver squelch circuit to close in the presence of modulation of the input signal.

2.1.14.2 Method of Measurement



a) Connect the equipment as illustrated.

b) If the receiver has a user accessible squelch control, adjust the squelch control to the position that requires the largest input signal to produce an unmuted audio output. (If the receiver does not have an accessible squelch control, the squelch should be adjusted as specified by the manufacturer.

c) Apply an input signal 12 dB above the measured tight squelch sensitivity (see 2.1.13 step o).

d) Adjust the receiver volume control for 10% of the rated audio output power with the signal generator modulated with standard modulation.

e) Increase the signal deviation to the rated system deviation.

f) Vary the modulation frequency slowly from 300 Hz to 3000 Hz.

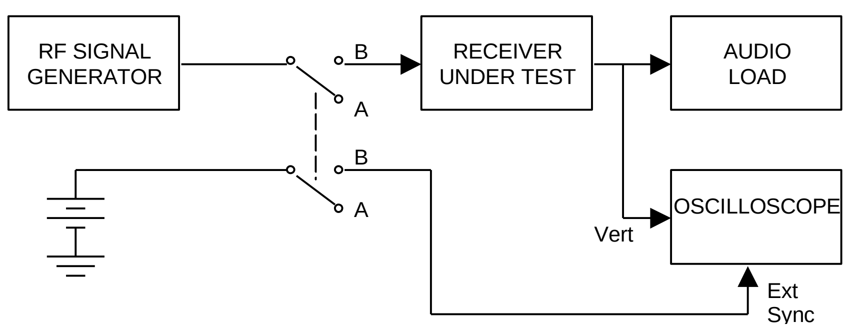
g) Record if the audio output drops more than 10 dB from the output obtained at each frequency with the squelch open.

2.1.15 Receiver Attack Time

2.1.15.1 Definition

Receiver attack time is the time required to produce audio power output after application of a modulated input signal.

2.1.15.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Adjust the squelch control as outlined in 2.1.13 for threshold setting.

c) Close the switch to position B.

d) Apply an input signal 12 dB above reference sensitivity.

e) Adjust the receiver volume control for rated audio output power.

f) Adjust the oscilloscope so that a 10% change in audio output can be observed easily.

g) Adjust the oscilloscope sync. to trigger when the switch is closed to position B.

h) Change the switch from position A to position B.

i) Observe the time required for the audio to reach 90% of rated output power.

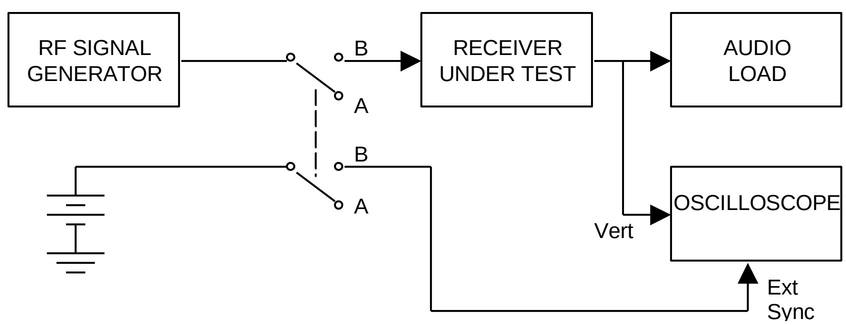
j) The receiver attack time is the average time of four trials recorded in step i).

2.1.16 Receiver Closing Time

2.1.16.1 Definition

The receiver closing time is that period of time between removal of an input signal and squelch closure.

2.1.16.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Remove the input signal.

c) Adjust the oscilloscope display to show noise.

d) Adjust the oscilloscope sync. to trigger when the switch is closed to position A.

e) Adjust the squelch control as outlined in 2.1.13 for threshold setting.

f) Close the switch to position B.

g) Adjust the input signal level to 12 dB above the reference sensitivity level.

h) Change the switch from position B to A.

i) Observe the time required for the noise to fall to less than 10% of the original value.

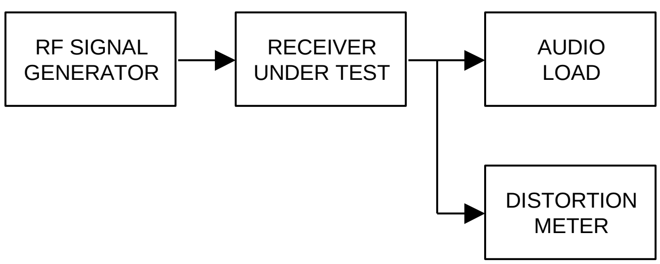
j) The receiver closing time is the average time of four trials recorded in step i).

2.1.17 Audio Sensitivity

2.1.17.1 Definition

The audio sensitivity is the minimum level of modulation, which at maximum volume control setting, will produce rated audio.

2.1.17.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Adjust the receiver volume control for maximum.

c) Apply a standard input signal to the receiver input terminals.

d) Adjust the signal generator deviation until rated audio output is achieved and record this deviation level.

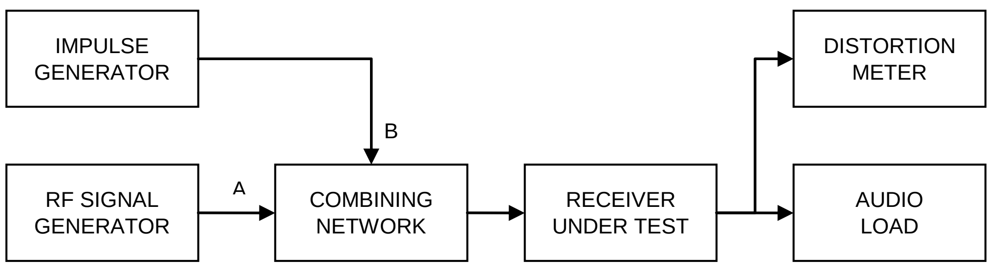
e) The level recorded in step d) is the audio sensitivity.

2.1.18 Impulse Blanking Effectiveness

2.1.18.1 Definition

The impulse blanking effectiveness is the ability of the noise blanker to prevent and suppress the effects of short duration steep rise time pulses (such as ignition noise) in the presence of desired signals. This test applies only to units that incorporate noise blanker circuits that may be enabled or disabled.

2.1.18.2 Method of Measurement



a) Connect the equipment as illustrated. Connect an impulse generator to terminal B of the appropriate matching or combining network.

b) Disable the blanker operation.

c) With the impulse generator off, apply the standard input signal to terminal A of the combining network. Reduce its level to obtain reference sensitivity. Record this level as P_{REF} .

d) Increase the level of the wanted signal by 6 dB.

e) Enable the blanker operation.

f) Turn on the impulse generator and set it for a 10 kHz repetition rate. Starting with a minimum level, slowly increase the impulse generator output and adjust its level to reestablish the standard SINAD.

g) Disable the blanker operation.

h) Increase the input signal level until the standard SINAD is obtained. Record this level as P_{DIS} .

i) Calculate the impulse blanking effectiveness by the following:

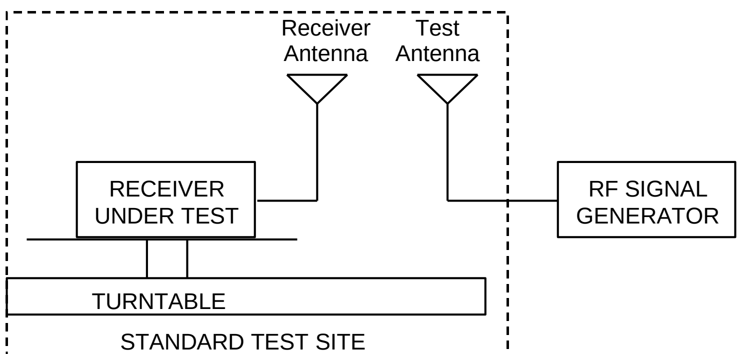
$$\textit{impulse blanking effectiveness} = P_{DIS} - P_{REF}$$

2.1.19 Average Radiation Sensitivity

2.1.19.1 Definition

The average radiation sensitivity of a receiver is the power received by a half wave dipole measured into a 50 Ω load when substituted for a receiver that is receiving a signal at the reference sensitivity.

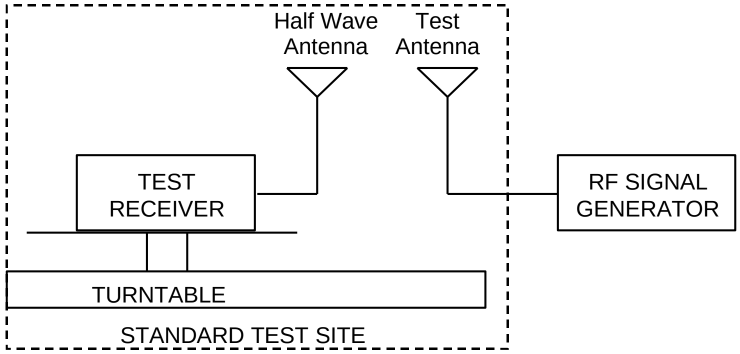
2.1.19.2 Method of Measurement



a) Place the receiver with its antenna to be tested on the turntable of the radiation test site.

b) Connect a signal generator modulated with standard test modulation to a vertically polarized 1/2 wave length test antenna and fasten this antenna to the supporting mast.

c) Raise and lower the mast so that reference sensitivity is obtained in the receiver for the minimum signal generator level. (The reference sensitivity may be determined either by measuring the SINAD level directly, or by calibrating the squelch circuit to unmute the receiver at the reference sensitivity level.)



d) Replace the receiver under test with a half wave vertically polarized antenna, connected to a calibrated receiver system. The center of the antenna should be in the same location as the receiver under test.

e) Record the power level measured by the calibrated receiver.

f) Repeat steps c), d), and e) seven times, rotating the receiver under test 45 degrees each time.

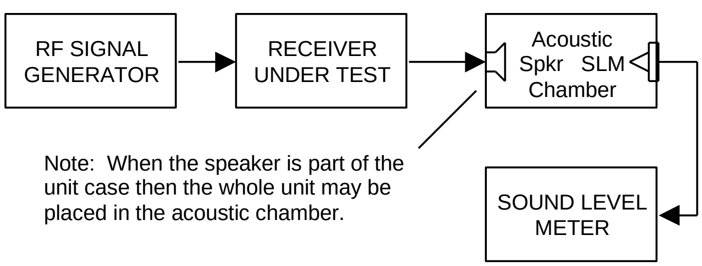
g) The average of the eight measurements recorded in step e) is the average radiation sensitivity.

2.1.20 Acoustic Audio Output

2.1.20.1 Definition

The acoustic audio output is the level registered on a sound level meter at a distance of 50 cm from the front of the receiver acoustic transducer.

2.1.20.2 Method of Measurement



a) Mount the receiver in the acoustic chamber.

b) Apply a standard input signal to the antenna input terminals.

c) Operate the receiver at rated output power.

d) Place the microphone of a sound level meter 50 cm from the front surface of the receiver acoustic transducer.

e) Record the reading of the sound level meter.

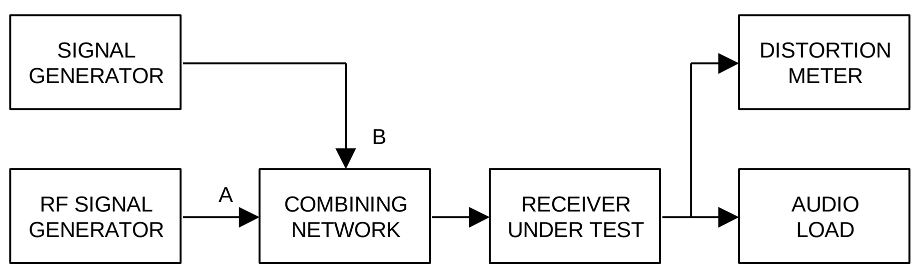
f) The level recorded in step e) is the acoustic audio output.

2.1.21 Blocking Rejection

2.1.21.1 Definition

The blocking rejection is the ratio of the level of an unwanted input signal to the reference sensitivity. The unwanted signal is of an amplitude that causes the SINAD produced by a wanted signal 3 dB in excess of the reference sensitivity to be reduced to the standard SINAD.

2.1.21.2 Method of Measurement



a) Connect the equipment as illustrated. Connect a second radio frequency signal generator (unwanted signal source) to terminal B of the appropriate matching or combining network.

b) In the absence of the unwanted signal, apply the standard input signal to terminal A of the combining network. Reduce its level to obtain reference sensitivity. Record this level as P_{REF} .

c) Increase the level of wanted input signal by 3 dB.

d) Apply an unwanted input signal, unmodulated, to terminal B of the combining network.

e) Adjust the unwanted signal frequency to 1 MHz, 2 MHz, 5 MHz, and 10 MHz above and below the wanted signal frequency and adjust its level each time to reestablish the standard SINAD. Record in dBm the lowest of the readings obtained for frequencies above the desired frequency as P_{HIGH}. Record in dBm the lowest of the readings obtained for frequencies below the desired frequency as P_{LOW} .

Note: In the event that a known spurious response falls on any of the above test frequencies, it is acceptable to slightly adjust the test frequency lower or higher to eliminate the effect of the spurious response.

f) Calculate the blocking rejection by the following:

$$\textit{blocking rejection high} = P_{HIGH} - P_{REF}$$

$$\textit{blocking rejection low} = P_{LOW} - P_{REF}$$

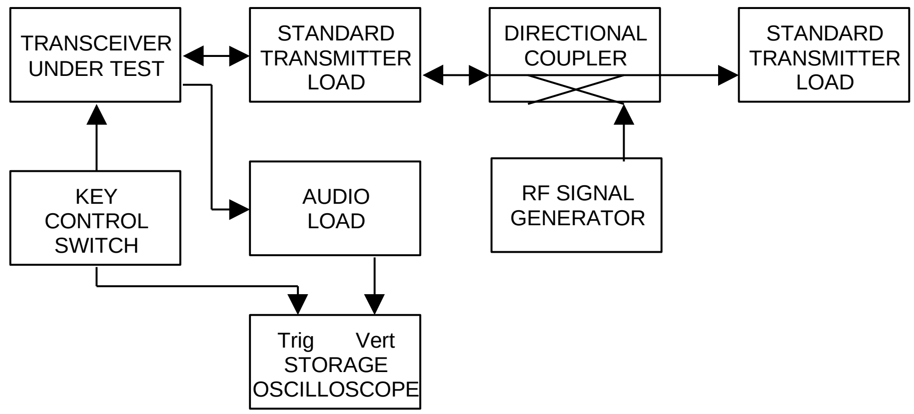
The smaller of the above is the blocking rejection.

2.1.22 Receiver Opening Time After PTT

2.1.22.1 Definition

Receiver opening time after PTT is the time required to produce receive audio output after the release of a transmitter push to talk (PTT).

2.1.22.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Adjust the squelch control as outlined in 2.1.13 for threshold setting.

c) Adjust the RF signal generator to provide a standard input signal to the receiver. The signal generator level must be adjusted to account for the loss of the standard transmitter load and the directional coupler coupling factor.

d) Adjust the receiver volume control for rated audio output power.

e) Adjust the oscilloscope so that a 10% change in audio output can be observed easily.

f) Adjust the oscilloscope to trigger when the key control switch is deactivated.

g) Key the transmitter for several seconds.

h) Unkey the transmitter and observe the time required for the audio to reach 90% of rated output power.

i) The receiver opening time after PTT is the average time of four trials recorded in step h).

2.2 Methods of Measurement for Transmitters

This section details test definitions and methods of measurement of the characteristics of FM or PM land mobile transmitters in vehicular (mobiles), fixed (base stations), or handheld (portable) installations. When the transmitter is equipped with special function subsystems, such as continuous tone coded squelch or selective signaling, the subsystems must be disabled. If the transmitter is equipped with an audio processing subsystem, this subsystem should be disabled. If it can not be disabled, this should be noted on the measured results.

This section does not cover testing of transmitters that include subsystems that cannot be disabled or bypassed.

The standards for each transmitter method of measurement can be found in sections 3.2.X, where X is the last digit of the method of measurement being performed.

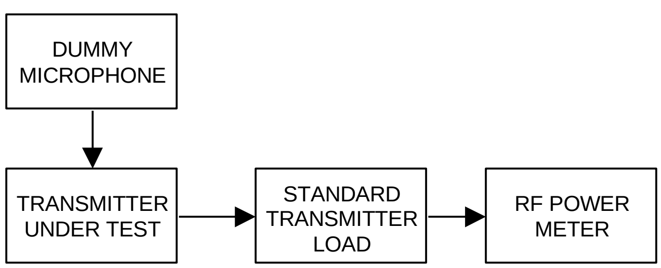
An example measurement uncertainty calculation for each transmitter method of measurement can be found in Annex B2.X (informative), where X is the last digit of the method of measurement being performed.

2.2.1 Conducted Carrier Output Power Rating

2.2.1.1 Definition

The conducted carrier power output rating for a transmitter is the power available at the output terminals of the transmitter when the output terminals are connected to the standard transmitter load.

2.2.1.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Measure the transmitter output power during the defined duty cycle (see

1.3.2). Correct for all losses in the RF path.

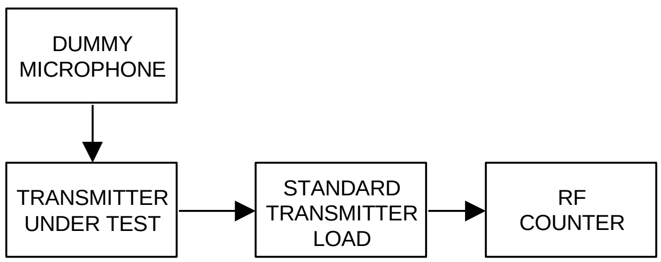
c) The value recorded in step b) is the conducted carrier output power rating.

2.2.2 Carrier Frequency Stability

2.2.2.1 Definition

The carrier frequency stability is the ability of the transmitter to maintain an assigned carrier frequency.

2.2.2.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Operate the equipment in standby conditions for 15 minutes before proceeding.

c) Record the carrier frequency of the transmitter as MCF_{MHz} .

d) Calculate the ppm frequency error by the following:

$$ppm\,error = \left(\frac{MCF_{MHz}}{ACF_{MHz}} - 1 \right) * 10^6$$

where

MCF_{MHz} is the Measured Carrier Frequency in MHz
ACF_{MHz} is the Assigned Carrier Frequency in MHz

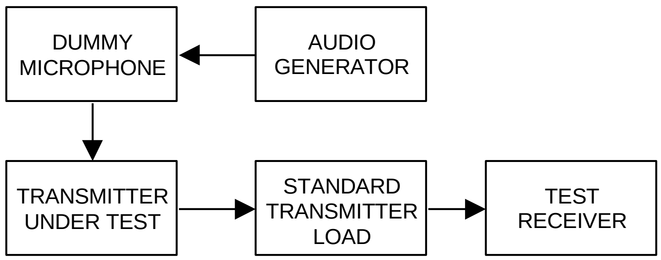
e) The value recorded in step d) is the carrier frequency stability.

2.2.3 Modulation Limiting

2.2.3.1 Definition

Modulation limiting is the transmitter circuit's ability to limit the transmitter from producing deviations in excess of a rated system deviation.

2.2.3.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

c) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤0.25 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

d) Apply a 1000 Hz modulating signal to the transmitter from the audio frequency generator, and adjust the level to obtain 60% of full rated system deviation.

e) Increase the level from the audio frequency generator by 20 dB in one step (rise time between the 10% and 90% points shall be 0.1 second maximum).

f) Measure both the instantaneous and steady-state deviation at and after the time of increasing the audio input level.

g) With the level from the audio frequency generator held constant at the level obtained in step e), slowly vary the audio frequency from 300 Hz to 3000 Hz and observe the steady-state deviation. Record the maximum deviation.

h) Set the test receiver to measure peak negative deviation and repeat steps d) through g).

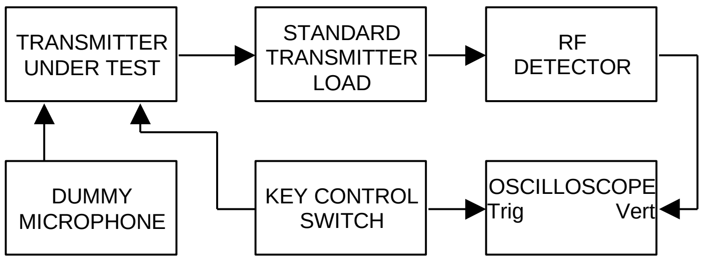
i) The values recorded in steps g) and h) are the modulation limiting.

2.2.4 Carrier Attack Time

2.2.4.1 Definition

Transmitter carrier attack time is the time required to produce 50% of steady-state carrier output power after changing the state of the transmitter from standby to transmit.

2.2.4.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Key the transmitter.

c) Measure the time interval for the transmitter's output power to reach 50% of its maximum value (70.7% of maximum voltage level displayed on the oscilloscope).

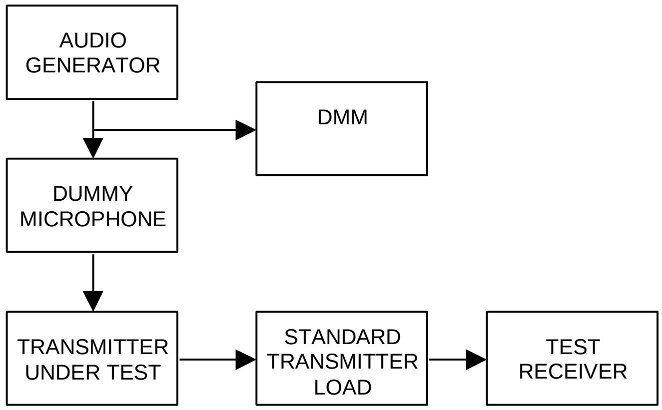
d) The value recorded in step c) is the transmitter carrier attack time.

2.2.5 Audio Sensitivity

2.2.5.1 Definition

The audio sensitivity is the input rms voltage level that must be applied to the input terminals of the dummy microphone circuit to produce the standard test modulation. Any microphone automatic gain control must be disabled.

2.2.5.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Set the DMM to measure rms voltage.

d) Apply a 1000 Hz tone from the audio generator and adjust its output level until 60% of rated system deviation is reached.

e) Record the DMM reading as the audio sensitivity.

2.2.6 Audio Frequency Response

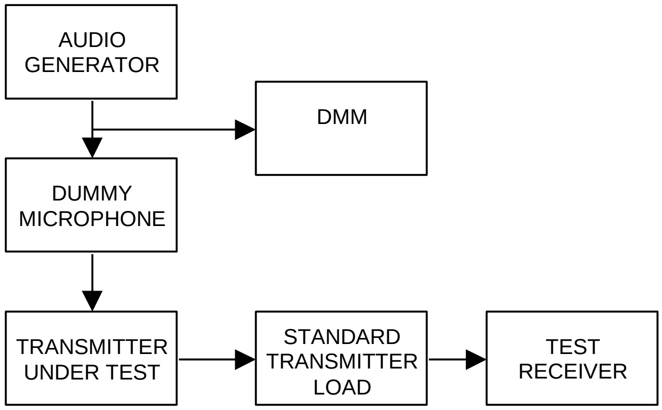
2.2.6.1 Definition

The audio frequency response is the degree of closeness to which the frequency deviation of the transmitter follows a prescribed characteristic.

2.2.6.2 Method of Measurement

Below are two test methods that will yield similar results for testing from 300 Hz to 3000 Hz, either method may be used. The first method is a constant deviation approach. The second method is a constant input approach.

2.2.6.2.1 Constant deviation test method (300 Hz to 3000 Hz)



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Set the DMM to measure rms voltage.

d) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

e) Apply a 1000 Hz tone and adjust the audio frequency generator to produce 20% of the rated system deviation.

f) Set the test receiver to measure rms deviation and record the deviation reading.

g) Record the DMM reading as V_{REF} .

h) Set the audio frequency generator to the desired test frequency between 300 Hz and 3000 Hz.

i) Vary the audio frequency generator output level until the deviation reading that was recorded in step f) is obtained.

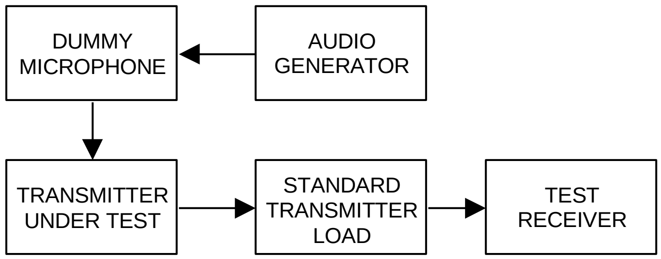
j) Record the DMM reading as V_{FREQ} .

k) Calculate the audio frequency response at the present frequency as:

$$audio\ \ frequency\ response = 20\ \log_{10}\left(\frac{V_{FREQ}}{V_{REF}}\right)$$

l) Repeat steps h) through k) for all the desired test frequencies.

2.2.6.2.2 Constant Input Test Method (300 Hz to 3000 Hz)



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

d) Apply a 1000 Hz tone and adjust the audio frequency generator to produce 20% of the rated system deviation.

e) Set the test receiver to measure rms deviation and record the deviation reading as DEV_{REF} .

f) Set the audio frequency generator to the desired test frequency between 300 Hz and 3000 Hz.

g) Record the test receiver deviation reading as DEV_{FREQ} .

h) Calculate the audio frequency response at the present frequency as:

$$audio\ \ frequency\ response = 20\ \log_{10}\left(\frac{DEV_{FREQ}}{DEV_{REF}}\right)$$

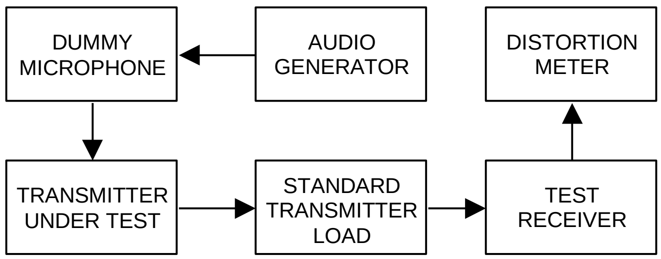
i) Repeat steps f) through h) for all the desired test frequencies.

2.2.7 Audio Distortion

2.2.7.1 Definition

The audio distortion is the voltage ratio, usually expressed as a percentage of the rms value of the undesired signal of the transmitter's demodulated output to the rms value of the complete signal at the output of the transmitter's demodulator.

2.2.7.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

d) Apply a 1000 Hz tone and adjust the audio frequency generator to produce 40% of the rated system deviation.

e) Set the test receiver for an audio bandwidth of 300 Hz to 3000 Hz. Set the 750 microsecond de-emphasis function to on.

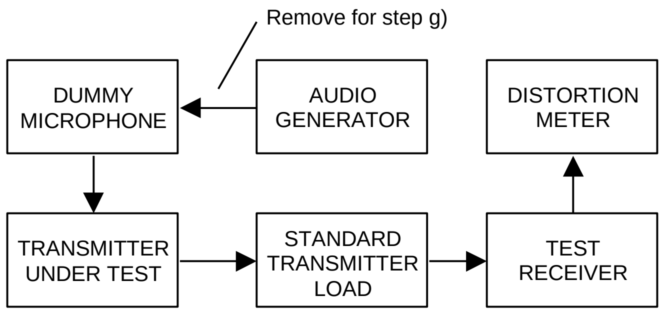
f) Measure the audio distortion of the transmitter.

2.2.8 FM Hum and Noise Ratio

2.2.8.1 Definition

The FM hum and noise is the ratio of the standard test modulation to the residual frequency modulation measured by the test receiver. This is to be performed with any audio compression/expansion circuit disabled.

2.2.8.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

d) Apply standard test modulation.

e) Set the test receiver to measure rms deviation. Set the audio bandwidth for 300 Hz to 3000 Hz. Set the 750 microsecond de-emphasis function to on.

f) Record the deviation reading from the test receiver as DEV_{TOTAL} .

g) Remove the modulation input signal (the audio input terminals shall remain terminated with the dummy microphone circuit specified by the manufacturer). Note the deviation level from the test receiver as DEV_{NOISE} .

h) Calculate the FM hum and noise as:

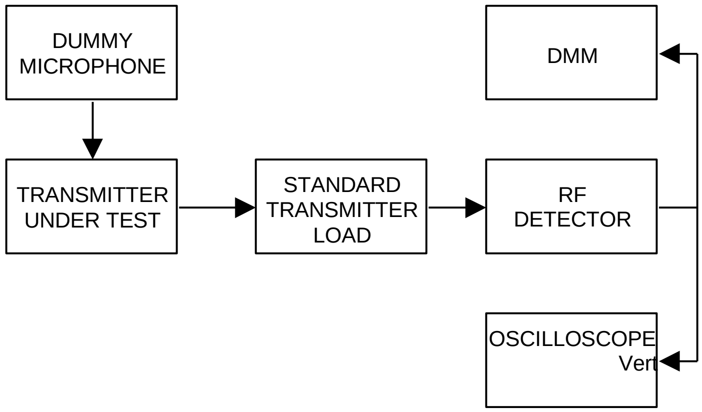
$$FM\ hum\ and\ noise = 20\ \log_{10}\left(\frac{DEV_{TOTAL}}{DEV_{NOISE}}\right)$$

2.2.9 AM Hum and Noise Ratio

2.2.9.1 Definition

AM hum and noise on the carrier is the ratio of the dc voltage detected from an unmodulated carrier to the detected peak ac voltage.

2.2.9.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the transmitter to operate at the nominal output power with no modulation.

c) Record the DMM dc voltage from the RF detector as V_{DC}.

d) Record the oscilloscope peak ac voltage reading from the RF detector as V_{PK}.

e) Calculate the AM hum and noise ratio as:

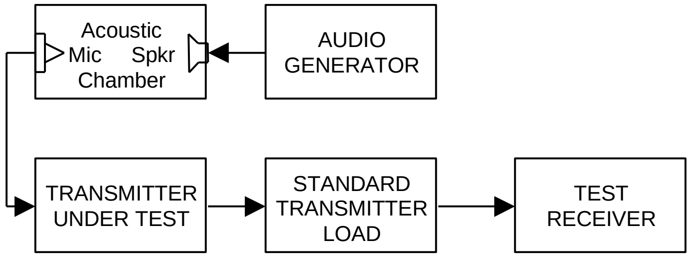
$$AM\ hum\ and\ noise = 20\ \log_{10}\left(\frac{V_{DC}}{V_{PK}}\right)$$

2.2.10 Acoustic Microphone Sensitivity

2.2.10.1 Definition

Acoustic microphone sensitivity is the acoustic sound pressure level that will produce 60% modulation of the transmitter.

2.2.10.2 Method of Measurement



a) Connect the equipment as illustrated.

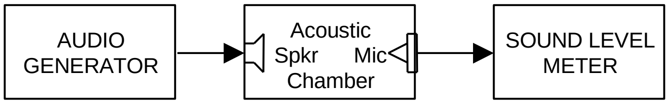
b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Ensure that the transmitter has been adjusted per the manufacturer's procedure for full rated system deviation.

d) Place the test microphone 5 cm away from the acoustic transducer (loud speaker) that has a free opening of less than 4 square cm.

e) Adjust the audio frequency generator to 1 kHz.

f) Adjust the level of the audio frequency generator to produce 60% of rated system deviation as indicated on the test receiver.



g) Reconnect the equipment as illustrated.

h) Place the diaphragm of the sound level meter (SLM) in the same plane that the test microphone was in.

i) Read the acoustic microphone level on the sound level meter.

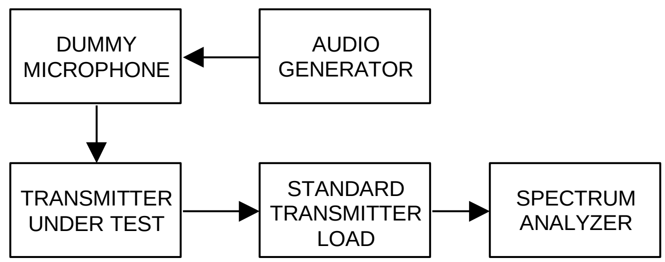
j) The value recorded in step i) is the acoustic microphone sensitivity.

2.2.11 Sideband Spectrum

2.2.11.1 Definition

The transmitter sideband spectrum denotes the sideband power produced at a discrete frequency separation from the carrier up to the test bandwidth (see 1.3.4.4) due to all sources of unwanted noise within the transmitter in a modulated condition.

2.2.11.2 Method of Measurement



a) Connect the equipment as illustrated. Use the table 17 to determine the spectrum analyzer resolution bandwidth:

Table 17 - Spectrum Analyzer Resolution Bandwidth

Frequency Band (MHz)	Mask for Equipment with Audio Low Pass Filter	Mask for Equipment without Low Pass Filter	Spectrum Analyzer Resolution Bandwidth (Hz)
25-50	B	C	300
72-76	B	C	300
138-174	NTIA	NTIA	300
150-174	B	C	300
150-174	D or E	D or E	100
380-420	NTIA	NTIA	300
421-512	B	C	300
421-512	D or E	D or E	100
809-824/854-869	B or EA	G or EA	300
806-809/851-854	B	H	300
896-901/935-940	I	J	300

b) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth per the above table.
2) Video Bandwidth at least 10 times the resolution bandwidth.
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = Positive Peak.
5) Span that will allow proper viewing of the test bandwidth (see 1.3.4.4).

c) Set the center frequency of the spectrum analyzer to the assigned transmitter frequency. Key the transmitter, and set the level of the unmodulated carrier to a full scale reference line. This is the 0 dB reference for the measurement.

d) Modulate the transmitter with a 2500 Hz sine wave at an input level 16 dB greater than that necessary to produce 50% of rated system deviation. The input level shall be established at the frequency of maximum response of the audio modulating circuit. Transmitters employing digital modulation techniques that bypass the limiter and the audio low-pass filter shall be modulated as specified by the manufacturer.

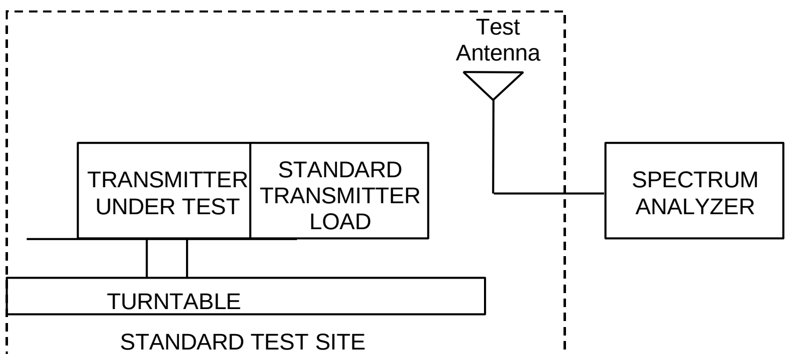
e) Record the resulting spectrum analyzer presentation of the emission level with an on-line recording device or in a photograph. It is recommended that the emission limit (as given in 3.2.11) be drawn on the plotted graph or photograph. The spectrum analyzer presentation is the sideband spectrum.

2.2.12 Unwanted Emissions: Radiated Spurious

2.2.12.1 Definition

Radiated spurious emissions are emissions from the equipment when transmitting into a nonradiating load on a frequency or frequencies that are outside an occupied band sufficient to ensure transmission of information of required quality for the class of communications desired.

2.2.12.2 Method of Measurement (Non-Radiating Load)



a) Connect the equipment as illustrated.

b) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1GHz.
2) Video Bandwidth = 300 kHz for spurious emissions below 1 GHz, and 3 MHz for spurious emissions above 1 GHz.
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = Positive Peak.

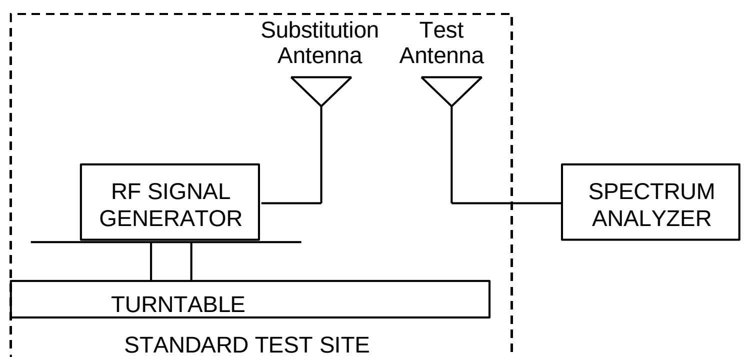
c) Place the transmitter to be tested on the turntable in the standard test site, or an FCC listed site compliant with ANSI C63.4-2001 clause 5.4. The transmitter is transmitting into a nonradiating load that is placed on the turntable. The RF cable to this load should be of minimum length. For transmitters with integral antennas, the tests are to be run with the unit operating into the integral antenna.

d) For each spurious measurement the test antenna should be adjusted to the correct length for the frequency involved. This length may be determined from a calibration ruler supplied with the equipment. Measurements shall be made from the lowest radio frequency generated in the equipment to the tenth harmonic of the carrier, except for the region close to the carrier equal to ± the test bandwidth (see 1.3.4.4).

e) Key the transmitter.

f) For each spurious frequency, raise and lower the test antenna from 1 m to 4 m to obtain a maximum reading on the spectrum analyzer with the test antenna at horizontal polarity. Then the turntable should be rotated 360° to determine the maximum reading. Repeat this procedure to obtain the highest possible reading. Record this maximum reading.

g) Repeat step f) for each spurious frequency with the test antenna polarized vertically.



h) Reconnect the equipment as illustrated.

i) Keep the spectrum analyzer adjusted as in step b).

j) Remove the transmitter and replace it with a substitution antenna (the antenna should be half-wavelength for each frequency involved). The center of the substitution antenna should be approximately at the same location as the center of the transmitter. At the lower frequencies, where the substitution antenna is very long, this will be impossible to achieve when the antenna is polarized vertically. In such case the lower end of the antenna should be 0.3 m above the ground.

k) Feed the substitution antenna at the transmitter end with a signal generator connected to the antenna by means of a nonradiating cable. With the antennas at both ends horizontally polarized, and with the signal generator tuned to a particular spurious frequency, raise and lower the test antenna to obtain a maximum reading at the spectrum analyzer. Adjust the level of the signal generator output until the previously recorded maximum reading for this set of conditions is obtained. This should be done carefully repeating the adjustment of the test antenna and generator output.

l) Repeat step k) with both antennas vertically polarized for each spurious frequency.

m) Calculate power in dBm into a reference ideal half-wave dipole antenna by reducing the readings obtained in steps k) and l) by the power loss in the cable between the generator and the antenna, and further corrected for the gain of the substitution antenna used relative to an ideal half-wave dipole antenna by the following formula:

$$P_d(\text{dBm}) = P_g(\text{dBm}) - \textit{cable loss}\ (\text{dB}) + \textit{antenna gain}\ (\text{dB})$$

where:

P_d is the dipole equivalent power and

P_g is the generator output power into the substitution antenna.

n) The P_d levels record in step m) are the absolute levels of radiated spurious emissions in dBm. The radiated spurious emissions in dB can be calculated by the following:

Radiated spurious emissions (dB) =

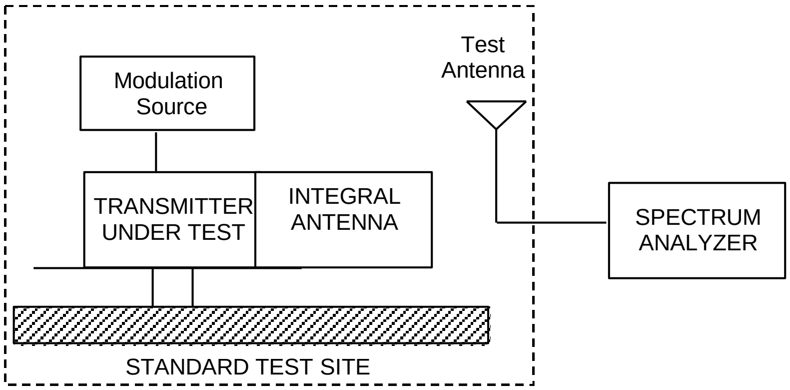
$$10\ \log_{10}\left(\frac{\textit{TX power in watts}}{0.001}\right) - \textit{the levels in step m)}$$

NOTE: It is permissible to use other antennas provided they can be referenced to a dipole.

2.2.12.3 Method of Measurement (EIRP in GNSS Band:1.559 to 1.610 GHz)

This test is specifically applicable to transmitter equipment designed for the 700

MHz frequency band. It is recommended that all land mobile equipment be characterized per this method and conform to the associated standard limit value. This test is only applicable to equipment using an integral antenna. See 2.2.12.4 for methods applicable to equipment that utilizes an external antenna.



a) Connect the equipment as illustrated.

b) Adjust the spectrum analyzer for the following settings:

   1) Resolution Bandwidth = 1 MHz.
   2) Video Bandwidth ≥ 3 times the resolution bandwidth.
   3) Sweep Speed slow enough to maintain measurement calibration.
   4) Detector Mode = mean or average.

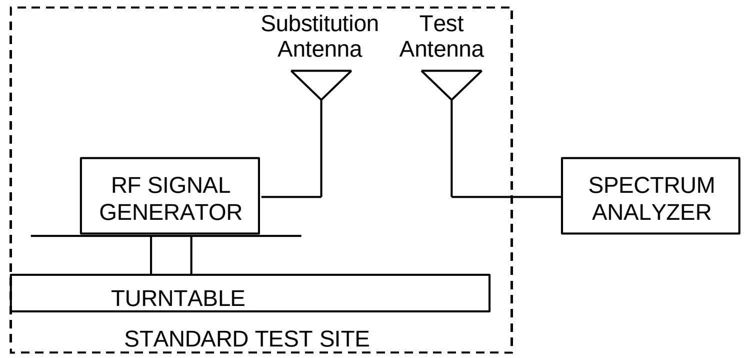
c) Place the transmitter to be tested on the turntable in the standard test site, or an FCC listed site compliant with ANSI C63.4-2001 clause 5.4.

d) For each spurious measurement the test antenna should be adjusted to the correct length for the frequency involved. This length may be determined from a calibration ruler supplied with the equipment. Measurements shall be made from 1.559 GHz to 1.610 GHz.

e) Key the transmitter with standard modulation applied to the transmitter.

f) For each spurious frequency, raise and lower the test antenna from 1 m to 4 m to obtain a maximum reading on the spectrum analyzer with the test antenna at horizontal polarity. Then the turntable should be rotated 360° to determine the maximum reading. Repeat this procedure to obtain the highest possible reading. Record this maximum reading.

g) Repeat step f) for each spurious frequency with the test antenna polarized vertically.



h) Reconnect the equipment as illustrated.

i) Keep the spectrum analyzer adjusted as in step b).

j) Remove the transmitter and replace it with a substitution antenna (the antenna should be half-wavelength for each frequency involved). The center of the substitution antenna should be approximately at the same location as the center of the transmitter.

k) Feed the substitution antenna at the transmitter end with a signal generator connected to the antenna by means of a nonradiating cable. With the antennas at both ends horizontally polarized, and with the signal generator tuned to a particular spurious frequency, raise and lower the test antenna to obtain a maximum reading at the spectrum analyzer. Adjust the level of the signal generator output until the previously recorded maximum reading for this set of conditions is obtained. This should be done carefully repeating the adjustment of the test antenna and generator output.

l) Repeat step k) with both antennas vertically polarized for each spurious frequency.

m) Calculate the equivalent isotropic radiated power (EIRP), in dBm, by reducing the readings obtained in steps k) and l) by the power loss in the cable between the generator and antenna, corrected for the gain of the substitution antenna used relative to an ideal half-wave dipole antenna, and then correct to an isotropic radiator.

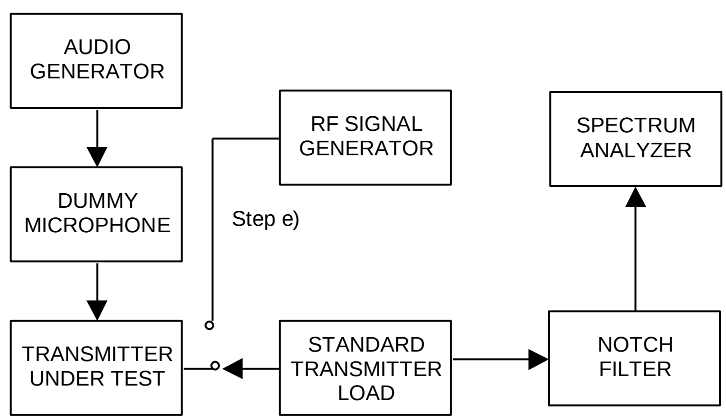
n) The levels record in step m) are the absolute levels of the wideband radiated spurious emissions, EIRP, in dBm.

o) For the narrowband spurious, repeat steps c) through n) using the following spectrum analyzer settings:

1) Resolution Bandwidth = 1 kHz.
2) Video Bandwidth = 3 kHz
3) Sweep Speed slow enough to maintain measurement calibration.
4) Detector Mode = mean or average.

NOTE: It is permissible to use other antennas provided they can be referenced to a dipole.

2.2.12.4 Method of Measurement (Calculated EIRP in the GNSS Band: 1.559 to 1.610 GHz)



a) Connect the equipment as illustrated.

b) Key the transmitter with standard modulation applied to the transmitter.

c) Use the spectrum analyzer settings prescribed in 2.2.12.3 b) and o) for the wideband and narrowband cases respectively.

d) Adjust the center frequency of the spectrum analyzer for incremental coverage of the GNSS frequency band.

e) Record the frequencies and levels of the spurious emissions for the wideband and narrowband configurations.

f) Replace the transmitter under test with the signal generator and adjust the signal level to reproduce the frequencies and levels of every spurious emission recorded in step d). Record the signal generator levels in dBm.

g) Calculate the equivalent isotropic radiated power (EIRP), in dBm, by correcting the measured levels by the loss of elements feeding the antenna and the isotropic gain of the antenna as follows:

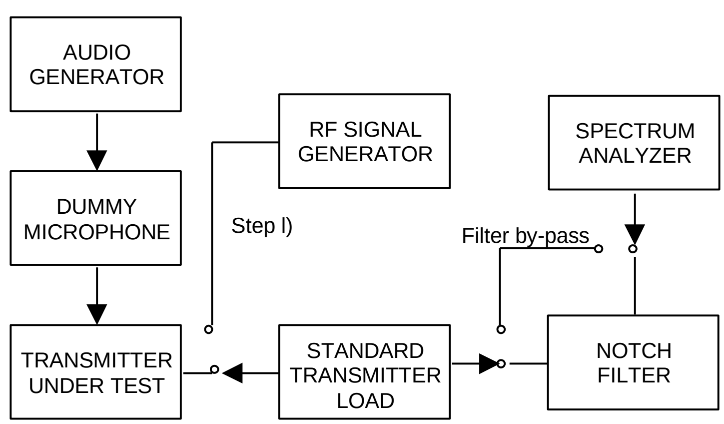
EIRP (dBm) = *Level* (dBm) – *Loss* (dB) + *Antenna Gain* (dBi)

2.2.13 Unwanted Emissions: Conducted Spurious

2.2.13.1 Definition

Conducted spurious emissions are emissions at the antenna terminals on a frequency or frequencies that are outside a band sufficient to ensure transmission of information of required quality for the class of communication desired.

2.2.13.2 Method of Measurement



a) Connect the equipment as illustrated, with the notch filter by-passed.

b) Set the center frequency of the spectrum analyzer to the assigned transmitter frequency, key the transmitter, and set the level of the carrier to the full scale reference line.

c) Modulate the transmitter with a 2500 Hz sine wave at an input level 16 dB greater than that necessary to produce 50% of rated system deviation. The input level shall be established at the frequency of maximum response of the audio modulating circuit.

d) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1 GHz.
2) Video Bandwidth ≥3 times the resolution bandwidth.
3) Sweep Speed ≤2000 Hz per second.
4) Detector Mode = mean or average power.

e) Adjust the center frequency of the spectrum analyzer for incremental coverage of the range from:

1) The lowest radio frequency generated in the equipment to the carrier frequency minus the test bandwidth (see 1.3.4.4).

2) The carrier frequency plus the test bandwidth to a frequency less than 2 times the carrier frequency.

f) Record the frequencies and levels of spurious emissions from step e).

g) Unkey the transmitter. Replace the transmitter under test with the signal generator and adjust the signal level to reproduce the frequencies and levels of every spurious emission recorded in step f). Record the signal generator levels in dBm.

h) Insert the notch filter.

i) Adjust the spectrum analyzer for the following settings:

1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1 GHz.
2) Video Bandwidth ≥3 times the resolution bandwidth.
3) Sweep Speed ≤2000 Hz per second.
4) Detector Mode = mean or average power.

j) Key the transmitter. Adjust the center frequency of the spectrum analyzer for incremental coverage of the range from a frequency equal to 2 times the carrier frequency and to the tenth harmonic of the carrier frequency.

k) Record the frequencies and levels of spurious emissions from step j).

l) Unkey the transmitter. Replace the transmitter under test with the signal generator and adjust the signal level to reproduce the frequencies and levels of every spurious emission recorded in step k). Record the signal generator levels in dBm.

m) The levels recorded in steps g) and l) are the absolute levels of conducted spurious emissions in dBm. The conducted spurious attenuation can be calculated by the following:

Spurious attenuation (dB) =

$$10\ \log_{10}\left(\frac{TX\ \ power\ in\ watts}{0.001}\right) - the\ levels\ in\ steps\ g)\ and\ l)$$

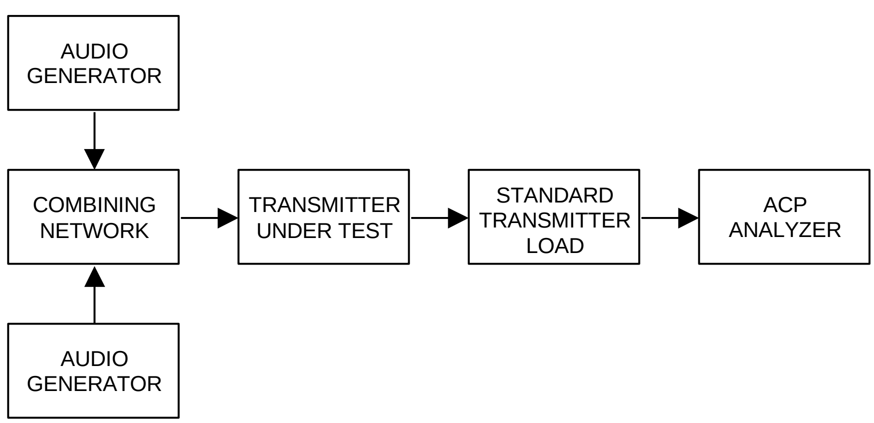
2.2.14 Unwanted Emissions: Adjacent Channel Power Ratio

2.2.14.1 Definition

The adjacent channel power ratio is the ratio of the total output power of a transmitter under defined conditions and modulation, to that part of the output power that falls within a specified passband centered on the nominal frequency of either of the adjacent channels or channels further offset above or below the assigned carrier frequency.

Two methods of measurement are described. One uses an adjacent channel power analyzer, and the other uses a measuring receiver.

2.2.14.2 Method of Measurement



a) Connect the equipment as illustrated. The transmitter shall be operated at the carrier power determined in 2.2.1. The adjacent channel power analyzer is set to use average power detection (sample or rms detector) and a span of 100 kHz.

b) The measurement bandwidth settings and markers of the analyzer shall be centered at the transmitter operating frequency, and at both the upper and lower adjacent channel frequencies using a power measurement bandwidth and resolution bandwidth as specified in 3.2.14 of this document. The video bandwidth shall be set to at least ten times the resolution bandwidth.

c) Remove modulation from the transmitter. Measure the carrier power with the adjacent channel power analyzer in a passband whose 6 dB bandwidth is the transmitter authorized bandwidth. Record this level in dBm as $P_{REF.}$

d) Adjust the frequency of one audio generator to 650 Hz. With the second audio generator off, adjust the amplitude of first audio generator to provide a transmitter modulation of 50% of rated system deviation. Record the audio generator level.

e) Turn off the first audio generator. Adjust the frequency of the second audio generator to 2200 Hz. Adjust the amplitude of the second audio generator to provide a transmitter modulation of 50% of rated system deviation. Record the audio generator level.

f) Turn both audio generators on and adjust the level of each to be 10 dB greater that the levels recorded in steps d) and e).

g) Key the transmitter.

h) The power shall be measured on the adjacent channel power analyzer in the specified measurement 6 dB bandwidth centered at both the upper and lower specified frequency offsets from the carrier frequency as listed in 3.2.14.3. Each lower frequency value shall be recorded in dBm as P_{ADJL}, and each upper frequency value shall be recorded in dBm as P_{ADJU}.

i) For each frequency offset specified in 3.2.14.3, calculate each lower adjacent channel power ratio, $ACPR_L$, as follows:

$$ACPR_L = P_{REF} - P_{ADJL}.$$

j) For each frequency offset specified in 3.2.14.3, calculate each upper adjacent channel power ratio, $ACPR_U$, as follows:

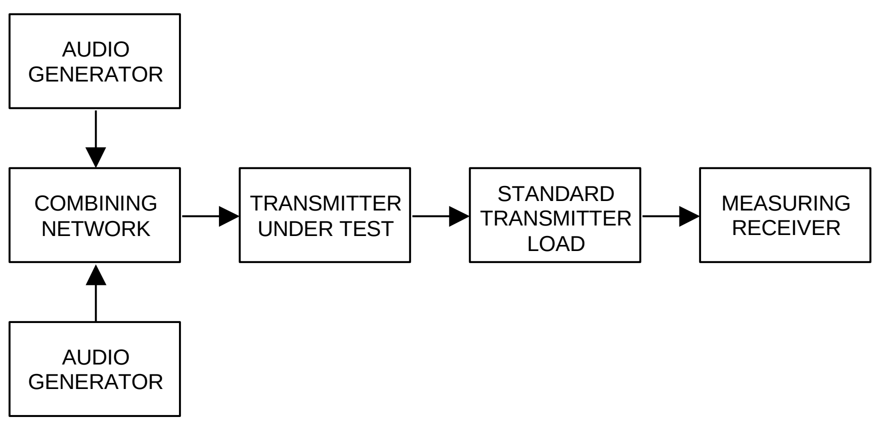
$$ACPR_U = P_{REF} - P_{ADJU}.$$

k) For each specified frequency offset, the adjacent channel power ratio is the lesser of $ACPR_L$ or $ACPR_U$.

Note: To accurately measure ACPR values greater than 70 dB, it may be necessary to increase the dynamic range of the measuring system. Measurement system dynamic range extension can be realized by utilizing selectivity to pass the frequency band of interest or attenuate the transmitter output signal. For the swept portion of the test, methods similar to those given in 2.2.12 using the noted resolution bandwidth and detector type are suggested.

2.2.14.3 Alternate Method of Measurement (Using a Measuring Receiver)

Note: This method is not applicable when making measurements on equipment in the 700 MHz frequency band.



a) Connect the equipment as illustrated.

b) The transmitter shall be operated at the carrier power determined in 2.2.1.

c) With the transmitter unmodulated, the measuring receiver should be tuned so that a maximum reading is obtained on the rms meter. The measuring receiver's variable attenuator setting, $ATT_{CARRIER}$, and the reading of the rms meter, $METER_{CARRIER}$, shall be recorded.

d) The frequency of the measuring receiver shall be adjusted above the carrier so that the measuring receiver's -6 dB response nearest to the transmitter carrier frequency is located at a displacement from the nominal carrier frequency as given in table 18:

Table 18 - Measuring Receiver Frequency Displacement

Channel Separation (kHz)	Specified Necessary 6 dB Bandwidth (kHz)	Displacement from the -6 dB point (kHz)
12.5	8.5	8.25
20	14	13
25 & 30	16	17

e) Adjust the frequency of one audio generator to 650 Hz. With the second audio generator off, adjust the amplitude of first audio generator to provide a transmitter modulation of 50% of rated system deviation. Record the audio generator level.

f) Turn off the first audio generator. Adjust the frequency of the second audio generator to 2200 Hz. Adjust the amplitude of the second audio generator to provide a transmitter modulation of 50% of rated system deviation. Record the audio generator level.

g) Turn both audio generators on and adjust the level of each to be 10 dB greater that the levels recorded in steps e) and f).

h) Key the transmitter.

i) The measuring receiver's variable attenuator shall be adjusted to obtain approximately the same rms meter reading, $METER_{CARRIER}$, in step c). The measuring receiver's variable attenuator setting, ATT_{ADJ} , and the reading of the rms meter, $METER_{ADJ}$, shall be recorded.

j) Calculate the adjacent channel power to carrier power ratio, ADJ_{RATIO} by the following:

$$ADJ_{RATIO} = ATT_{ADJ} - ATT_{CARRIER} + 20 \log_{10}\left(\frac{METER_{ADJ}}{METER_{CARRIER}}\right) \quad \text{(dB)}$$

k) Remove the modulating signal from the transmitter.

l) Repeat steps d) through j) with the frequency of the measuring receiver adjusted below the carrier.

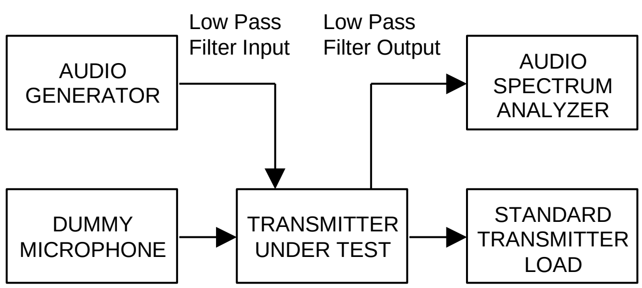
m) The adjacent channel power ratio is the lesser of the values recorded in steps j) and l).

2.2.15 Audio Low Pass Filter Response

2.2.15.1 Definition

The audio low pass filter response is the frequency response of the post limiter low pass filter circuit above 3000 Hz.

2.2.15.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Connect the audio frequency generator as close as possible the input of the post limiter low pass filter within the transmitter under test.

c) Connect the audio spectrum analyzer to the output of the post limiter low pass filter within the transmitter under test.

d) Apply a 1000 Hz tone from the audio frequency generator and adjust the level per manufacturer's specifications.

e) Record the dB level of the 1000 Hz spectral line on the audio spectrum analyzer as LEV_{REF} .

f) Set the audio frequency generator to the desired test frequency between 3000 Hz and the upper low pass filter limit.

g) Record audio spectrum analyzer levels, at the test frequency in step f).

h) Record the dB level on the audio spectrum analyzer as LEV_{FREQ} .

i) Calculate the audio frequency response at the test frequency as:

$$\textit{low pass frequency response} = LEV_{FREQ} - LEV_{REF}$$

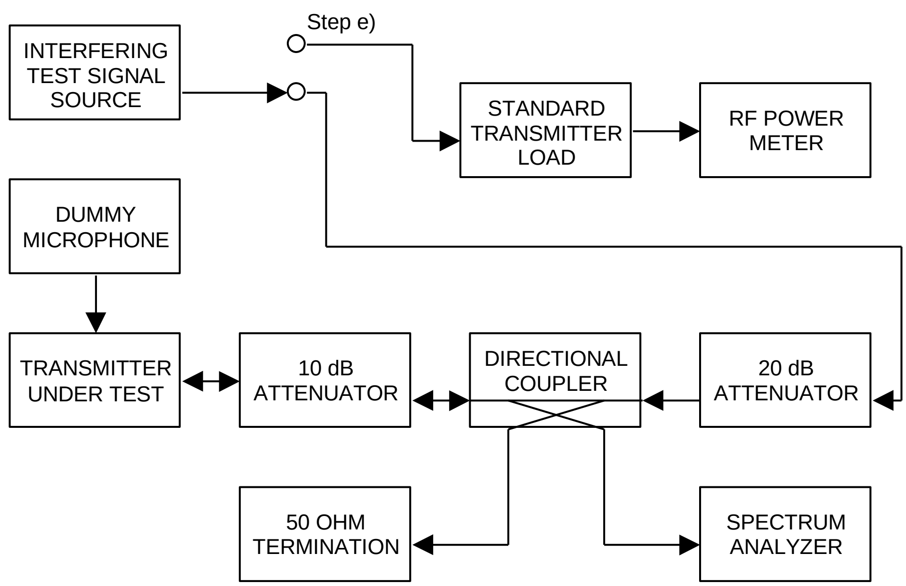
j) Repeat steps f) through i) for all the desired test frequencies.

2.2.16 Intermodulation Attenuation

2.2.16.1 Definition

Intermodulation attenuation is the capability of a transmitter to avoid the generation of signals in the nonlinear elements caused by the presence of the carrier and an interfering signal entering the transmitter via the antenna. It is specified as the ratio, in dB, of the power level of the third order intermodulation product to the carrier power level.

2.2.16.2 Method of Measurement



a) Connect the equipment as illustrated. In order to reduce the influence of mismatch errors it is important that the 10 dB power attenuator is coupled to the transmitter under test with the shortest possible connection. The interfering test signal source may either be a transmitter providing the same power output as the transmitter under test or a signal generator and a linear power amplifier capable of delivering the same output power as the transmitter under test. The transmitter under test and the interfering test signal source shall be physically separated in such a way that the measurement is not influenced by direct radiation.

b) Adjust the spectrum analyzer to give a maximum indication with a frequency scan width of 500 kHz.

c) Remove any modulation from the interfering test signal source.

d) Set the frequency of the interfering test signal source to within 50 kHz to 100 kHz above the frequency of the transmitter under test. The frequency shall be chosen in such a way that the intermodulation components to be measured do not coincide with other spurious components.

e) Adjust the power output of the interfering test signal source to equal the carrier power level of the transmitter under test. This is the power level that was measured in 2.2.1.

f) Record the largest third order intermodulation component from the spectrum analyzer as I_{LVL} .

g) Record the transmitter under test carrier power level from the spectrum analyzer as C_{LVL} .

h) Calculate the intermodulation attenuation as:

$$Intermodulation\ attenuation = C_{LVL} - I_{LVL}$$

i) Set the frequency of the interfering test signal source to within 50 kHz to 100 kHz below the frequency of the transmitter under test. The frequency shall be chosen in such a way that the intermodulation components to be measured do not coincide with other spurious components.

j) Repeat steps e) through h).

k) The lesser of the values recorded in steps h) and j) is the intermodulation attenuation.

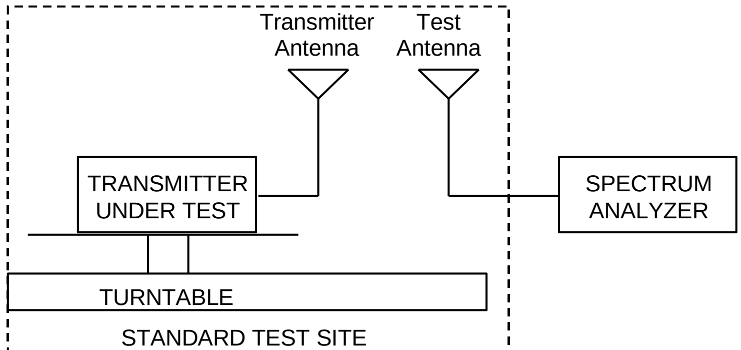
2.2.17 Radiated Power Output

2.2.17.1 Average Radiated Output Power

2.2.17.1.1 Definition

The average radiated power of a licensed device is the equivalent power required, when delivered to a half-wave dipole antenna, to produce at a distant point the same average received power as produced by the licensed device.

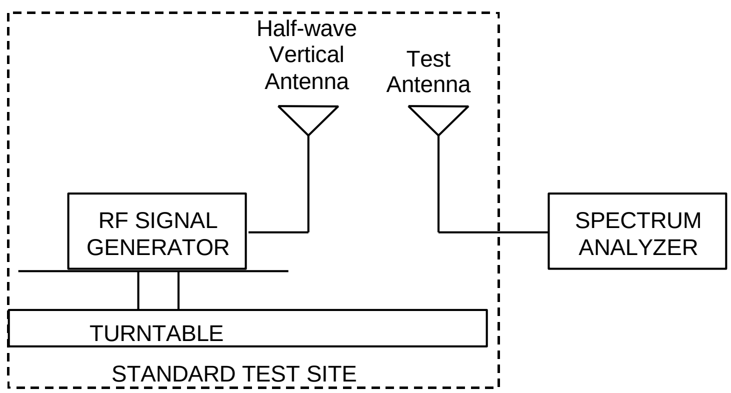
2.2.17.1.2 Method of Measurement



a) Connect the equipment as illustrated. Place the transmitter to be tested on the turntable in the standard test site. Both antennas shall be vertically polarized.

b) Raise and lower the test antenna from 1 m to 6 m with the transmitter antenna facing the test antenna and record the highest received signal in dBm as LVL_i .

c) Repeat step b) for seven additional readings at 45^o interval positions of the turn table.



d) Replace the transmitter under test with a half-wave vertically polarized antenna. The center of the antenna should be at the same location as the transmitter under test. Connect the antenna to a signal generator with a known output power and record the path loss in dB as *LOSS*.

e) Calculate the average radiated output power from the readings in step c) and d) by the following:

$$average radiated\ power = 10\log_{10}(1/8\sum_{i=1}^{i=8} 10^{\frac{LVL_i + LOSS}{10}})dBm$$

NOTE: It is permissible to use other antennas provided they can be referenced to a dipole.

2.2.17.2 Effective Radiated Power (ERP)

2.2.17.2.1 Definition and Application

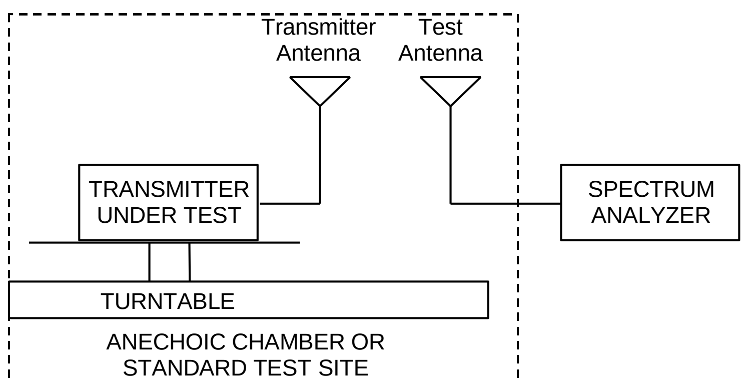
The Effective Radiated Power is defined as the product of the power applied to an antenna and its gain relative to an ideal half wave dipole in a given direction. Maximum ERP is the maximum ERP in any direction.

For equipment using an antenna with known radiation characteristics ERP is a characteristic that can be calculated as well as measured,

(Note: Effective Isotropic Radiated Power (EIRP) can be computed using the following:

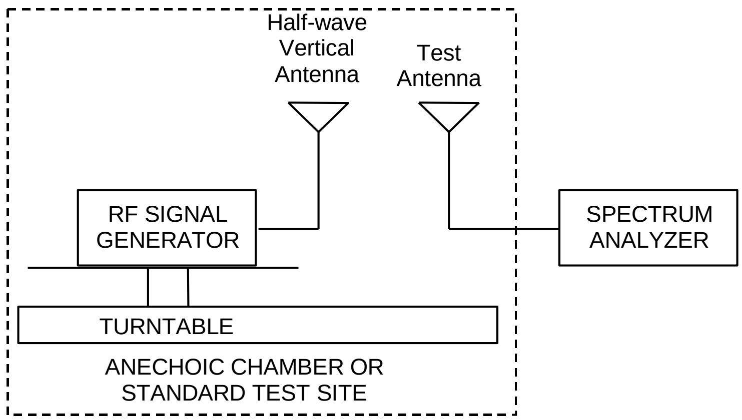
EIRP (dBm) = *ERP* (dBm) + 2.15 (dB.)

2.2.17.2.2 Method of measurement



a) Connect the equipment as illustrated. Mount the equipment with the manufacturer specified antenna in a vertical orientation on a manufacturer specified mounting surface located on a non-conducting rotating platform of a RF anechoic chamber (preferred) or a standard radiation site.

b) Key the transmitter, then rotate the EUT 360° azimuthally and record spectrum analyzer power level (LVL) measurements at angular increments that are sufficiently small to permit resolution of all peaks. If a standard radiation test site is used, raise and lower the test antenna to obtain a maximum reading at each angular increment. (Note: several batteries may be needed to offset the effect of battery voltage droop, which should not exceed 5% of the manufactured specified battery voltage during transmission).



c) Replace the transmitter under test with a vertically polarized half-wave dipole (or an antenna whose gain is known relative to an ideal half-wave dipole). The center of the antenna should be at the same location as the center of the antenna under test.

d) Connect the antenna to a signal generator with a known output power and record the path loss (in dB) as *LOSS*. If a standard radiation test site is used, raise and lower the test antenna to obtain a maximum reading.

LOSS = *Generator Output Power* (dBm) – *Analyzer reading* (dBm)

e) Determine the effective radiated output power at each angular position from the readings in steps b) and d) using the following equation:

ERP (dBm) = *LVL* (dBm) + *LOSS* (dB)

f) The maximum ERP is the maximum value determined in the preceding step.

2.2.17.2.3 Method of Calculation

When calculating ERP, in addition to knowing the antenna radiation and matching characteristics, it is necessary to know the loss values of all elements (e.g. transmission line attenuation, mismatches, filters, combiners) interposed between the point where transmitter output power is measured, and the point where power is applied to the antenna. ERP can then be calculated as follows:

ERP (dBm) = *Output Power* (dBm) - *Losses* (dB) + *Antenna Gain* (dBd)

where:

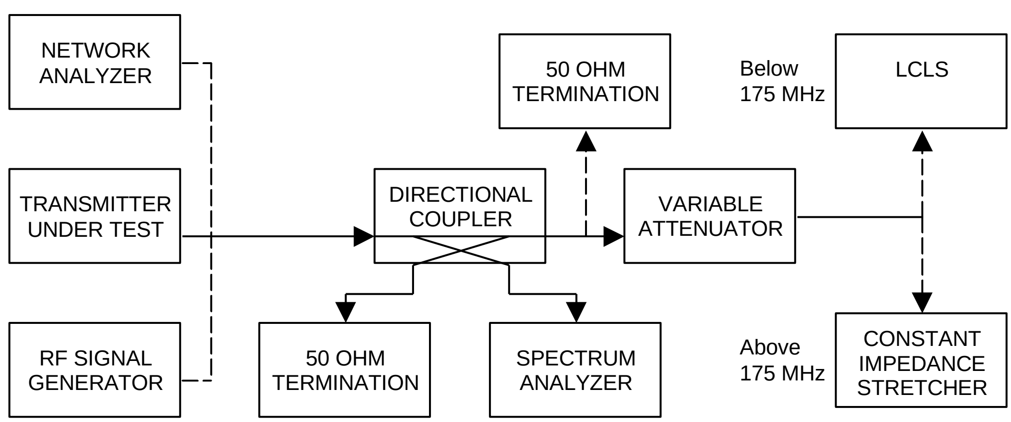
dBd refers to gain relative to an ideal dipole.

2.2.18 Transmitter Stability into VSWR

2.2.18.1 Definition

Transmitter stability into VSWR is the ability of a transmitter not to produce any spurious greater than allowed for the conducted spurious emissions when operated in a load different from the standard load.

2.2.18.2 Method of Measurement



a) Connect the equipment as illustrated.

b) For frequencies up to 175 MHz, recommend using a lumped constant line stretcher (LCLS) as the variable load (see 1.5.26 for the typical values of the inductors and capacitors).

c) For frequencies above 175 MHz, use constant impedance line stretcher with a RF short as the variable load.

d) Select the value for the attenuator that will produce the test VSWR required by the appropriate applicable standard.

e) Calibrate the variable load using the network analyzer at the frequencies of interest.

f) Set the center frequency of the spectrum analyzer to the center of the test bandwidth (see 1.3.4.4), key the transmitter into the 50 Ω load, and set the level of the unmodulated carrier to a full scale reference line.

g) Adjust the spectrum analyzer for the following settings:

   1) Resolution Bandwidth = 10 kHz for spurious emissions below 1 GHz, and 1 MHz for spurious emissions above 1 GHz.
   2) Video Bandwidth ≥3 times the resolution bandwidth.
   3) Sweep Speed ≤2000 Hz per second.
   4) Detector Mode = mean or average power.

h) Adjust the center frequency of the spectrum analyzer for incremental coverage of the range from:

   1) The lowest radio frequency generated in the equipment to the carrier frequency minus the test bandwidth (see 1.3.4.4).

   2) The carrier frequency plus the test bandwidth to a frequency less than 2 times the carrier frequency.

i) Key the transmitter into the variable load. Vary the phase angle of the load over 360 degrees with the line stretcher. Record the frequency and level of the highest unwanted spurious on the spectrum analyzer.

j) Replace the transmitter under test with the RF signal generator. Replace the variable attenuator with the 50 Ω termination and adjust the signal level from the RF signal generator to reproduce the frequency and level of the highest unwanted spurious recorded in step i).

k) The level recorded in step j) is the absolute level of conducted spurious emissions in dBm. The conducted spurious attenuation can be calculated by the following:

Spurious attenuation (dB) =

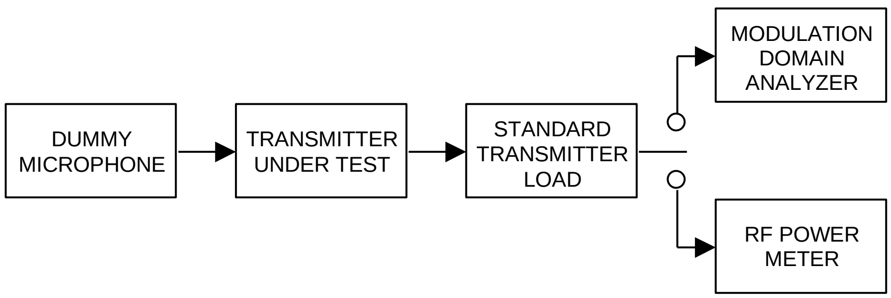
$$10\ \log_{10}\left(\frac{TX\ \ power\ in\ watts}{0.001}\right) - the\ level\ in\ step\ i)$$

2.2.19 Transient Frequency Behavior

2.2.19.1 Definition

Transient frequency behavior is a measure of the difference, as a function in time, of the actual transmitter frequency to the assigned transmitter frequency when the transmitted RF output power is switched on or off.

2.2.19.2 Method of Measurement (Using a Modulation Domain Analyzer)



a) Connect the equipment as illustrated.

b) Connect the output of the standard transmitter load to the RF power meter. Supply sufficient attenuation via the RF attenuator to provide a level that is approximately 40 dB below the maximum allowable input to the modulation domain analyzer.

c) Unkey the transmitter.

d) Disconnect the RF power meter and connect the modulation domain analyzer in its place. Set the envelope trigger of the modulation domain analyzer to the minimum level that will trigger when the transmitter is keyed.

e) Reduce the attenuation of the RF attenuator so that the input to the to the modulation domain analyzer is increased by 30 dB when the transmitter is keyed.

f) Set the modulation domain analyzer to trigger on the rising edge of the waveform in order to capture a single-shot turn-on of the transmitter signal.

g) Adjust the display of the modulation domain analyzer for proper viewing of the transmitter transient behavior. Set the timebase reference to the left for observing the transmitter turn-on transient.

h) Key the transmitter.

i) Observe the stored display of the modulation domain analyzer. The signal trace shall be maintained within the allowable limits during the periods t_1 and t_2, and shall also remain within limits following t_2.

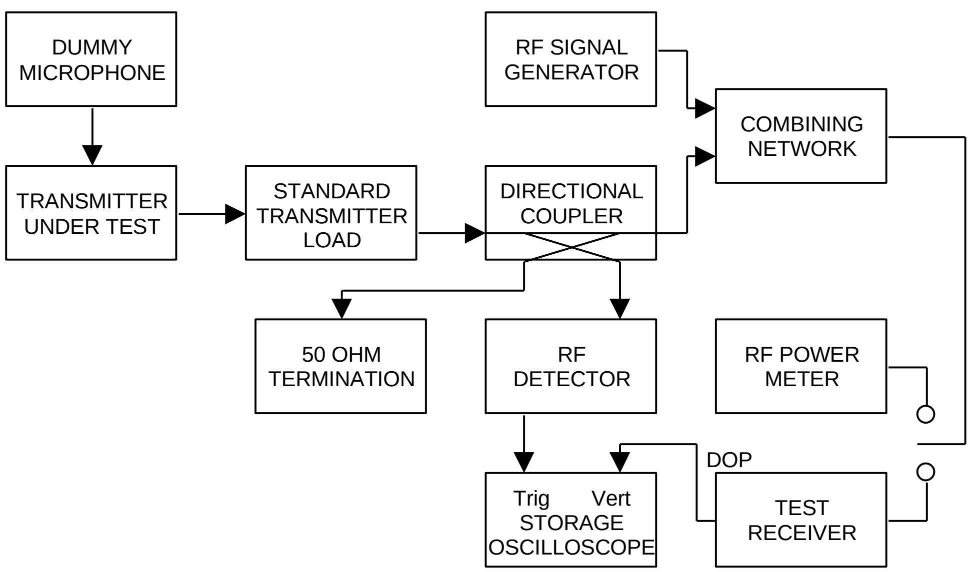
j) Adjust the modulation domain analyzer to trigger on the falling edge of the transmitter waveform in order to capture a single-shot turn-off transient of the transmitter signal.

k) Adjust the display of the modulation domain analyzer for proper viewing of the transmitter transient behavior. Set the timebase reference to the right for observing the transmitter turn-off transient.

l) Unkey the transmitter.

m) Observe the stored display of the modulation domain analyzer. The signal trace shall be maintained within the allowable limits during the period t_3.

2.2.19.3 Alternate Method of Measurement (Using a Test Receiver)



a) Connect the equipment as illustrated.

b) Connect the test receiver Demodulator Output Port (DOP) to the vertical input channel of the storage oscilloscope. Connect the output of the RF peak detector to the external trigger on the storage oscilloscope. Connect the output of the RF combiner to the RF power meter.

c) Set the test receiver to measure FM deviation with the audio bandwidth set at ≤50 Hz to ≥15,000 Hz, and tune the RF frequency to the transmitter assigned frequency.

d) Set the signal generator to the assigned transmitter frequency and modulate it with a 1 kHz tone at ±25 kHz deviation and set its output level to -100 dBm.

e) Key the transmitter.

f) Supply sufficient attenuation via the RF attenuator to provide an input level to the test receiver that is 40 dB below the test receiver maximum allowed input power when the transmitter is operating at its rated power level. Note this power level on the RF power meter.

g) Unkey the transmitter.

h) Adjust the RF level of the signal generator to provide RF power into the RF power meter equal to the level noted in step f). This signal generator RF level shall be maintained throughout the rest of the measurement.

i) Disconnect the RF power meter and connect the output of the RF combiner network to the input of the test receiver.

j) Set the horizontal sweep rate on the storage oscilloscope to 10 milliseconds per division and adjust the display to continuously view the 1000 Hz tone from the DOP. Adjust the vertical amplitude control of the oscilloscope to display the 1000 Hz at ±4 divisions vertically centered on the display.

k) Adjust the oscilloscope so it will trigger on an increasing magnitude from the RF peak detector at 1 division from the left side of the display, when the transmitter is turned on. Set the controls to store the display.

l) Reduce the attenuation of the RF attenuator so the input to the RF peak detector and the RF combiner is increased by 30 dB when the transmitter is turned on.

m) Key the transmitter and observe the stored display. The output at the DOP, due to the change in the ratio of power between the signal generator input power and the transmitter output power will, because of the capture effect of the test receiver, produce a change in display: For the first part of the sweep it will show the 1 kHz test signal. Then once the receiver's demodulator has been captured by the transmitter power, the display will show the frequency difference from the assigned frequency to the actual transmitter frequency versus time. The instant when the 1 kHz test signal is completely suppressed (including any capture time due to phasing) is considered to be t_{on} . The trace should be maintained within the allowed divisions during the period t_1 and t_2. See the figure in the appropriate standards section.

n) During the time from the end of t_2 to the beginning of t_3 the frequency difference should not exceed the limits set by the FCC in 47 CFR 90.214 and outlined in 3.2.2. The allowed limit is equal to the transmitter frequency times its FCC frequency tolerance times ±4 display divisions divided by 25 kHz. For example, at a transmitter assigned frequency of 500 MHz and a frequency tolerance of 5 ppm. This would be 500 MHz times 5 ppm times ±4 divisions divided by 25 kHz. This equals ±0.4 divisions in this example. Greater vertical sensitivity may be required to view this accurately.

o) Key the transmitter and observe the stored display. The trace should be maintained within the allowed divisions after the end of t_2 and remain within it until the end of the trace. See the figure in the appropriate standards sections.

p) To test the transient frequency behavior during the period t_3 the transmitter shall be keyed.

q) Adjust the oscilloscope trigger controls so it will trigger on a decreasing magnitude from the RF peak detector, at 1 division from the right side of the display, when the transmitter is turned off. Set the controls to store the display. The moment when the 1 kHz test signal starts to rise is considered to provide t_{off} .

r) The transmitter shall be unkeyed.

s) Observe the display. The trace should remain within the allowed divisions during period t_3. See the figures in the appropriate standards section.

2.3 Methods of Measurement for Unit Characteristics

This section details the methods of measurement for general characteristics of communications equipment, including environmental testing. Unless otherwise noted, all parameters are measured during the time that the actual environment is present.

2.3.1 Power Supply Voltage Range

2.3.1.1 Definition

Power supply voltage range denotes the range of power supply voltages over which the equipment will operate with no more than a specified amount of degradation in overall performance. No internal adjustments of the equipment are permitted during this test.

2.3.1.2 Method of Measurement

a) Connect the equipment to a variable voltage power source. Adjust the voltage to the maximum voltage specified for the equipment.

b) Perform the desired tests, using the method of measurement specified in section 2.

c) Repeat step b) with the power source adjusted for the minimum specified voltage for the equipment.

2.3.2 Temperature Range

2.3.2.1 Definition

Temperature range denotes the range of ambient temperature over which the transceiver will operate with no more than a specified maximum amount of degradation in overall performance. No internal adjustments of the transceiver are allowed during the temperature cycle.

2.3.2.2 Method of Measurement

a) Place the transceiver, installed in the case normally supplied, in a temperature chamber that has a rate of change in the temperature of ≤200 degrees C/hour.

b) With the power source to the transceiver removed, adjust the temperature of the chamber to the minimum temperature specified for the desired test. Maintain a constant temperature in the chamber without forced circulation of air directly on the transceiver for a period of time that will allow the temperature in the transceiver to stabilize.

c) Apply the power source to the transceiver and allow 15 minutes, or the time specified by the manufacturer, for the unit to stabilize.

d) Perform the desired test, using the method of measurement specified in section 2, over the duty cycle specified in 1.3.2.

e) Remove the power source from the transceiver.

f) Carrier frequency stability measurements should be made in ≤10 degrees C increments from the minimum to maximum temperatures.

g) Adjust the temperature of the chamber to the maximum temperature specified for the desired test. Maintain a constant temperature in the chamber without forced circulation of air directly on the transceiver.

h) Repeat steps c) and d).

2.3.3 High Humidity

2.3.3.1 Definition

High humidity denotes the relative humidity at which a transceiver will operate with no more than a specified maximum amount of degradation in overall performance. No internal adjustments of the transceiver are allowed during the humidity cycle.

2.3.3.2 Method of Measurement

a) Place the transceiver, installed in the case normally supplied, in a humidity chamber. This procedure shall be conducted in a manner that does not cause condensation.

b) With the power source to the transceiver removed, adjust the humidity of the chamber to the maximum humidity specified for the desired test. Maintain the constant specified temperature in the chamber without forced circulation of air directly on the transceiver.

c) After 8 hours in the chamber, apply the power source to the transceiver.

d) Perform the desired test, using the method of measurement specified in section

2, over the duty cycle specified in 1.3.2.

2.3.4 Vibration Stability

2.3.4.1 Definition

Vibration stability denotes the amount of mechanical vibration during and after which the equipment will operate with no more than a specified amount of degradation in overall performance, and without sustaining physical damage. No internal adjustments of the equipment are permitted during this test.

2.3.4.2 Method of Measurement

a) Mount the equipment under test to a vibration table, using the manufacturer's supplied mounting hardware, where applicable.

b) Adjust the vibration table for the amplitude and frequency range of vibration, and the frequency sweep rate specified for the equipment.

c) During the vibration perform the desired tests, using the method of measurements specified in section 2.

2.3.5 Shock Stability

2.3.5.1 Definition

Shock stability denotes the amount of mechanical shock after which the equipment does not sustain physical damage, and no more than a specified amount of degradation in overall performance results. No internal adjustments of the equipment are permitted during this test.

2.3.5.2 Method of Measurement

a) Apply the specified shock to the equipment, either through a calibrated shock table, or a drop from a specified height, as the specification dictates.

b) After the specified number of shock cycles perform the desired tests, using the methods of measurement in section 2.

2.3.6 DC Supply Noise Susceptibility

2.3.6.1 Definition

Supply noise susceptibility denotes the level of power supply noise during which the equipment will operate with no more than a specified amount of degradation in overall performance. No internal adjustments of the equipment are permitted during this test.

2.3.6.2 Method of Measurement

a) Connect the equipment to a power supply that has the ability to superimpose a sinusoidal signal to the dc source.

b) Adjust the sinusoidal signal to the specified frequency and amplitude.

c) Perform the desired tests, using the method of measurement in section 2.

2.3.7 Battery Life

2.3.7.1 Definition

The minimum battery life is the number of hours that the equipment will operate under the standard duty cycle on a single complement of batteries before the battery end point has been reached.

2.3.7.1 Method of Measurement

a) Adjust the equipment at the standard test voltage for rated carrier output power and rated audio output power.

b) Operate the equipment under the standard duty cycle, starting with a fully charged battery complement.

c) Operate the equipment until any of the following conditions are met:

   1) The manufacturer's specified discharge voltage is reached.

   2) The receiver reference sensitivity is degraded by 6 dB from the value recorded at the standard test voltage.

   3) The transmitter carrier output power is degraded by 6 dB from the value recorded at the standard test voltage.

4) The transmitter carrier frequency stability exceeds the allowable FCC limit.

d) The battery life is the time from the start of the test until the conditions of step c) are met.

2.3.8 Dimensions

2.3.8.1 Definition

The dimensions are the physical size of the unit.

2.3.8.1 Method of Measurement

The equipment shall be measured together with all accessories that are required for operation and support during its intended use. The measurement shall give the overall physical size of the unit, that is the size of a box that is required to contain the unit. The following may be excluded from the measurement:

a) Antennas that protrude beyond the basic equipment.

b) Interconnection cables, such as power, microphone, antenna, etc.

c) Optional mounting hardware.

d) Optional convenience accessories, such as belt clips, holsters, etc.

For equipment that consists of more than one physical piece, each piece may be measured separately.

2.3.9 Weight

2.3.9.1 Definition

The weight is the physical weight of the unit.

2.3.9.2 Method of Measurement

The equipment shall be weighed together with all accessories required for operation and support during its intended use. The following may be excluded from the weight:

a) Optional mounting hardware.

b) Optional convenience accessories, such as belt clips, holsters, etc.

For equipment that consists of more than one physical piece, each piece may be weighed separately.

2.4 Methods of Measurement for Subaudible Signaling

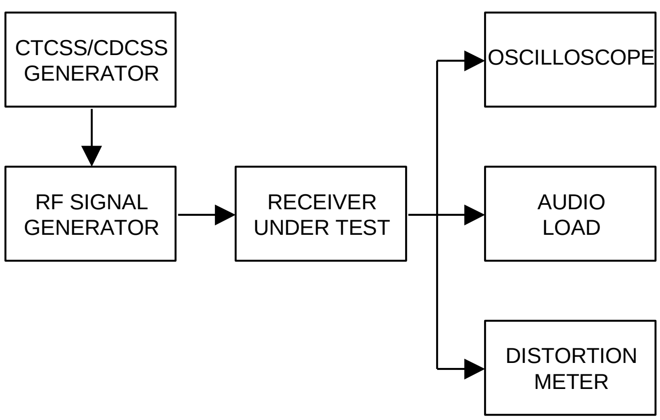
This section details the test definitions and methods of measurement of the characteristics of FM and PM land mobile equipment in vehicle (mobile), fixed (base station), or handheld (portable) classifications. The special function subsystems for subaudible signaling such as tone coded squelch (CTCSS) or digital coded squelch (CDCSS) shall be enabled as applicable. Measurements are explicit for all CTCSS code frequencies and CDCSS code words specified by the manufacturer. Equipment with both tone and digital squelch shall be measured with tone coded squelch first and then retested with the digital squelch.

2.4.1 Squelch Opening SINAD

2.4.1.1 Definition

The squelch opening SINAD is the RF level and SINAD obtained at the output of the receiver at a level just adequate to open the squelch circuits of the receiver when a signal from a RF signal generator modulated with standard modulation and standard CTCSS or CDCSS modulation is fed to the antenna terminal of the receiver.

2.4.1.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal with standard subaudible modulation to the receiver input terminals.

c) Adjust the receiver volume to obtain rated output power.

d) Remove the RF input signal.

e) Increase the input signal to the minimum level that produces a continuous audio output not lower than 10 dB below the rated audio output for a period of at least 10 seconds. Record this level and the resulting SINAD.

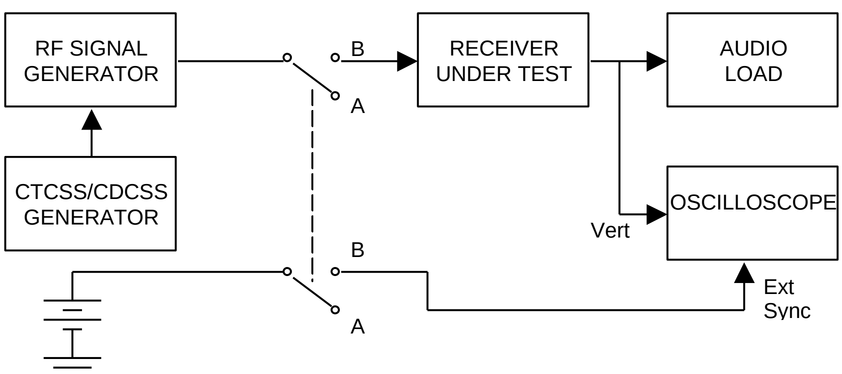
f) The levels recorded in step e) are the squelch opening SINAD and RF level.

2.4.2 Receiver Audio Attack Time

2.4.2.1 Definition

The receiver audio attack time is the elapsed time between the application of a receiver input signal 12 dB above the reference sensitivity modulated with the standard test modulation and standard subaudible modulation, and the time that the audio voltage at the receiver output is greater than 90% of its rated output.

2.4.2.2 Method of Measurement



a) Connect the equipment as illustrated.

b) With the switch in position B, apply a standard input signal with standard subaudible modulation to the receiver input terminals.

c) Adjust the receiver volume to obtain rated audio output.

d) Place the switch in position A and allow the receiver to squelch the audio.

e) With the switch in position A, adjust the input signal to a level 12 dB above the reference sensitivity.

f) Change the switch from position A to position B and record the time from the beginning of the RF signal to when the receiver audio output is greater than 90% of the rated output level.

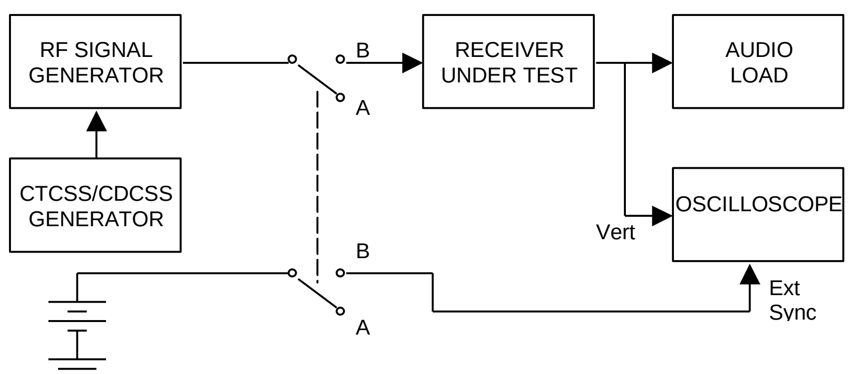
g) The receiver audio attack time is the average of four trial recorded in step f).

2.4.3 Receiver Audio Closing Time (with Squelch Tail Elimination disabled)

2.4.3.1 Definition

The receiver audio closing time is the elapsed time between the removal of an RF signal 12 dB above the reference sensitivity modulated with the standard modulation and standard subaudible modulation, and the time that the audio voltage at the receiver output is reduced to less than 10% of its rated output. This method of measurement is applicable only when squelch tail elimination is not enabled.

2.4.3.2 Method of Measurement



a) Connect the equipment as illustrated.

b) With the switch in position B, apply a standard input signal with standard subaudible modulation to the receiver input terminals.

c) Adjust the receiver volume to obtain rated audio output.

d) With the switch in position B, adjust the input signal to a level 12 dB above the reference sensitivity.

e) Change the switch from position B to position A and record the time from the end of the input signal to when the receiver audio output is less than 10% of the rated output level.

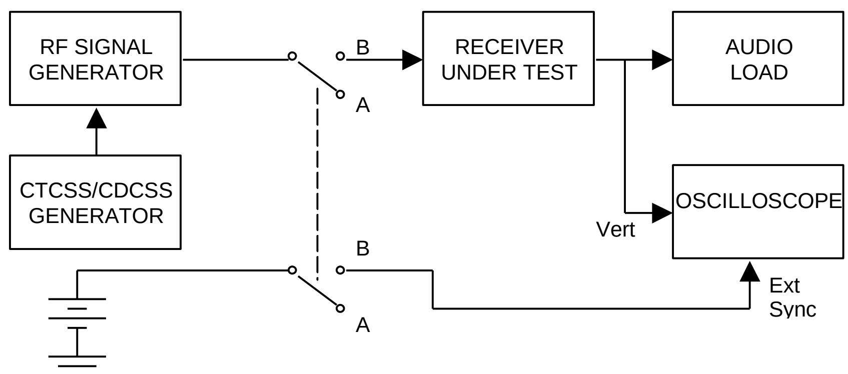
f) The receiver audio closing time is the average of four trials recorded in step e).

2.4.4 Receiver Audio Attack Time with RF Carrier Frequency Offset

2.4.4.1 Definition

The receiver audio attack time is the elapsed time between the application of an RF Signal offset in frequency and 12 dB above the reference sensitivity modulated with the standard modulation and standard subaudible modulation, and the time that the audio voltage at the receiver output is greater than 90% of it rated output. The frequency offset of the RF signal is related to the frequency of operation, the system rated deviation and the stability requirement for transmitters.

2.4.4.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Apply a standard input signal with standard subaudible modulation. Offset the RF signal generator's frequency below the channel center frequency (assigned frequency) by the transmitter frequency stability required for the operational frequency range and channel bandwidth.

c) Adjust the receiver under test to provide rated audio output to the load with a standard level signal.

d) With the switch in position B, adjust the RF input signal to a level 12 dB above the reference sensitivity.

e) Change the switch from position B to position A and allow the receiver to squelch the audio.

f) Change the switch from position A to position B and record the time from the beginning of the RF signal to the time at which the receiver audio output is greater than 90% of the rated output level.

g) The receiver audio attack time with RF carrier frequency offset (low side) is the average of four trials recorded in step f).

h) Adjust the RF signal generator frequency to the channel center frequency plus the offset.

i) Change the switch from position A to position B and record the time from the beginning of the RF signal to the time at which the receiver audio output is greater than 90% of the rated output level.

j) The receiver audio attack time with RF carrier frequency offset (high side) is the average of four trials recorded in step i).

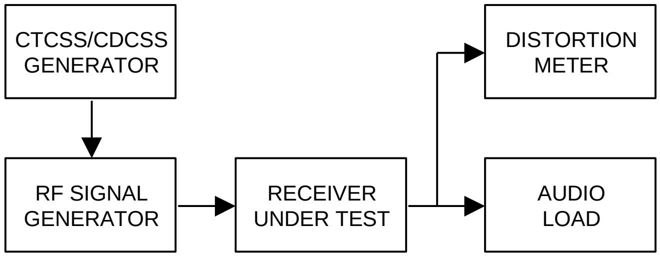
k) The receiver audio attack time with RF carrier frequency offset is the greater of the averages from step g) and j).

2.4.5 Receiver Hum and Noise Ratio

2.4.5.1 Definition

The receiver hum and noise ratio is a measurement of the residual power remaining at the receiver audio output when the standard modulation has been removed but the standard CTCSS or CDCSS modulation remains.

2.4.5.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Establish standard modulation and standard subaudible modulation on the RF signal generator at the standard input level and apply this to the receiver input. If testing with CTCSS, choose the highest CTCSS code frequency specified by the manufacturer and adjust the receiver per the manufacturer's procedure. If testing with CDCSS, choose octal code 532 and adjust the receiver per the manufacturer's procedure.

c) Adjust the volume control to obtain rated output power and record the audio output level as V_{REF} .

d) Remove the standard modulation from the RF signal generator, leaving just the standard CTCSS or CDCSS modulation, and record the audio output level as V_{NOISE} .

e) The receiver hum and noise ratio is calculated as follows:

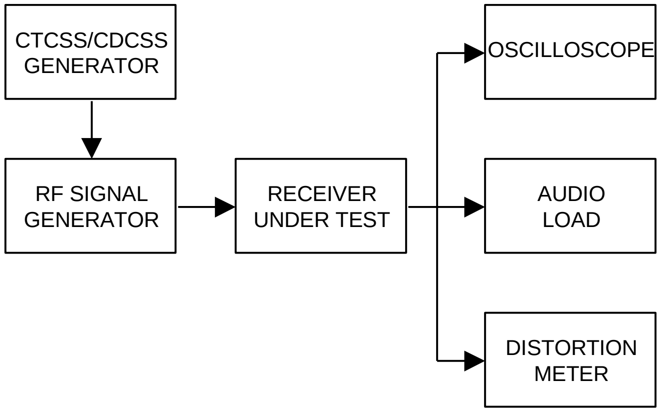
$$\textit{hum and noise ratio} = 20\ \log_{10}\left(\frac{V_{REF}}{V_{NOISE}}\right)$$

2.4.6 CTCSS Decoder Response Bandwidth

2.4.6.1 Definition

The CTCSS decoder response bandwidth is defined as that range of input CTCSS Code Frequencies that will result in proper decoding when the standard input signal with CTCSS modulation is applied to the receiver.

2.4.6.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Establish standard modulation and standard subaudible modulation on the RF signal generator. Adjust the receiver under test to provide rated audio output to the load with a standard input level signal.

c) Reduce the frequency of the CTCSS tone until the audio output has been squelched. Increase the frequency of the tone until the audio has unmuted and record this frequency as F_{Low} .

d) Increase the frequency of the CTCSS tone above the selected CTCSS code frequency until the audio output has been squelched. Decrease this frequency until the audio output has unmuted and record this frequency as F_{High} .

e) The values recorded in steps c) and d) are the CTCSS decoder response bandwidth.

2.4.7 False Response Rate

2.4.7.1 Definition

The false response rate is the number of times that the audio squelch circuit allows a burst of noise from the speaker when no signal is present at the input.

2.4.7.2 Method of Measurement

a) Adjust the external controls of the radio to manufacturer specifications for CTCSS or CDCSS and verify the equipment is able to receive a receiver reference sensitivity level signal encoded with the correct subaudible signaling.

b) Remove the signal and terminate the antenna port with the appropriate resistive load.

c) Record the number of times the receiver unmutes over the next 30 minute period.

d) If a single false response occurs within the thirty minute period, continue the test for another thirty minute period. If no false response occurs within that second period, disregard the first false response recorded in c).

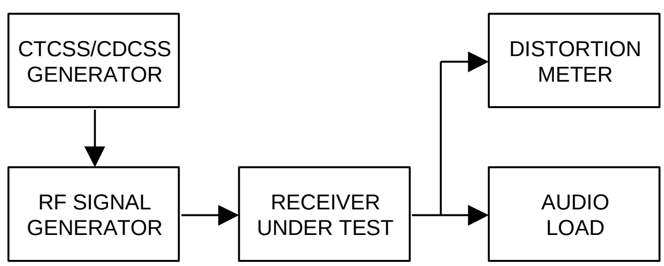
e) The number recorded in step c) is the false response rate.

2.4.8 Receiver Audio Response

2.4.8.1 Definition

The audio frequency response denotes the degree of closeness to which the audio output of a receiver follows a 6 dB per octave de-emphasis curve with constant frequency deviation over a given continuous frequency range with the subaudible signaling circuitry enabled.

2.4.8.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Establish standard modulation and standard subaudible modulation on the RF signal generator. Apply this signal at the standard input signal level to the receiver input terminals.

c) Adjust the receiver volume control for 50% of the rated audio output power.

d) Reduce the 1000 Hz generator modulation to 20% of the maximum rated system deviation.

e) Record the audio output level as V_{REF} .

f) Vary the modulation frequency from 300 Hz to 3000 Hz.

g) When the modulation frequency is varied record the audio output level as V_{REFQ} .

h) Calculate the audio frequency response at the frequency of interest by the following:

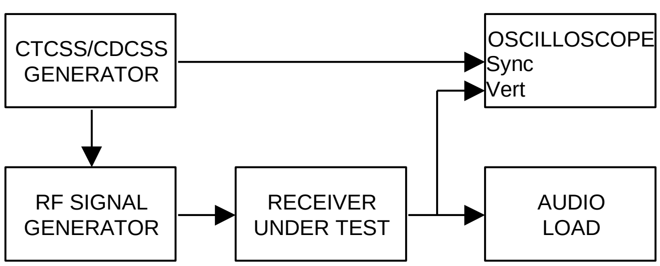
$$receiver\ audio\ response = 20\ \log_{10}\left(\frac{V_{FREQ}}{V_{REF}}\right)$$

2.4.9 Squelch Tail Elimination

2.4.9.1 Definition

Equipment that has been provided with special reverse burst CTCSS circuitry or turn off code for CDCSS circuitry shall be tested to verify its operation. This circuitry, during the last milliseconds of a transmission, changes phase or waveform of the subaudible signal to allow the receiver to rapidly detect the end of a transmission and thus significantly reduce or eliminate the duration of the noise burst heard in the receiver.

2.4.9.2 Method of Measurement



a) Connect the equipment as illustrated. The sync output from the subaudible signaling generator is to be used to trigger the oscilloscope to allow viewing of the start of the CTCSS reverse burst or CDCSS audio turn off code.

b) Adjust the CTCSS/CDCSS generator to duplicate the phase reversal or turn off code characteristics specified.

c) Establish standard modulation and standard subaudible modulation on the RF signal generator. Apply a RF signal 12 dB above reference sensitivity to the receiver and adjust the receiver to provide rated audio output to the audio load.

d) Switch the CTCSS/CDCSS generator to the reverse burst or CDCSS audio turn off code and measure the time until the receiver audio output is less than 10% of the rated output level.

e) Repeat steps c) and d) until four measurements have been obtained.

f) The squelch tail elimination time is the maximum time measured in step e) minus the specified duration of the reverse burst/turn off code time.

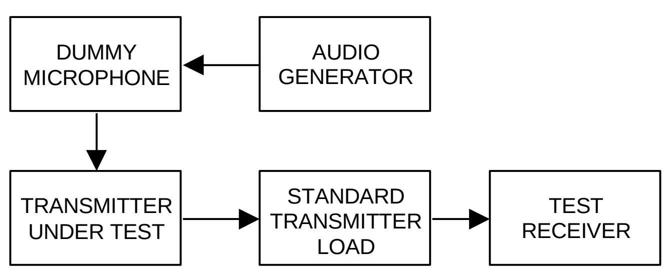
g) If the equipment contains both CDCSS and CTCSS with reverse burst, test both sections, the CTCSS and the CDCSS.

2.4.10 Transmitter Modulation Limiting

2.4.10.1 Definition

Modulation limiting is the transmitter circuit's ability to prevent the transmitter from producing deviations due to subaudible signaling and excessive voice modulation in excess of a rated system deviation.

2.4.10.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Adjust the transmitter per the manufacturer's procedure for full rated system deviation with the subaudible signaling enabled.

c) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤0.25 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

d) Apply a 1000 Hz modulating signal to the transmitter from the audio frequency generator, and adjust the level to obtain 60% of full rated system deviation.

e) Increase the level from the audio frequency generator by 20 dB in one step (rise time between the 10% and 90% points shall be 0.1 second maximum).

f) Measure both the instantaneous and steady-state deviation at and after the time of increasing the audio input level.

g) With the level from the audio frequency generator held constant at the level obtained in step e), slowly vary the audio frequency from 300 Hz to 3000 Hz and observe the steady-state deviation. Record the maximum deviation.

h) Set the test receiver to measure peak negative deviation and repeat steps d) through g).

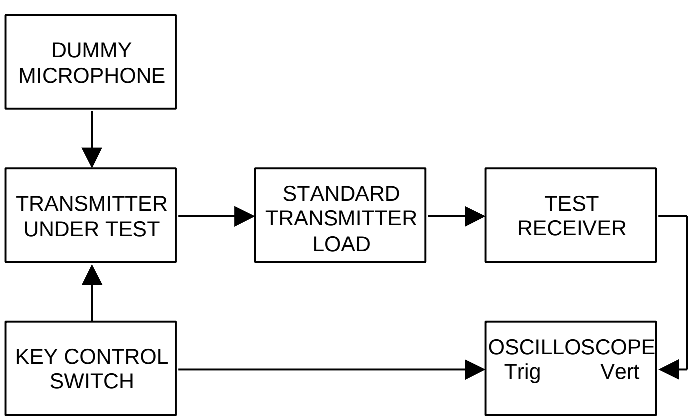
i) The values recorded in steps g) and h) are the transmitter modulation limiting.

2.4.11 Encoder Response Time

2.4.11.1 Definition

The encoder response time is the elapsed time from the moment the push-to-talk control circuit is activated at the transmitter until the CTCSS tone or CDCSS NRZ data level at the output of the transmitter has reached 90% of maximum voltage.

2.4.11.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤0.25 Hz to ≥15,000 Hz and pretune the receiver to the transmitter operating frequency. Turn the de-emphasis function off.

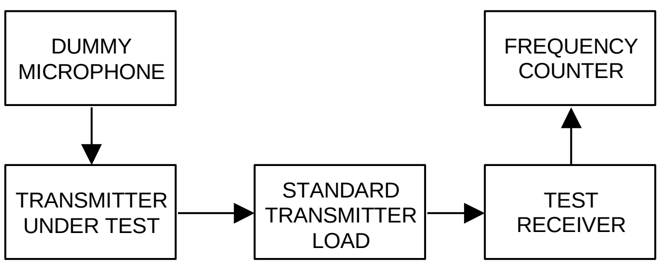
c) Key the transmitter and measure the time from the PTT to when the test receiver voltage output has increased to 90% of the maximum in the case of CTCSS. Measure the time from the PTT to the beginning of the NRZ waveform or the time for the output of the test receiver to settle within 20% of its final level whichever is the longest in the case of CDCSS.

2.4.12 CTCSS Encoder Frequency

2.4.12.1 Definition

CTCSS encoder frequency is the assigned CTCSS code frequency of the encoder.

2.4.12.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation with de-emphasis off. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz.

c) With only the CTCSS modulation, key the transmitter and measure the frequency of the CTCSS detected signal.

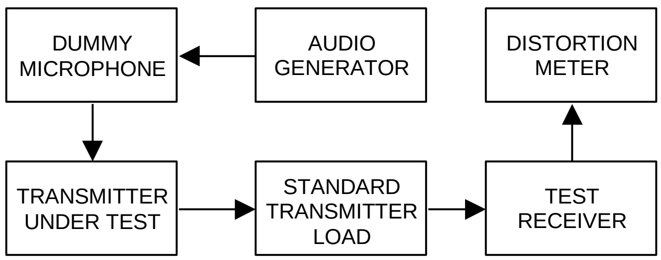
d) The value recorded in step c) is the CTCSS encoder frequency.

2.4.13 CTCSS Tone Distortion

2.4.13.1 Definition

The CTCSS tone distortion is the undesired content in the modulation at the transmitter output expressed as a percentage of the tone modulation voltage.

2.4.13.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation with de-emphasis off. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz.

c) Adjust the transmitter according to the manufacturer's procedure for full rated system deviation. The transmitter shall be modulated with standard test modulation and CTCSS modulation.

d) Reset the test receiver to measure peak positive deviation with de-emphasis on and the audio bandwidth set for ≤50 Hz to ≥3,000 Hz.

e) With only the CTCSS modulation applied the transmitter, key the transmitter and measure the distortion of the CTCSS detected signal.

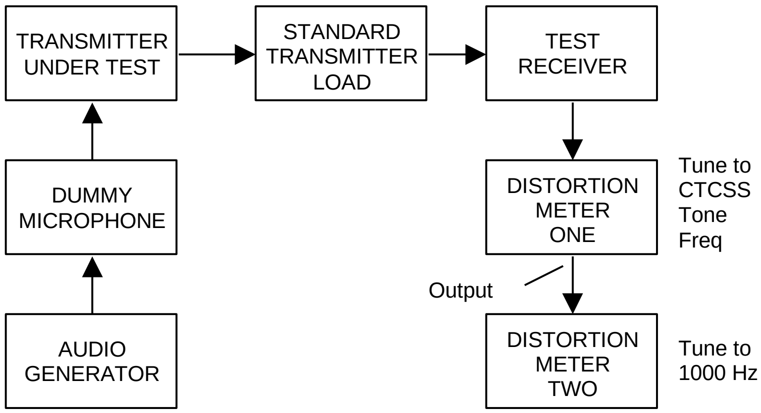
f) The value measured in step e) is the CTCSS tone distortion.

2.4.14 Transmitter SINAD

2.1.14.1 Definition

The transmitter SINAD is a measure of the signal to noise ratio at the transmitter output with both the subaudible signaling and a 1000 Hz tone.

2.1.14.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation with de-emphasis off. Set the audio bandwidth for ≤50 Hz to ≥15,000 Hz for a CTCSS system and ≤0.25 Hz to ≥15,000 for a CDCSS system.

c) Adjust the transmitter according to the manufacturer's procedure for full rated system deviation.

d) The transmitter shall then be modulated by a 1000 Hz tone to produce 60% of the rated system deviation.

e) Reset the test receiver to measure peak positive deviation with de-emphasis on. Set the audio bandwidth for ≤300 Hz to ≥3,000 Hz.

f) Adjust distortion meter one for the CTCSS modulation frequency if testing a CTCSS system or to 67.2 Hz for a CDCSS system.

g) Adjust distortion meter two for the 1000 Hz tone. Read the SINAD on distortion meter two.

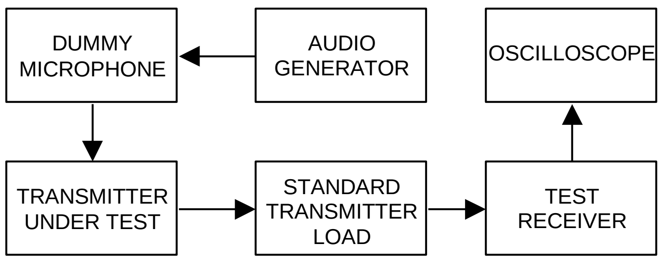
h) The value recorded in step g) is the transmitter SINAD.

2.4.15 CDCSS Waveform Distortion

2.4.15.1 Definition

CDCSS modulation is a direct frequency shift of the RF carrier that must be decoded correctly at the receiving end. Since the code by definition is allowed to have six one's or zero's in a row, insufficient low frequency coupling or overshoot in the filters subsequent to the generation of the code could cause decoding problems at the receiver.

2.4.15.2 Method of Measurement

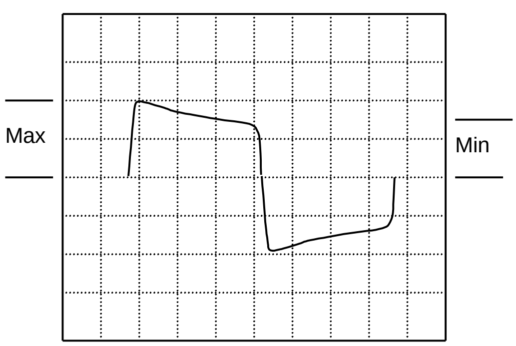


a) Connect the equipment as illustrated.

b) Adjust the transmitter according to the manufacturer's instructions for full rated system deviation. The transmitter shall then be modulated with CDCSS modulation. Program the CDCSS modulation for code 627 (octal).

c) Set the test receiver audio bandwidth of ≤0.25 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

d) Key the transmitter and measure the signal 'droop' as shown in the figure below from the beginning of the long string of one's and zero's to the end of the string. (Octal 627 has the maximum length of one's and zero's).



e) Calculate the CDCSS waveform distortion as:

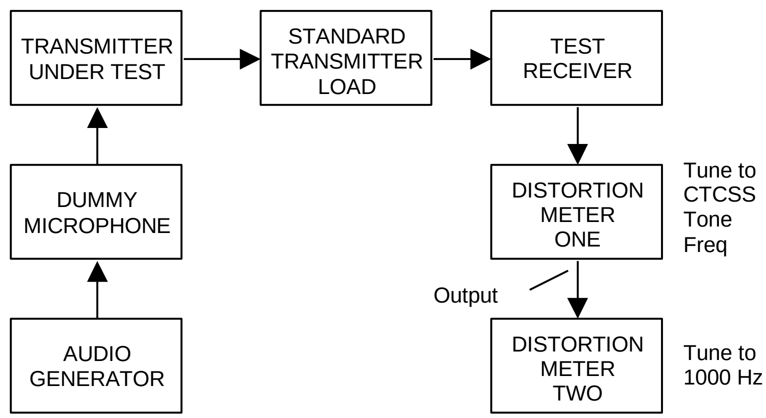
$$waveform\ \ distortion = \frac{Max - Min}{Max} 100\%$$

2.4.16 Transmitter FM Hum and Noise Ratio

2.4.16.1 Definition

The transmitter FM hum and noise ratio is the ratio of the standard test modulation to the residual frequency modulation measured by the test receiver with the subaudible signaling present on the transmitted signal. This is to be performed with any audio compression/expansion circuit disabled.

2.4.16.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Set the test receiver to measure peak positive deviation. Set the audio bandwidth for ≤0.25 Hz to ≥15,000 Hz. Turn the de-emphasis function off.

c) Adjust the transmitter per the manufacturer's procedure for full rated system deviation with the subaudible signaling enabled.

d) Apply standard test modulation.

e) Set the test receiver to measure rms deviation. Set the audio bandwidth for 300

Hz to 3000 Hz. Set the 750 microsecond de-emphasis function to on.

f) Adjust distortion meter one for the CTCSS modulation frequency if testing a CTCSS system or to 67.2 Hz for a CDCSS system.

g) Record the voltage reading from distortion meter two as REF_{TOTAL} .

h) Remove the modulation input signal (the audio input terminals shall remain terminated with the dummy microphone circuit specified by the manufacturer) and record the voltage level from distortion meter two as REF_{NOISE} .

i) Calculate the transmitter FM hum and noise as:

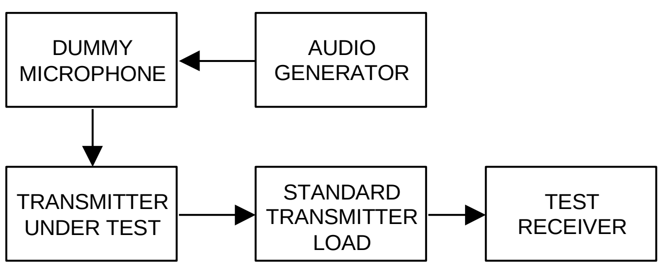
$$FM\ hum\ and\ noise = 20\ \log_{10}\left(\frac{REF_{TOTAL}}{REF_{NOISE}}\right)$$

2.4.17 Transmitter Subaudible Deviation

2.4.17.1 Definition

The transmitter subaudible deviation is the peak deviation on the transmitter carrier resulting from the subaudible signaling.

2.4.17.2 Method of Measurement



a) Connect the equipment as illustrated.

b) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

c) Set the test receiver to measure peak positive deviation with de-emphasis off. Set the audio bandwidth for ≤0.25 Hz to ≥15,000 Hz.

d) Measure the steady-state deviation of the transmitter with only the subaudible signaling present.

e) Set the test receiver to measure peak negative deviation and repeat step d).

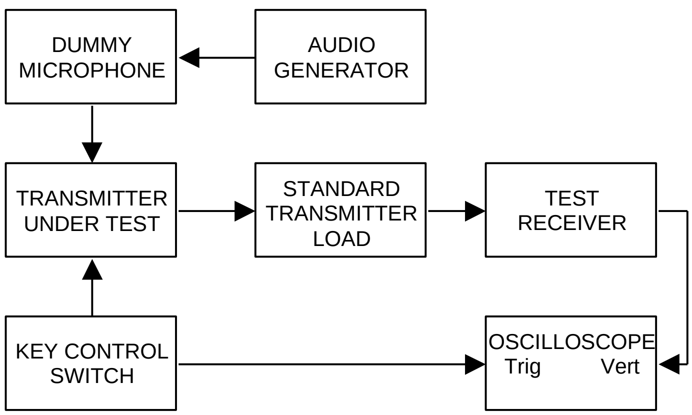
f) The transmitter subaudible deviation is the average of the two readings from steps d) and e).

2.4.18 Transmitter Squelch Tail Elimination Burst

2.4.18.1 Definition

The transmitter squelch tail elimination burst is the burst of signaling transmitted just prior to turning off the RF transmitter carrier. This signaling is different for CTCSS and CDCSS.

2.4.18.2 Method of Measurement



a) Connect the equipment as illustrated. Trigger the oscilloscope on the trailing edge of the PTT signal and adjust it to capture the recovered signal from the test receiver.

b) Adjust the transmitter per the manufacturer's procedure for full rated system deviation.

c) Set the test receiver to measure peak positive deviation with de-emphasis off. Set the audio bandwidth for ≤0.25 Hz to ≥15,000 Hz and pretune the instrument to the transmitter frequency.

d) Set the oscilloscope to capture the last 250 milliseconds of the transmitted modulation and measure the period of the CTCSS reverse burst or the CDCSS turn off code.

e) The value recorded in step d) is the transmitter squelch tail elimination burst.

3 Standards for All Equipment

This section details the performance standards for mobile, portable, and base station communications FM or PM equipment as defined in the following paragraphs.

Mobile communications equipment are radio transmitters, receivers or combinations of both that are capable of, or the manufacturer's intentions include, or a reasonable user's expectations encompass providing communications in a non-stationary environment, and ordinarily does not include an integral power source or antenna. Such equipment is further defined as that which is capable of being physically mounted on or to any vehicle used to transport people, goods or services where the vehicle also provides mobility for a requisite power source or antenna. This includes control stations, that may be AC line powered.

Portable communications equipment are radio transmitters, receivers, vocoders, or combinations of these that can be hand-carried or worn on the person, and that are operated from their own portable power sources and antennas. The temperature operating range of the power source is not included. It excludes accessories such as chargers, power boosters, batteries, etc.

Base station communications equipment are radio transmitters, receivers or combinations of both that are capable of, or the manufacturer's intentions include, or a reasonable user's expectations encompass providing communications in a stationary environment, and ordinarily includes an integral power source. Such equipment is further defined as that which is physically mounted on or in a stationary structure. This includes mobile relay stations and repeaters.

The equipment shall be assembled with any requisite adjustments made in accordance with the manufacturer's instructions for the operating mode required. Where alternative modes are available, it is recommended that relevant adjustments are made and equipment measurement procedures are repeated for these modes.

For all types of equipment, mobile, portable and base station, cases where any of the elements, receiver, transmitter or voice modulator are absent, the test(s) that pertain to the absent elements are not applicable

Unless otherwise indicated, associated equipment normally used with the mobile under test such as control units, power and interface cabling, etc., shall be included during the measurement procedures.

Unless otherwise indicated or required, it is recommended that special function subsystems (coded squelch, impulse noise blankers, etc.) are disabled while conducting the measurement procedures. If not disabled and such may have a material impact on results, it is recommended that this fact is recorded with the results.

Unless otherwise noted, all RF power measurements assume a 50 Ω impedance (0 dBm = 1 milliWatt and 0 dBW = 1 Watt). If the equipment under test requires a special interface device to accomplish a measurement procedure, the manufacturer shall specify such device.

Except where specifically noted, the equipment shall meet specifications after being subjected to shock (see 3.3.5) and vibration (see 3.3.4) requirements.

3.1 Standards for Receivers

In the following sections, any specific standard that directly reflects a performance requirement mandated by FCC Part 15 Regulations shall be designated as a "required standard." Where there are standards that are more stringent than Part 15 for a particular sections, the latter shall be included and designated as a "recommended standard".

3.1.1 Radiated Spurious Output Power (Per 47 CFR 15.109)

3.1.1.1 Applicable method of measurement and definition are given in 2.1.1.

3.1.1.2 Required Standard

The total radiation on any discrete frequency shall not exceed the following levels at 3 meters from the receiver:

Table 19 - Radiated Spurious Output Power

Frequency (> - <)	**Radiated Power at 3 meters**	
MHz	**-dBW**	**µV/m**
30 - 88	95 - 104	100
88 - 216	101 - 109	150
216 - 960	106 - 119	200
Above 960	111	500

3.1.2 Conducted Spurious Output Power (Per 47 CFR 15.111)

3.1.2.1 Applicable methods of measurement & definition are given in 2.1.2.

3.1.2.2 Required Standard

No spurious output appearing at the antenna terminals shall exceed 316 μV across 50Ω (-87 dBW).

3.1.3 Power Line Conducted Spurious Output Voltage (Per 47 CFR 15.107)

3.1.3.1 Applicable method of measurement and definition are given in 2.1.3.

3.1.3.2 Required Standard

The equipment shall meet this standard whenever operated from a manufacturer-specified power supply connected to the power lines or if the backup battery is being charged from a manufacturer-specified battery charger connected to the power lines.

Radio frequency levels measured from the power line to ground at the power line input terminal of the specified battery charger or power supply shall not exceed the levels in the following table when measured in a resolution bandwidth ≥ 9 kHz:

Table 20 - Power Line Conducted Spurious Output Voltage

Frequency Range of Emission (MHz)	Quasi-Peak (dBμV)	Average (dBμV)
0.15 – 0.5	66 - 56*	56 – 46*
0.5 – 5	56	46
5 - 30	60	50

* Decreases with the logarithm of the frequency

3.1.4 Reference Sensitivity

3.1.4.1 Applicable method of measurement and definition are given in 2.1.4.

3.1.4.2 Recommended Standard

The maximum RF input level for reference sensitivity shall be as follows:

Table 21 - Reference Sensitivity

Receiver Class	Fixed Station	Mobile Station	Portable Station
A	-116 dBm	-116 dBm	-116 dBm
B	-113 dBm	-113 dBm	-113 dBm

3.1.5 Signal Displacement Bandwidth

3.1.5.1 Applicable method of measurement and definition are given in 2.1.5.

3.1.5.2 Recommended Standard

The minimum signal displacement bandwidth shall not be less than 40% of the rated system deviation. See 1.3.4.4.

3.1.6 Adjacent Channel Rejection

3.1.6.1 Applicable method of measurement and definition are given in 2.1.6.

3.1.6.2 Recommended Standard

The minimum adjacent channel rejection shall meet or exceed the following specified limits:

Table 22 - Adjacent Channel Rejection

Channel Bandwidth	Fixed Station	Mobile Station	Portable Station
≥ 20.0 kHz	75 dB (class A) 70 dB (class B)	75 dB (class A) 70 dB (class B)	70 dB (class A) 60 dB (class B)
15.0 kHz	65 dB (class A) 60 dB (class B)	65 dB (class A) 60 dB (class B)	65 dB (class A) 60 dB (class B)
12.5 kHz	45 dB(class A) 40 dB (class B)	45 dB (class A) 40 dB (class B)	45 dB (class A) 40 dB (class B)

3.1.7 Offset Channel Selectivity

3.1.7.1 Applicable method of measurement and definition are given in 2.1.7.

3.1.7.2 Recommended Standard

The offset channel selectivity specification shall apply to receivers in the 806 MHz to 809 MHz and 851 MHz to 854 MHz frequency bands.

The offset channel selectivity shall not be less than 20 dB.

3.1.8 Spurious Response Rejection

3.1.8.1 Applicable method of measurement and definition are given in 2.1.8.

3.1.8.2 Recommended Standard

The spurious response immunity shall meet or exceed the following specified limits:

Table 23 - Spurious Response Rejection

Receiver Class	Fixed Station	Mobile Station	Portable Station
A	75 dB	75 dB	70 dB
B	70 dB	70 dB	60 dB

3.1.9 Intermodulation Rejection

3.1.9.1 Applicable method of measurement and definition are given in 2.1.9.

3.1.9.2 Recommended Standard

The intermodulation rejection ratio shall meet or exceed the following specified limits:

Table 24 - Intermodulation Rejection

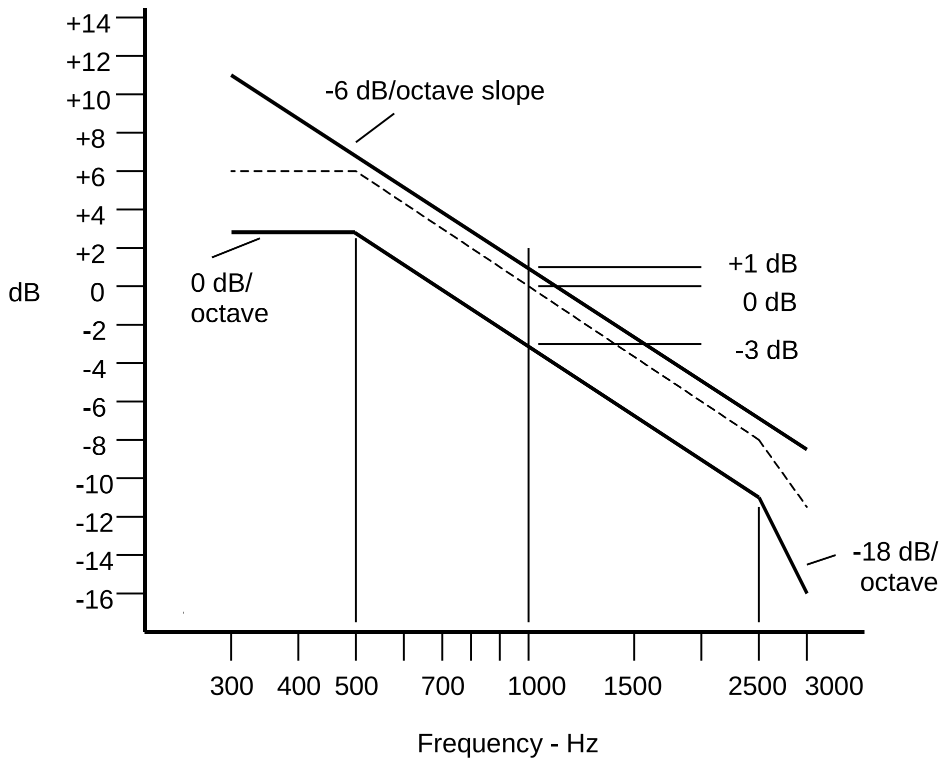
Receiver Class	Fixed Station	Mobile Station	Portable Station
A	75 dB	75 dB	70 dB
B	70 dB	70 dB	50 dB

3.1.10 Audio Frequency Response

3.1.10.1 Applicable method of measurement and definition are given in 2.1.10.

3.1.10.2 Recommended Standard

3.1.10.2.1 Audio Output (refer to the following figure)



Receiver audio frequency response shall not vary more than +1, -3 dB from a standard 6 dB per octave de-emphasis curve over the frequency range of 300 Hz to 3000 Hz, except for additional attenuation of 6 dB per octave below 500 Hz and 12 dB per octave above 2500. The reference frequency shall be 1000 Hz.

3.1.10.2.2 Special Devices

The audio frequency response of receivers designed to operate with special devices, such as selective signaling apparatus, shall be adequate to ensure operation of the specific apparatus.

3.1.11 Hum and Noise Ratio

3.1.11.1 Applicable method of measurement and definition are given in 2.1.11.

3.1.11.2 Recommended Standard

Table 25 - Hum and Noise Ratio

	Unsquelched			Squelched
	Rated System Deviation			
Frequency Range	±2.5 kHz	±4.0 kHz	±5.0 kHz	
25 MHz- 512 MHz	34 dB	38 dB	40 dB	-57 dBW
512 MHz-1000 MHz	31 dB	35 dB	37 dB	-57 dBW

3.1.12 Audio Distortion

3.1.12.1 Applicable method of measurement and definition are given in 2.1.12.

3.1.12.2 Recommended Standard

Table 26 - Audio Distortion

Audio Output Level	Audio Distortion
Rated Audio Power	±10%
17 dB below Rated	±5%

3.1.13 Audio Squelch Sensitivity

3.1.13.1 Applicable method of measurement and definition are given in 2.1.13.

3.1.13.2 Recommended Standard

3.1.13.2.1 Threshold Squelch Sensitivity

The SINAD shall be less than 8 dB after threshold squelch opening.

3.1.13.2.2 Minimum Tight Squelch Sensitivity.

The SINAD shall be greater than 15 dB after tight squelch opening.

3.1.13.2.3 Maximum Tight Squelch Sensitivity

The receiver input signal level shall be no more than 10 dB greater than the measured reference sensitivity value. For any receiver input signal greater than tight squelch sensitivity, it shall not be possible to squelch the audio output.

3.1.13.2.4 Preset Squelch Sensitivity

On units not equipped with external squelch adjustments intended for routine operator adjustment, the SINAD shall be less than 12 dB after preset squelch opening.

3.1.14 Squelch Blocking

3.1.14.1 Applicable method of measurement and definition are given in 2.1.14.

3.1.14.2 Recommended Standard

Under test conditions specified in 2.1.14, the audio output shall not be subject to step changes in amplitude and shall not drop more than 10 dB from that output obtained with the squelch open.

3.1.15 Receiver Attack Time

3.1.15.1 Applicable method of measurement and definition are given in 2.1.15.

3.1.15.2 Recommended Standard

The receiver attack time shall not exceed 150 milliseconds.

3.1.16 Receiver Closing Time

3.1.16.1 Applicable method of measurement and definition are given in 2.1.16.

3.1.16.2 Recommended Standard

The receiver squelch closing time shall not exceed 250 milliseconds.

3.1.17 Audio Sensitivity

3.1.17.1 Applicable method of measurement and definition are given in 2.1.17.

3.1.17.2 Recommended Standard

The audio sensitivity shall be less than 40% of the rated system deviation.

3.1.18 Impulse Blanking Effectiveness

3.1.18.1 Applicable method of measurement and definition are given in 2.1.18.

3.1.18.2 Recommended Standard

Mobiles shall only be required to meet this specification when impulse noise blankers are installed.

The impulse blanking effectiveness shall meet or exceed 40 dB.

3.1.19 Average Radiation Sensitivity

3.1.19.1 Applicable to portable equipment only. Method of measurement and definition are given in 2.1.19.

3.1.19.2 Recommended Standard

Table 27 - Average Radiation Sensitivity

	Equipment with an external antenna		Equipment with an integral antenna	
Frequency range	dBm	μV	dBm	μV
25 MHz – 512 MHz	-95	4	-77	30
512 MHz – 1000 MHz	-89	8	-71	60

3.1.20 Acoustic Audio Output

3.1.20.1 Applicable method of measurement and definition are given in 2.1.20.

3.1.20.2 Recommended Standard

The acoustic output shall be stated by the manufacturer in SPL.

3.1.21 Blocking Rejection

3.1.21.1 Applicable method of measurement and definition are given in 2.1.21.

3.1.21.2 Recommended Standard

The blocking rejection ratio shall be at least that specified as follows:

Table 28 - Blocking Rejection

Receiver Class	**Fixed Station**	**Mobile Station**	**Portable Station**
A	90 dB	90 dB	80 dB
B	80 dB	80 dB	70 dB

3.1.22 Receiver Opening Time after PTT

3.1.22.1 Applicable method of measurement and definition are given in 2.1.22.

3.1.22.2 Recommended Standard

The receiver opening time after PTT shall be manufacturer specified.

3.2 Standards for Transmitters

In the following subclauses, any specific standard that directly reflects a performance requirement mandated by FCC Part 90 regulations shall be designated as a required standard. Where there are standards more stringent than Part 90 for a particular subclause, the latter shall be designated a "recommended standard".

3.2.1 Conducted Carrier Output Power Rating (FCC 90)

3.2.1.1 Applicable method of measurement and definition are given in 2.2.1.

3.2.1.2 Required Standard

The manufacturer shall specify the conducted carrier output power rating. It shall not be higher than that obtained under the conditions given in 2.2.1, nor that for which the equipment has been type-accepted by the FCC.

No recommendations as to standardized output power levels are made with the exceptions noted in the following clause.

3.2.1.3 Recommended Standard (47 CFR 90.541)

Equipment designed to operate in the frequencies specified in 47 CFR 90.541 (769-775/799-805 MHz) must not exceed the limits in the following table.

Table 29 - Conducted Carrier Output Power Rating

Station Type	Maximum output power
Mobile, and Control	30 Watts
Portable (handheld)	3 Watts

3.2.2 Carrier Frequency Stability (Per 47 CFR 90.213 and 90.539)

3.2.2.1 Applicable method of measurement and definition are given in 2.2.2.

3.2.2.2 Required Standard

The maximum permissible departure from the assigned frequency shall be as follows:

Table 30 - Carrier Frequency Stability

Assigned Frequency (MHz)	**Channel Bandwidth (kHz)**	**Mobile and Portable Stability (PPM)**	**Base Station Stability (PPM)**
25 to 50	20	20	20
138 to 174	25 & 30	5.0	5.0
	12.5 & 15	5.0	2.5
	12.5 (NTIA only)	2.5	1.5
380 to 420 (NTIA only)	25	5.0	5.0
	12.5	2.0	0.5
421 to 512	25	5.0	5.0
	12.5	2.5	1.5
769 to 775	25	1.5[3]	0.1
	12.5	1.5[3]	0.1
799 to 805	25	1.5 [3]	Not Authorized
	12.5	1.5 [3]	Not Authorized
806 to 809	12.5	1.5	Not Authorized
809 to 824	25	2.5	Not Authorized
851 to 854	12.5	1.5	1.0
854 to 869	25	2.5	1.5
896 to 901	12.5	1.5	0.1
935 to 940	12.5	1.5	0.1

Notes:

1. Paging transmitters operating on paging-only frequencies shall operate with frequency stability of 5 ppm in the 150-174 MHz band and 2.5 ppm in the 421-512 MHz band.
2. Control stations may operate with the frequency tolerance specified for associated mobile frequencies.
3. Secondary use in public safety band, mobile to mobile operation.

3.2.3 Modulation Limiting

3.2.3.1 Applicable method of measurement and definition are given in 2.2.3.

3.2.3.2 Recommended Standard (maximum)

The instantaneous peak and steady state deviations shall not exceed rated system deviation (see 1.3.4.4) at any audio frequency or change in level, as specified in the method of measurement.

3.2.3.3 Recommended Standard (minimum)

The minimum value of modulation limiting as measured in 3.2.3.2 shall be at least 60% of the rated system deviation.

3.2.4 Carrier Attack Time

3.2.4.1 Applicable method of measurement and definition are given in 2.2.4.

3.2.4.2 Recommended Standard

The carrier level shall increase to 50% or more of its maximum value in less than 100 milliseconds.

3.2.5 Audio Sensitivity

3.2.5.1 Applicable method of measurement and definitions are given in 2.2.5.

3.2.5.2 Recommended Standard

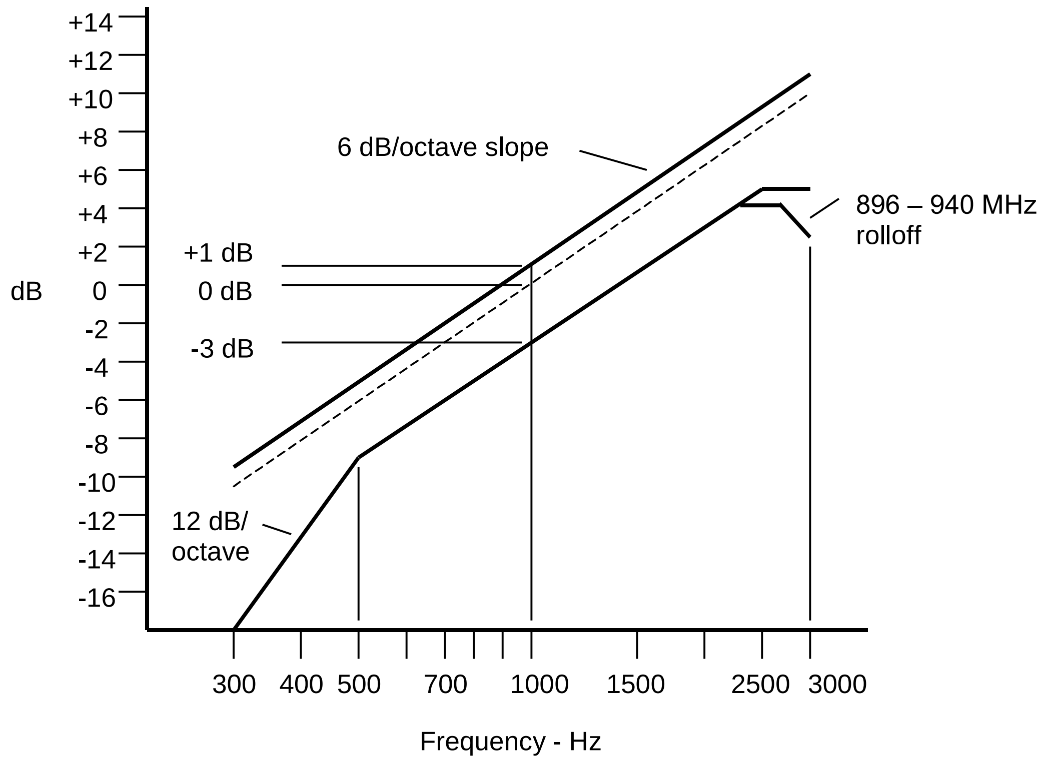
The manufacturer shall specify the audio frequency sensitivity of any external connection intended for modulating signals, including the microphone audio input connector.

3.2.6 Audio Frequency Response

3.2.6.1 Applicable method of measurement and definition are given in 2.2.6.

3.2.6.2 Recommended Standard

300 Hz to 3000 Hz (refer to the following figure)



The audio frequency response from 300 Hz to 3000 Hz shall not vary more than +1 dB or -3 dB from a true 6 dB per octave pre-emphasis characteristic as referenced to the 1000 Hz level. The exception is from 500 Hz to 300 Hz, where an additional 6 dB per octave rolloff is allowed.

The following exceptions are also permissible:

a) An additional 6 dB per octave attenuation is allowed from 2500 Hz to 3000 Hz in equipment operating in the 25 MHz to 869 MHz range.

b) An additional 6 dB per octave rolloff is allowed from 2300 Hz to 2700 Hz, and an additional 12 dB per octave is allowed from 2700 Hz to 3000 Hz, in equipment operating in the 896 MHz to 940 MHz range, and all narrowband (12.5 kHz and 15 kHz channelization) equipment.

3.2.7 Audio Distortion

3.2.7.1 Applicable method of measurement and definition are given in 2.2.7.

3.2.7.2 Recommended Standard

The audio distortion shall not exceed 10%.

3.2.8 FM Hum and Noise Ratio

3.2.8.1 Applicable method of measurement and definition are given in 2.2.8.

3.2.8.2 Recommended Standard

The FM hum and noise ratio shall be greater than the following specified limits:

Table 31 - FM Hum and Noise Ratio

	Rated System Deviation		
Frequency Range	±2.5 kHz	±4.0 kHz	±5.0 kHz
25 MHz - 512 MHz	34 dB	38 dB	40 dB
512 MHz - 1000 MHz	31 dB	35 dB	37 dB

3.2.9 AM Hum and Noise Ratio

3.2.9.1 Applicable method of measurement and definition are given in 2.2.9.

3.2.9.2 Recommended Standard

The AM hum and noise ratio shall be greater than 34 dB.

3.2.10 Acoustic Microphone Sensitivity

3.2.10.1 Applicable method of measurement and definition are given in 2.2.10.

3.2.10.2 Recommended Standard

The manufacturer shall specify the acoustic microphone sensitivity.

3.2.11 Sideband Spectrum (Per 47CFR 90.210 and 90.691)

Up to test bandwidth. (see 1.3.4.4)

3.2.11.1 Applicable method of measurement and definition are given in 2.2.11.
The power of any emission component shall be attenuated below the unmodulated carrier output power in accordance with the following tables. Conventions are as follows:

a) Carrier Frequency is transmitter output frequency.

b) Displacement Frequency (f_d) is the magnitude of the difference between the carrier frequency and the emission component frequency in kHz.

c) *COP* is the Carrier Output Power in Watts.

d) *RBW* is the resolution bandwidth setting of the measurement spectrum analyzer

3.2.11.2 Required Standard for Transmitters Equipped with Audio Low Pass Filters

Transmitters equipped with audio low pass filters (see 3.2.15) shall meet the appropriate in-band, out-of-band and spurious emission attenuation mask characteristics within the test bandwidth using only the resolution bandwidth (*RBW*) specified in Table 32. See table 1 for authorized bandwidth values.

Table 32 - Emission Masks for Transmitters Equipped with Audio Low Pass Filters

Channel Bandwidth	**Attenuation Mask**	**Frequency Range (MHz)**	***RBW*(Hz)**
20,25 & 30 kHz	B (see Table 33)	25-50 72-76 138-174 150 band (Paging only) 421-512 *806-809 & *851-854 809-824 & 854-869	300
12.5 & 15 kHz	D (see Table 34)	150-174 421-512	100
6.25 & 7.5 kHz	E (see Table 35)	150-174 421-512	100
25 kHz and greater	EA (see Table 36)	821-824 866-869	300
12.5 kHz	I (see Table 37)	896-901 & 935-940	300
12.5 kHz	NTIA (see Table 38)	138-174 380-420	300

***** In this range 25 kHz equipment is used on 12.5 kHz spaced channels

Table 33 - Emission Mask B

Displacement Frequency (% of Authorized Bandwidth)	**Minimum Attenuation (dB)**
50 to 100	25 dB
100 to 250	35 dB
>250	$43 + 10 \log_{10}(COP)$

Table 34 - Emission Mask D

Channel Bandwidth (kHz)	**Displacement Frequency Range**	**Minimum Attenuation (dB)**
12.5 & 15	>5.625 kHz to 12.5 kHz	$7.27(f_d - 2.88)$
	>12.5 kHz	Whichever is less attenuation; 70 or $50 + 10 \log_{10}(COP)$

Table 35 - Emission Mask E

Channel Bandwidth (kHz)	**Displacement Frequency Range**	**Minimum Attenuation (dB)**
6.25 & 7.5	>3.0 kHz to 4.6 kHz	Whichever is less attenuation; 65 or $30 + 16.67(f_d - 3)$ or $55 + 10 \log_{10}(COP)$
	Greater than 4.6 kHz	Whichever is less attenuation; 65 or $55 + 10 \log_{10}(COP)$

Table 36 - Emission Mask EA

Channel Bandwidth (kHz)	Displacement Frequency Range	Minimum Attenuation (dB)
25	End of licensee's frequency block to 37.5 kHz	Whichever is less attenuation; 80 or 116 $\log_{10}(f_d/6.1)$ or 50 + 10 $\log_{10}$ (*COP*)
	>37.5 kHz	Whichever is less attenuation; 80 or 43 + 10 $\log_{10}$ (*COP*)

Table 37 - Emission Mask I

Displacement Frequency (f_d)	Attenuation (dBc)
6.8 kHz < f_d ≤ 9.0 kHz	25 dB
9.0 kHz < f_d ≤ 15 kHz	35 dB
15 kHz < f_d	43 +10 $\log_{10}$(*COP*) or 70, whichever is less attenuation

Table 38 - Emission Mask NTIA

Channel Bandwidth (kHz)	Displacement Frequency Range (kHz)	Minimum Attenuation (dB)
12.5	>2.5 to 12.5	$7(f_d - 2.5)$
	>12.5	Whichever is less attenuation; 70 or 50 + 10 $\log_{10}$ (*COP*)

3.2.11.3 Required Standard for transmitters NOT equipped with audio low pass filters.

Transmitters not equipped with audio low pass filters shall meet the appropriate in-band, out-of-band and spurious emission attenuation mask characteristics within the test bandwidth using only the resolution bandwidth (*RBW*) specified in Table 39. See Table 1 for authorized bandwidth values.

Table 39 - Emission Masks for Transmitters not Equipped with Audio Low Pass Filters

Channel Bandwidth	**Attenuation Mask**	**Frequency Range (MHz)**	***RBW*(Hz)**
20,25 & 30 kHz	C (see Table 40)	25-50 72-76 138-174 150 band (paging only) 421-512	300
12.5 & 15 kHz	D (see Table 34)	150-174 421-512	100
6.25 & 7.5 kHz	E (see Table 35)	150-174 421-512	100
12.5 kHz	NTIA (see Table 38)	138-174 406-420	300
25 kHz and greater	EA (see Table 36)	821-824/866-869	300
25 kHz	G (see Table 41)	450 band (paging only) 809-824/854-869 929-930	300
12.5 kHz	H (see Table 42)	*806-809/851-854	300
12.5 kHz	J (see Table 43)	896-901/935-940	300

***** In this range 25 kHz equipment is used on 12.5 kHz spaced channels

Table 40 - Emission Mask C

Displacement Frequency (f_d)	**Attenuation (dB)**
5 kHz < $f_d \le$ 10 kHz	$83 \log_{10}(f_d/5)$
10 kHz < $f_d \le$ 250 % of authorized bandwidth*	$29 \log_{10}(f_d^2/11)$ or 50, whichever is less attenuation
250 % of authorized bandwidth < f_d	$43 + 10 \log_{10}(COP)$

* Authorized bandwidth = 20 kHz

Table 41 - Emission Mask G

Displacement Frequency (f_d)	**Attenuation (dB)**
10 kHz < f_d ≤ 250 % of authorized bandwidth*	116 $\log_{10}(f_d/6.1)$ or 50 + 10 $\log_{10}(COP)$ or 70, whichever is less attenuation
250 % of authorized bandwidth < f_d	43 + 10 $\log_{10}(COP)$

* Authorized bandwidth = 20 kHz

Table 42 - Emission Mask H

Displacement Frequency (f_d)	**Attenuation (dB)**
4.0 kHz < f_d ≤ 8.5 kHz	107 $\log_{10}(f_d/4)$
8.5 kHz < f_d ≤ 15.0 kHz	40.5 $\log_{10}(f_d/1.16)$
15.0 kHz < f_d ≤ 25.0 kHz	116 $\log_{10}(f_d/6.1)$
25.0 kHz < f_d	43 + 10 $\log_{10}(COP)$

Table 43 - Emission Mask J

Displacement Frequency (f_d)	**Attenuation (dB)**
2.5 kHz < f_d ≤ 6.25 kHz	53 $\log_{10}(f_d/2.5)$
6.25 kHz < f_d ≤ 9.50 kHz	103 $\log_{10}(f_d/3.9)$
9.50 kHz < f_d	157 $\log_{10}(f_d/5.3)$ or 50 + 10 $\log_{10}(COP)$ or 70, whichever is less attenuation

3.2.12 Undesired Emissions: Radiated Spurious

3.2.12.1 Applicable method of measurement and definition are given in 2.2.12.

3.2.12.2 Required Standard (Non-radiating load (47 CFR 90.210))

47 CFR 90.210 Emission masks (b), (c), (g), (h) and (i) and 90.691

Radiated spurious emissions in dB = 43 + 10 $\log_{10}$ *(power out in Watts)*
or an equivalent absolute level of -13 dBm (50 μW).

47 CFR 90.210 Emission masks (d)and (j)

Radiated spurious emissions in dB = 50 + 10 $\log_{10}$ *(power out in Watts)*
or an equivalent absolute level of -20 dBm (10 μW).

47 CFR 90.210 Emission masks (e)

Radiated spurious emissions in dB = 55 + 10 $\log_{10}$ *(power out in Watts)*
or an equivalent absolute level of -25 dBm (3 μW).

700 MHz Band (47 CFR 90.543(c))

On any frequency outside of the tables in 3.2.14, spurious emissions shall be attenuated at least 43 + 10 $\log_{10}$(P) dB below the average carrier power.

3.2.12.3 EIRP Emissions in GNSS Band (47 CFR 90.543(e))

Unwanted radiated emissions in the band 1559-1610 MHz shall be limited to -70 dBW/MHz equivalent isotropically radiated power (EIRP) for wideband signals, and -80 dBW EIRP for discrete emissions of less than 700 Hz bandwidth.

3.2.12.4 Calculated EIRP Emissions in GNSS Band (47 CFR 90.543(e))

Same as 3.2.12.3

3.2.13 Undesired Emissions: Conducted Spurious (Per 47 CFR 90.210 and 90.691)

3.2.13.1 Applicable method of measurement and definition are given in 2.2.13.

3.2.13.2 Required Standard

Conducted spurious emissions shall be attenuated below the maximum level of emission of the carrier frequency, in accordance with the following formula:

47 CFR 90.210 Emission masks (b), (c), (g), (h) and (i) and 90.691

Spurious attenuation in dB = 43 + 10 $\log_{10}$ *(power out in Watts)* or an equivalent absolute level of -13 dBm (50 μW).

47 CFR 90.210 Emission masks (d) and (j)

Radiated spurious emissions in dB = 50 + 10 $\log_{10}$ *(power out in Watts)*
or an equivalent absolute level of -20 dBm (10 μW).

47 CFR 90.210 Emission masks (e)

Radiated spurious emissions in dB = 55 + 10 $\log_{10}$ *(power out in Watts)*
or an equivalent absolute level of -25 dBm (3 μW).

3.2.14 Undesired Emissions: Adjacent Channel Power Ratio

3.2.14.1 Applicable method of measurement and definition are given in 2.2.14.

3.2.14.2 Recommended Standard

3.2.14.3 All frequency bands below 1 GHz excluding frequencies in FCC Part 90.543 (769-775/799-805 MHz).

Adjacent channel power ratio for fixed, mobile and portable stations is shown within the following specified channel bandwidths:

Table 44 - Adjacent Channel Power Ratio

Channel Bandwidth	Measurement Bandwidth	Fixed Station (dB)	Mobile Station (dB)	Portable Station (dB)
≥ 25.0 kHz	16 kHz	70 if < 512 MHz 60 if > 512 MHz	70 if < 512 MHz 60 if > 512 MHz	70 if < 512 MHz 60 if > 512 MHz
20.0 kHz	14 kHz	70 if < 512 MHz 60 if > 512 MHz	70 if < 512 MHz 60 if > 512 MHz	70 if < 512 MHz 60 if > 512 MHz
15.0 kHz	8.5 kHz	70 dB	70	70
12.5 kHz	8.5 kHz	60 if < 512 MHz 50 if > 512 MHz	60 if < 512 MHz 50 if > 512 MHz	60 if < 512 MHz 50 if > 512 MHz

Note: The resolution bandwidth must be no greater than 2% of the measurement bandwidth.

3.2.14.4 700 MHz Band (90.543 (a) mobile devices)

Table 45 - 12.5 kHz Mobile Transmitter ACPR Requirements

Offset from Center Frequency (kHz)	Nominal Resolution Bandwidth (Hz)	Measurement Bandwidth (kHz)	Maximum ACPR (dB)
9.375	100	6.25	40
15.625	100	6.25	60
21.875	100	6.25	60
37.50	300	25.00	60
62.50	300	25.00	65
87.50	300	25.00	65
150.00	1000	100.00	65
250.00	1000	100.00	65
350.00	1000	100.00	65
>400 to paired RX Band	30000	30 (swept)	75
In paired RX Band	30000	30 (swept)	100

Table 46 - 25 kHz Mobile Transmitter ACPR Requirements

Offset from Center Frequency (kHz)	Nominal Resolution Bandwidth (Hz)	Measurement Bandwidth (kHz)	Maximum ACPR (dB)
15.625	100	6.25	40
21.875	100	6.25	60
37.50	300	25.00	60
62.50	300	25.00	65
87.50	300	25.00	65
150.00	1000	100.00	65
250.00	1000	100.00	65
350.00	1000	100.00	65
>400 to paired RX Band	30000	30 (swept)	75
In paired RX Band	30000	30 (swept)	100

Table 47 - 12.5 kHz Base Transmitter ACPR Requirements

Offset from Center Frequency (kHz)	Nominal Resolution Bandwidth (Hz)	Measurement Bandwidth (kHz)	Maximum ACPR (dB)
9.375	100	6.25	40
15.625	100	6.25	60
21.875	100	6.25	60
37.50	300	25.00	60
62.50	300	25.00	65
87.50	300	25.00	65
150.00	1000	100.00	65
250.00	1000	100.00	65
350.00	1000	100.00	65
>400 to paired RX Band	30000	30 (swept)	80
In paired RX Band	30000	30 (swept)	100

Table 48 - 25 kHz Base Transmitter ACPR Requirements

Offset from Center Frequency (kHz)	Nominal Resolution Bandwidth (Hz)	Measurement Bandwidth (kHz)	Maximum ACPR (dB)
15.625	100	6.25	40
21.875	100	6.25	60
37.50	300	25.00	60
62.50	300	25.00	65
87.50	300	25.00	65
150.00	1000	100.00	65
250.00	1000	100.00	65
350.00	1000	100.00	65
>400 to paired RX Band	30000	30 (swept)	80
In paired RX Band	30000	30 (swept)	100

Notes:

[1] The nominal resolution bandwidth is recommended based on common spectrum analyzer capabilities. In some instances it may be desirable to utilize pre-configured adjacent channel power algorithms that may use resolution bandwidths other than the common 1, 3, 10. In such circumstances the RBW should be no larger than 2% of the specified measurement BW.

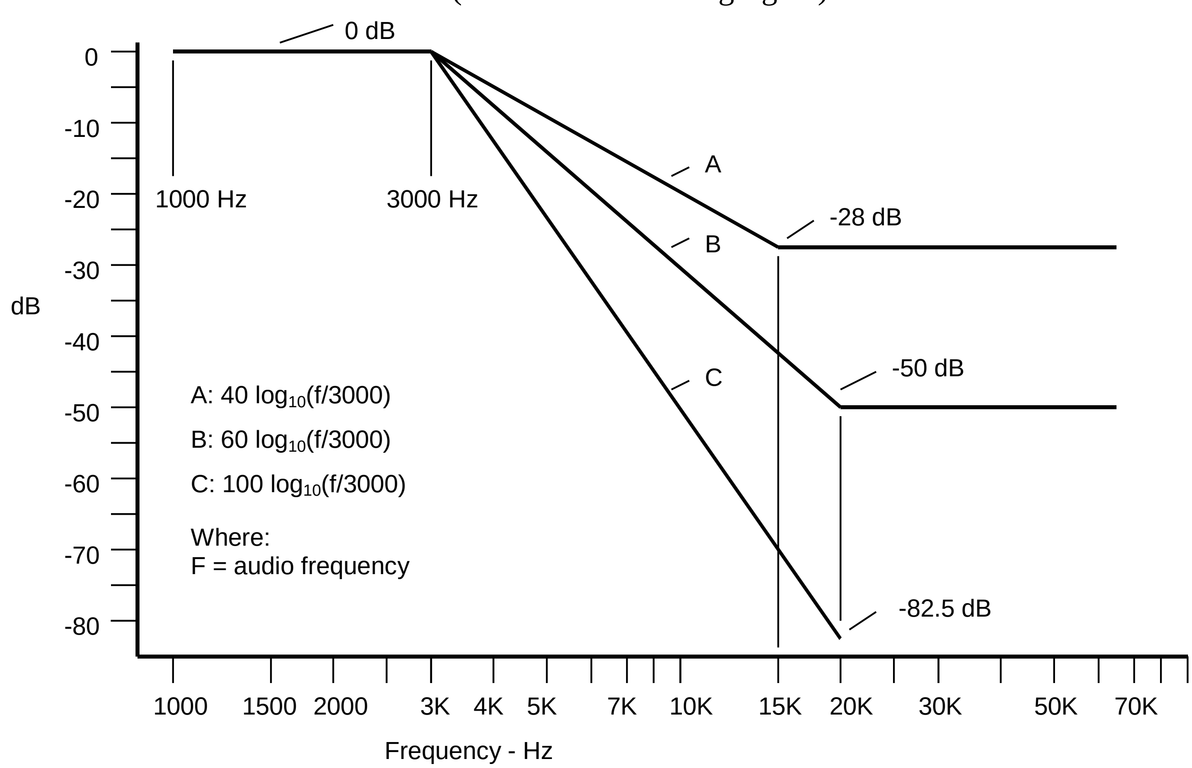
[2] The section is not applicable when unit is transmitting on base transmission frequencies

(s) Measurement is to be conducted using a swept mode.

3.2.15 Audio Low Pass Filter Response

3.2.15.1 Applicable method of measurement and definition are given in 2.2.15.

3.2.15.2 Recommended Standard (refer to the following figure)



For audio frequencies above 3000 Hz, the audio response of the post limiter low-pass filter shall meet or exceed the following requirements:

a) For equipment operating on 20, 25 or 30 kHz channel bandwidth in the 25 MHz to 174 MHz range:

   At frequencies from 3000 Hz through 15,000 Hz the attenuation shall be greater than the attenuation at 1000 Hz by at least: $40 \log_{10} (f / 3000)$ dB

   where: f is the audio frequency in Hz.

   At frequencies above 15,000 Hz, the attenuation shall be greater than the attenuation at 1000 Hz, by at least: 28 dB.

b) For equipment operating with 25 kHz bandwidth channels between 406 and 512 MHz through 896 MHz, and between 929 MHz through 930 MHz:

   At frequencies from 3000 Hz through 20,000 Hz, the attenuation shall be greater than the attenuation at 1000 Hz by at least: $60 \log_{10} (f / 3000)$ dB

   where: f is the audio frequency in Hz.

   At frequencies above 20,000 Hz the attenuation shall be greater than the attenuation at 1000 Hz by at least: 50 dB.

c) For equipment operating on channels between 896 MHz through 901 MHz, between 935 MHz through 940 MHz, and 12.5 or 15 kHz spaced channels in the frequency range 138-174 MHz and 406-512 MHz.

   At frequencies from 3000 Hz through 20,000 Hz the attenuation shall be greater than the attenuation at 1000 Hz by at least: $100 \log_{10} (f / 3000)$ dB

   where: f is the audio frequency in Hz.

3.2.16 Intermodulation Attenuation

3.2.16.1 Applicable only to base station equipment; method of measurement and definition are given in 2.2.16.

3.2.16.2 Recommended Standard

The intermodulation attenuation shall meet or exceed 40 dB.

3.2.17 Average Radiated Power Output

3.2.17.1 Applicable only to portable equipment, except where noted; method of measurement and definition are given in 2.2.17.

3.2.17.2 Standard: Average Radiated Output Power

The manufacturer's rating of average radiated power output at Standard Test Voltage (Power Supply Voltage Range 5.3.1) shall not be higher than the average radiated power measured. The manufacturer shall specify the equipment position.

No recommendations as to standardized power output levels are made.

3.2.17.3 Standard: Effective Radiated Output Power (ERP) (FCC 27.50 and FCC 90.545)

Equipment designed to operate in FCC Part 90.543 (769-775/799-805 MHz) bands must not exceed the following limits

Table 49 - Average Radiated Power Output

Station Type	Maximum ERP
Portable	3 Watts
Low Power Portable	2 Watts

Note: Narrowband low power channels are listed in 90.531 (b) (3) and (b) (4).

3.2.18 Transmitter Stability into VSWR

3.2.18.1 Applicable method of measurement and definition are given in 2.2.18.

3.2.18.2 Recommended Standard

Conducted spurious emissions, when measured into a VSWR of 3:1, shall be attenuated below the maximum level of emission of the carrier frequency in accordance with the following formula:

$$\textit{Spurious attenuation in dB} = 43 + 10 \log_{10} \textit{(power out in Watts)}$$

or an equivalent absolute level of -13 dBm (50 µW).

3.2.18.3 Environmental parameter induced variation in carrier operation into VSWR. See 3.3.1 - 3.3.5

Table 50 - Transmitter Stability into VSWR Environmental parameters

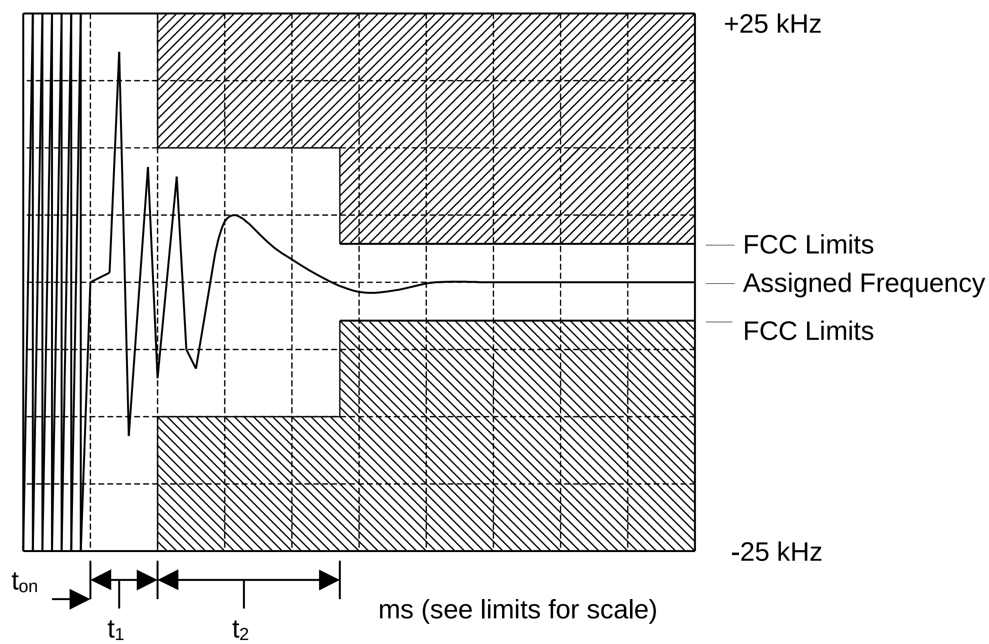
Environmental Parameter	Specification Limit	Conditions
Voltage	no DFS	±10%
Temperature	no DFS	-30 ºC to +60 ºC

3.2.19 Transient Frequency Behavior of Transmitter (Per 47 CFR 90.214).

3.2.19.1 Applicable method of measurement and definition are given in 2.2.19.

3.2.19.2 Required Standard

Switch on condition t_{on}, t_1, and t_2



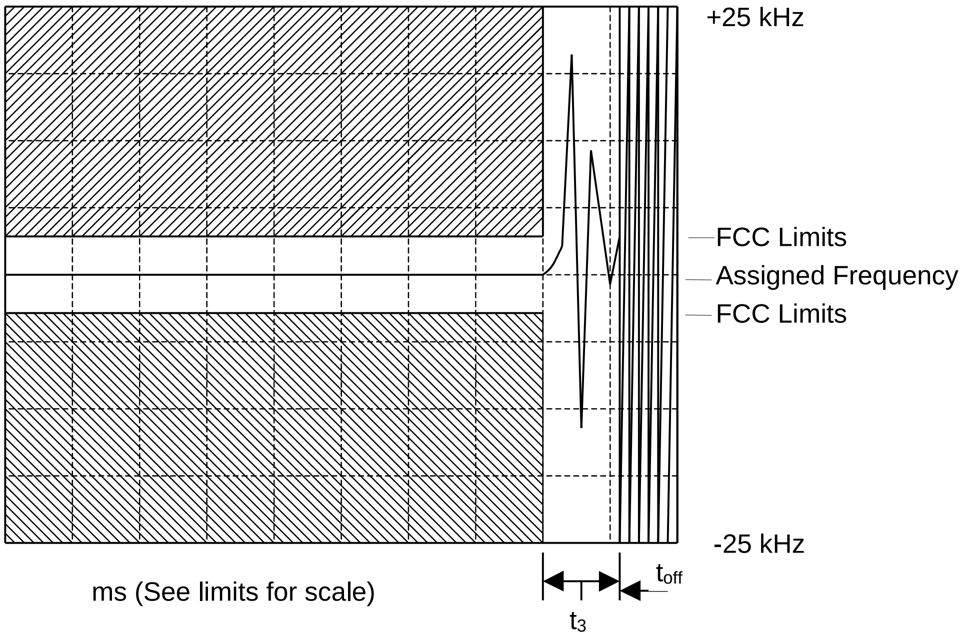


Table 51 - Transient Frequency Difference Limits

Time Interval	**Max. Permitted Frequency Difference for 25 and 30 kHz Channel Bandwidth (in kHz)**	**Max. Permitted Frequency Difference for 12.5 and 15 kHz Channel Bandwidth (in kHz)**
t_1 or t_3	25	12.5
t_2	12.5	6.25

Table 52 - Transient Duration Limits

Time Intervals	**Frequency Ranges (MHz)**		
	30 to 174	406 to 512	806 to 940
t_1	5.0 ms	10.0 ms	20.0 ms
t_2	20.0 ms	25.0 ms	50.0 ms
t_3	5.0 ms	10.0 ms	10.0 ms

During the period t_1 and t_3, the frequency difference shall not exceed ±25 kHz.

During the period $t_{2,}$ the frequency difference shall not exceed ±12.5 kHz.

If the transmitter carrier output power rating is 6 Watts or less, the frequency deviation during t_1 and t_3 may be greater than ±25 kHz. The corresponding plot of frequency versus time during t_1 and t_3 shall be recorded in the test data.

FCC limits are per 47 CFR 90.213.

3.3 Standards for Unit Characteristics

The information in the following tables is a summary of the environmental requirements for all equipment.

This section defines allowed degradation from standards (DFS) in 3.1 and 3.2, in accordance with 1.3.6 for performance under specific environmental parameter conditions. No DFS, where used, means no degradation from the standard is allowed.

Unless otherwise specified, all tests shall be done at the standard atmospheric conditions specified in 1.4.5.

All equipment shall meet all standards specified in 3.3.1 through 3.3.9.

3.3.1 Power Supply Voltage Range

3.3.1.1 Applicable method of measurement and definition are given in 2.3.1.

3.3.1.2 Standard

All tests required at Standard Atmospheric Conditions (1.4.5) shall be performed at the standard test voltage (Standard Conditions for the Power Supply (1.4.4) except the Portable Battery Life Test (2.3.7).

For tests performed at the standard test voltage, the batteries may be disconnected but not removed and an external source connected through leads that are shielded and filtered to prevent altering the radiation or reception pattern of the portable system.

For tests required with voltage variations, the following limits shall be imposed:

a) Receivers:
At the highest and lowest receiver voltages encountered during the Portable Battery Life Test (3.3.7) or;

At least ±10% voltage range from the standard test voltage, or as specified in the table as required by the specific test.

b) Transmitters:
At the highest and lowest transmitter voltages encountered during the Portable Battery Life (3.3.7) or;

At least ±10% voltage range from the standard test voltage, or as specified in the table as required by the specific test.

c) The following tests should be performed and limits observed at both the lower and upper voltage limits.

Table 53 - Power Supply Voltage Range

Characteristic	Performance Limit
Reference Sensitivity 3.1.4	3 dB DFS @ ±10% voltage (mobile and base) 3 dB DFS @ ±20% voltage (portable)
Signal Displacement BW 3.1.5	No DFS
Adjacent Channel Rejection 3.1.6	6 dB DFS
Offset Channel Selectivity 3.1.7	No DFS
Spurious Response Rejection 3.1.8	No DFS
Intermodulation Rejection 3.1.9	3 dB DFS
Hum and Noise Ratio 3.1.11	3 dB DFS
Receiver Audio Distortion 3.1.12	10% (@ -17 dB) @ ±10% voltage (mobile) 10% (@ -17 dB) @ ±20% voltage (portable) No DFS (@ -17 dB) @ ±10% voltage (base)
Audio Squelch Sensitivity 3.1.13	No DFS and receiver shall be squelchable over voltage range
Threshold Squelch	12 dB SINAD@ ±10% voltage (mobile, base)
Threshold Squelch	12 dB SINAD@ ±20% voltage (portable)
Minimum Tight Squelch	12 dB SINAD
Maximum Tight Squelch	No DFS
Preset Squelch	16 dB SINAD@ ±10% voltage (mobile, base)
Preset Squelch	16 dB SINAD@ ±20% voltage (portable)
Squelch Blocking 3.1.14	No DFS
Audio Sensitivity 3.1.17	40% (@ 1/2 rated power)
Carrier Output Power Rating 3.2.1	3 dB DFS @ ±10% voltage 6 dB DFS @ ±20% voltage
Carrier Frequency Stability 3.2.2	no DFS @ ±15% voltage range
Modulation Limiting 3.2.3	Shall be between 50% and 100% of the rated system deviation
Transmitter Audio Distortion 3.2.7	10%
FM Hum and Noise Ratio 3.2.8	No DFS
Stability into VSWR 3.2.18	No DFS

3.3.2 Temperature Range

3.3.2.1 Applicable method of measurement and definition are given in 2.3.2.

3.3.2.2 Standard

a) The lower temperature limit for all equipment is -30 ºC.

b) The upper temperature limit for all equipment is +60 ºC.

c) The following tests shall be performed and limits observed at both the lower and upper temperature limits.

Table 54 - Temperature Range

Characteristic	Performance Limit
Reference Sensitivity 3.1.4	6 dB DFS
Signal Displacement BW 3.1.5	20% of rated system deviation
Adjacent Channel Rejection 3.1.6	12 dB DFS
Offset Channel Selectivity 3.1.7	10 dB DFS
Spurious Response Rejection 3.1.8	10 dB DFS
Intermodulation Rejection 3.1.9	6 dB DFS
Hum and Noise Ratio 3.1.11	10 dB DFS
Receiver Audio Distortion 3.1.12	10% (@ -17 dB)
Audio Squelch Sensitivity 3.1.13	No DFS and receiver shall be squelchable over voltage range
Threshold Squelch	12 dB SINAD
Minimum Tight Squelch	12 dB SINAD
Maximum Tight Squelch	No DFS
Preset Squelch	16 dB SINAD
Squelch Blocking 3.1.14	No DFS
Audio Sensitivity 3.1.17	60% (@ 1/2 rated power)
Carrier Output Power Rating 3.2.1	3 dB DFS
Carrier Frequency Stability 3.2.2	No DFS
Modulation Limiting 3.2.3	Shall be between 40% and 100% of the rated system deviation
Transmitter Audio Distortion 3.2.7	10%
FM Hum and Noise Ratio 3.2.8	6 dB DFS
Stability into VSWR 3.2.18	No DFS

3.3.3 High Humidity

3.3.3.1 Applicable method of measurement and definition are given in 2.3.3.

3.3.3.2 Standard

a) The relative humidity shall be between 90% and 95% at a temperature of +50 ºC.

b) The following tests shall be performed and limits observed while the equipment is subjected to the specified relative humidity.

Table 55 - High Humidity

Characteristic	Performance
Reference sensitivity 3.1.4	10 dB DFS
Signal Displacement BW 3.1.5	20% of rated system deviation
Adjacent Channel Rejection 3.1.6	12 dB DFS
Offset Channel Selectivity 3.1.7	10 dB DFS (mobile) 6 dB DFS (base)
Spurious Response Rejection 3.1.8	10 dB DFS
Intermodulation Rejection 3.1.9	6 dB DFS
Hum and Noise Ratio 3.1.11	10 DFS
Receiver Audio Distortion 3.1.12	10% (@ -17 dB)
Audio Squelch Sensitivity 3.1.13	No DFS and receiver shall be squelchable over voltage range
Threshold Squelch	12 dB SINAD
Minimum Tight Squelch	12 dB SINAD
Maximum Tight Squelch	No DFS
Preset Squelch	16 dB SINAD
Squelch Blocking 3.1.14	No DFS
Audio Sensitivity 3.1.17	60% (@ 1/2 rated power)
Carrier Output Power Rating 3.2.1	3 dB DFS
Carrier Frequency Stability 3.2.2	No DFS
Modulation Limiting 3.2.3	shall be between 40% and 100% of the rated system deviation
Transmitter Audio Distortion 3.2.7	10%
FM Hum and Noise Level 3.2.8	6 dB DFS

3.3.4 Vibration Stability

3.3.4.1 Applicable method of measurement and definition are given in 2.3.4.

3.3.4.2 Standard for mobile and portable equipment

No fixed part shall become loose nor shall any moveable part shift in position or adjustment under either of the two conditions of vibration.

The vibration test shall consist of two parts:

a) The unit shall complete three five-minute cycles of simple harmonic motion having an amplitude of 0.38 mm (total excursion of 0.76 mm) applied initially at a frequency of 10 Hz, and increased at a uniform rate to 30 Hz in 2 1/2 minutes, then decreased at a uniform rate to 10 Hz in 2 1/2 minutes.

b) The unit shall next complete three five-minute cycles of simple harmonic motion having an amplitude of 0.19 mm (total excursion 0.38 mm) applied initially at a frequency of 10 Hz and increased at a uniform rate to 60 Hz in 2 1/2 minutes, then decreased at a uniform rate to 30 Hz in 2 1/2 minutes.

The above two-part test shall be applied for a total of 30 minutes in each of three directions. Directions shall be parallel to both axes of the base and perpendicular to the plane of the base.

In addition, the equipment shall meet the specifications listed in the following table during vibration:

Table 56 - Vibration Stability

Characteristic	**Performance Limit**
Reference Sensitivity 3.1.4	No DFS
Carrier Output Power Rating 3.2.1	No DFS
Carrier Frequency Stability 3.2.2	No DFS
Modulation Limiting 3.2.3	Shall be between 50% to 100% of rated system deviation
Hum and Noise Level 3.2.8	15 dB DFS

3.3.4.3 Standard for base station equipment

No fixed part shall become loose nor shall any moveable part shift in position or adjustment under either of the two conditions of vibration.

The vibration test shall consist of two parts:

a) The unit shall complete three five-minute cycles of simple harmonic motion having an amplitude of 0.07 mm (total excursion of 0.14 mm) applied initially at a frequency of 10 Hz, and increased at a uniform rate to 30 Hz in 2 1/2 minutes, then decreased at a uniform rate to 10 Hz in 2 1/2 minutes.

b) The unit shall next complete three five-minute cycles of simple harmonic motion having an amplitude of 0.035 mm (total excursion 0.07 mm) applied initially at a frequency of 30 Hz, and increase at a uniform rate to 60 Hz in 2 1/2 minutes, then decreased at a uniform rate to 30 Hz in 2 1/2 minutes.

The above two-part test shall be applied for a total of 30 minutes in each of three directions. Directions shall be parallel to both axes of the base and perpendicular to the plane of the base.

In addition, the equipment shall meet the specifications listed in the following table during vibration:

Table 57 - Vibration Stability (Base Station)

Characteristic	Performance Limit
Reference Sensitivity 3.1.4	No DFS
Carrier Output Power Rating 3.2.1	No DFS
Carrier Frequency Stability 3.2.2	No DFS
Modulation Limiting 3.2.3	Shall be between 50% to 100% of rated system deviation
Hum and Noise Level 3.2.8	15 dB DFS

3.3.5 Shock Stability

3.3.5.1 Applicable method of measurement and definition are given in 2.3.5.

3.3.5.2 Standard for mobile equipment

The equipment shall meet all electrical requirements and suffer no mechanical damage when subjected to a series of not less than ten impacts in each plane (total thirty). Each impact shall consist of a half sine wave acceleration of 20 g peak amplitude of 11 milliseconds duration.

Acceleration shall be applied to the manufacturer's mounting facilities and may be measured by means of a suitable accelerometer. The equipment shall be operated under standard test conditions and during one-half the impacts in each plane.

The equipment shall suffer no more than superficial mechanical damage and shall meet the requirements as specified in each of the standards sections without degradation after being shocked.

3.3.5.3 Standard for portable equipment

Shock stability is the ability of the equipment (including battery) to maintain specified mechanical and electrical performance after being shocked.

Shock will be delivered to the equipment by a drop on a smooth concrete floor with non-restrictive guides to assure free-fall dropping on the equipment surface to be tested.

Portable equipment shall be dropped once on each of six surfaces from a height of 100 cm onto a smooth concrete floor.

The equipment shall suffer no more than superficial mechanical damage and shall meet the requirements as specified in each of the standards sections without degradation after shock.

3.3.5.4 Standard for base station equipment

This test is not applicable to base station equipment.

3.3.6 DC Supply Noise Susceptibility

3.3.6.1 Applicable method of measurement and definition are given in 2.3.6.

3.3.6.2 Standard for mobile equipment

The equipment shall be capable of withstanding 500 millivolts (peak to peak) of 800 Hz to 8000 Hz ripple superimposed on the power supply (100 mV if equipment is to be connected directly to the vehicle's battery) with no more than a 6 dB degradation in the hum and noise specifications of 3.1.11.2 and 3.2.8.2.

3.3.6.3 Standard for portable equipment

The equipment shall meet this standard whenever the unit battery is being charged from a manufacturer specified battery charger or operated as specified by the manufacturer from a mobile power supply.

The equipment shall be capable of withstanding 500 millivolts of 800 Hz to 8000 Hz ripple superimposed on the power supply (100 mV if equipment is to be connected directly to the vehicle's battery) with no more than a 6 dB degradation in the hum and noise specifications of 3.1.11.2 and 3.2.8.2.

3.3.6.4 Standard for base station equipment

The equipment shall be capable of withstanding 100 millivolts of 50 Hz to 40,000 Hz ripple superimposed on the power supply with no more than a 6 dB degradation in the hum and noise specifications of 3.1.11.2 and 3.2.8.2.

3.3.7 Battery Life - Portables Only

3.3.7.1 Applicable method of measurement and definition are given in 2.3.7.

3.3.7.2 Standard

For equipment with a manufacturer specified battery life of less than sixteen hours, the standard duty cycle shall be performed over the hours specified by the manufacturer.

For equipment with a manufacturer specified battery life in excess of sixteen hours, the standard duty cycle shall be performed for eight hours followed by sixteen hours rest.

a) Standard duty cycle for equipment consisting of a transmitter and receiver may be either of the following:

   1) 10-10-80 : Six seconds receive at manufacturer's stated audio output power, six seconds transmit at manufacturer's stated carrier output power and 48 seconds at standby.

   2) 5-5-90 : Three seconds receive at manufacturer's stated audio output power, three seconds transmit at manufacturer's stated carrier output power and 54 seconds at standby.

b) Standard duty cycle for equipment consisting of a voice-receiver only:

   Six seconds receive at manufacturer's stated audio output power and 54 seconds standby.

c) Standard duty cycle for equipment consisting of a transmitter only:

Six seconds transmit at manufacturer's stated carrier output power and 54 seconds standby.

d) Standard duty cycle for equipment consisting of a alerting receiver only:

A message every thirty minutes during an eight hour period for a total of fifteen messages. A message shall consist of an alerting indication followed, if applicable, by six seconds of manufacturer's stated audio output power.

The minimum battery supply life is the number of hours that the equipment will operate under the standard duty cycle on a single complement of batteries before the battery end-point has been reached.

The equipment shall be adjusted to the standard test voltage (Standard Conditions for the Power Supply 1.4.4), receive at the manufacturer's stated audio output power, transmit at the manufacturer's stated carrier output power, and shall be operated at the appropriate standard duty cycle, with a fully charged battery complement.

The battery end-point shall be determined by whichever of the following occurs first:

1) Manufacturer's recommended lowest discharge voltage has been reached.

2) Receiver Reference Sensitivity (5.1.4) is degraded 6 dB from the manufacturer's rating.

3) The Carrier Output Power (5.2.1) of the transmitter is degraded 6 dB from the manufacturer's rating.

4) Transmitter Carrier Frequency Stability exceeds the limits of 5.2.2.

3.3.8 Dimensions

3.3.8.1 Applicable method of measurement and definition are given in 2.3.8.

3.3.8.2 The manufacturer shall specify the dimensions in metric units per 2.3.8.2.

Portable equipment shall be measured together with all accessories required for operation and support during its intended use, with the exception that an antenna that protrudes beyond the basic equipment case may be excluded from the size measurement.

3.3.9 Weight

3.3.9.1 Applicable method of measurement and definition are given in 2.3.9.

3.3.9.2 The manufacturer shall specify the weight in metric units per 2.3.9.2.

Portable equipment shall be measured together with all accessories required for operation and support during its intended use.

3.4 Standards for Subaudible Signaling.

This section details the subaudible signaling performance standards for land mobile communications FM or PM equipment. This communications equipment includes radio transmitters or receivers or combinations of both whether it is mounted in a vehicle, stationary, or portable.

The equipment shall be assembled with any requisite adjustments made in accordance with the manufacturer's instructions for the operating mode required. Where alternative modes are available relevant adjustments should be made and equipment measurement procedures repeated for these modes.

Unless otherwise indicated, any associated equipment normally used with the mobile under test such as control units, interface cabling, etc., shall be included during the measurement procedures.

Unless otherwise indicated or required, it is recommended that special function subsystems other than the subaudible signaling be disabled while conducting the measurement procedures. If not disabled and such may have a material impact on results, this fact should be recorded with the results.

Except where specifically noted, the equipment shall meet specifications after being subject to required shock and vibration. These requirements are specified in the individual equipment type characteristics (See 3.3).

3.4.1 Squelch Opening SINAD

3.4.1.1 Applicable method of measurement and definition are given in 2.4.1.

3.4.1.2 Standard

The SINAD with CTCSS signaling shall be less than 8 dB, and the SINAD with CDCSS shall be less than 10 dB.

3.4.1.3 Environmental Parameters

Table 58 - Squelch Opening SINAD Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	3 dB DFS	±10%
Temperature	3 dB DFS	-30 °C to +60 °C
Humidity	3 dB DFS	90-95% @ 50 °C
Vibration	3 dB DFS	During

3.4.2 Receive Audio Attack Time

3.4.2.1 Applicable method of measurement and definition are given in 2.4.2.

3.4.2.2 Standard

The maximum attack time for CTCSS modulation shall be 250 ms except for frequencies below 100 Hz. Below 100 Hz the time shall be computed by the following formula:

$$\textit{Maximum attack time} = \frac{25000}{code\ \ frequency\ \ (Hz)} \quad \text{(ms)}$$

The maximum attack time for CDCSS modulation shall be 350 ms.

3.4.2.3 Environmental Parameters

Table 59 - Receive Audio Attack Time Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	Twice the standard	±10%
Temperature	Twice the standard	-30 °C to +60 °C
Humidity	Twice the standard	90-95% @ 50 °C

3.4.3 Receive Audio Closing Time (with Squelch Tail Elimination disabled)

3.4.3.1 Applicable method of measurement and definition are given in 2.4.3.

3.4.3.2 Standard

The maximum time for audio closing shall be 250 ms.

3.4.3.3 Environmental Parameters

Table 60 - Receive Audio Closing Time (With Squelch Tail Elimination Disabled) Environmental Parameters

Environmental Parameter	Specification Limit	Conditions
Voltage	500 ms	±10%
Temperature	500 ms	-30 °C to +60 °C
Humidity	500 ms	90-95% @ 50 °C

3.4.4 Receive Audio Attack Time with RF Carrier Frequency Offset

3.4.4.1 Applicable method of measurement and definition are given in 2.4.4.

3.4.4.2 Standard

The maximum attack time for CTCSS modulation shall be 250 ms except for frequencies below 100 Hz. Below 100 Hz the time shall be computed by the following formula:

$$\textit{Maximum attack time} = \frac{25000}{code\ \ frequency\ \ (Hz)} \quad \text{(ms)}$$

The maximum attack time for CDCSS modulation shall be 350 ms.

3.4.4.3 Environmental Parameters

Table 61 - Receive Audio Attack Time with RF Carrier Frequency Offset Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	Twice the standard	±10%
Temperature	Twice the standard	-30 °C to +60 °C
Humidity	Twice the standard	90-95% @ 50 °C

3.4.5 Receiver Hum and Noise Ratio

3.4.5.1 Applicable method of measurement and definition are given in 2.4.5.

3.4.5.2 Standard

The "Unsquelched Hum and Noise" level shall be at least the level shown below for the manufacturer's specified CTCSS Code Frequencies and CDCSS Code words.

Table 62 - Receive Hum and Noise Ratio

System Deviation (kHz)	**Unsquelched Hum and Noise Level (dB)**
±2.5	28
±4.0	30
±5.0	30

3.4.5.3 Environmental Parameters

Table 63 - Receive Hum and Noise Ratio Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.6 CTCSS Decoder Response Bandwidth

3.4.6.1 Applicable method of measurement and definition are given in 2.4.6.

3.4.6.2 Standard

The decoder response bandwidth shall allow decoding of the selected tone within its operating tolerance and be sufficiently narrow so as not to decode any adjacent tone in the Code Frequency list operating within its tolerance.

Table 64 - CTCSS Decoder Response Bandwidth

Measured Tone	Specification Limit
F_{Low}	≥next lower CTCSS Tone Code x 1.005
F_{High}	≤next higher CTCSS Tone Code x 0.995
F_{Low}	≤selected CTCSS Tone Code x 0.995
F_{High}	≥selected CTCSS Tone Code x 1.005

3.4.6.3 Environmental Parameters

Table 65 - CTCSS Decoder Response bandwidth Environmental Parameters

Environmental Parameter	Specification Limit	Conditions
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.7 False Response Rate

3.4.7.1 Applicable method of measurement and definition are given in 2.4.7.

3.4.7.2 Standard

With the subaudible circuitry enabled, the radio shall not exhibit more than one false response in a thirty-minute period.

3.4.7.3 Environmental Parameters

Table 66 - False Response Rate Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.8 Receiver Audio Response

3.4.8.1 Applicable method of measurement and definition are given in 2.4.8.

3.4.8.2 Standard

With the subaudible tone circuitry enabled, the receiver audio frequency response shall not vary more than +1, -3 dB from a standard 6 dB per octave de-emphasis curve over the frequency range of 300 Hz to 3000 Hz, except for additional attenuation of 6 dB per octave below 500 Hz and additional 12 dB per octave above 2500 Hz is allowed. The reference frequency shall be 1000 Hz.

3.4.9 Squelch Tail Elimination

3.4.9.1 Applicable method of measurement and definition are given in 2.4.9.

3.4.9.2 Standard

With the subaudible circuitry enabled, the radio shall meet manufacturer specifications for CTCSS or CDCSS audio squelch closing time as tested with the reverse burst of tone or turn off code. In no case shall it have a longer closing time than 50 ms to be considered reverse burst.

3.4.9.3 Environmental Parameters

Table 67 - Squelch Tail Elimination Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.10 Transmitter Modulation Limiting

3.4.10.1 Applicable method of measurement and definition are given in 2.4.10.

3.4.10.2 Standard

With the subaudible signaling section enabled, the instantaneous peak and steady state deviations shall not exceed rated system deviation at any audio frequency or reasonable change in input level.

3.4.10.3 Environmental Parameters

Table 68 - Transmitter Modulation Limiting Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C
Vibration	No DFS	During

3.4.11 Encoder Response Time

3.4.11.1 Applicable method of measurement and definition are given in 2.4.11.

3.4.11.2 Standard

For CTCSS Code Frequencies ≥100 Hz

Response Time = 150 ms maximum

Below 100 Hz the maximum attack time shall be computed by the following formula:

$$\text{Maximum attack time } = 15000/(\mathit{code\ \ frequency}) \quad \text{(ms)}$$

For CDCSS Codes:

Response Time = 150 ms maximum

3.4.11.3 Environmental Parameters

Table 69 - Encoder Response Time Environmental Parameters

Environmental Parameter	Specification Limit	Conditions
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.12 CTCSS Encoder Frequency

3.4.12.1 Applicable method of measurement and definition are given in 2.4.12.

3.4.12.2 Standard

The Encoder Frequency shall be ±0.3% of the assigned frequency.

3.4.12.3 Environmental Parameters

Table 70 - CTCSS Encoder Frequency Environmental Parameters

Environmental Parameter	Specification Limit	Conditions
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.13 CTCSS Tone Distortion

3.4.13.1 Applicable method of measurement and definition are given in 2.4.13.

3.4.13.2 Standard

The CTCSS distortion shall be less than 5%.

3.4.13.3 Environmental Parameters

Table 70 - CTCSS Tone Distortion Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.14 Transmitter SINAD

3.4.14.1 Applicable method of measurement and definition are given in 2.4.14.

3.4.14.2 Standard

The transmitter SINAD shall be greater than 20 dB.

3.4.14.3 Environmental Parameters

Table 71 - Transmitter SINAD Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.15 CDCSS Waveform Distortion

3.4.15.1 Applicable method of measurement and definition are given in 2.4.15.

3.4.15.2 Standard

The total waveform droop shall be less than 30% after a transmission of six ones or six zeros in a row.

3.4.15.3 Environmental Parameters

Table 72 - CDCSS Waveform Distortion Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.16 Transmitter FM Hum and Noise

3.4.16.1 Applicable method of measurement and definition are given in 2.4.16.

3.4.16.2 Standard

Table 73 - Transmitter Hum and Noise

Rated System Deviation (kHz)	**FM Hum and Noise Level (dB)**
±2.5	30
±4.0	33
±5.0	35

3.4.16.3 Environmental Parameters

Table 74 - Transmitter Hum and Noise Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.17 Transmitter Subaudible Deviation

3.4.17.1 Applicable method of measurement and definition are given in 2.4.17.

3.4.17.2 Standard

Table 75 - Transmitter Subaudible Deviation

Rated System Deviation (kHz)	**Subaudible Signaling Deviation Limits (Hz)**
±2.5	350 to 600
±4.0	400 to 800
±5.0	500 to 1000

3.4.17.3 Environmental Parameters

Table 76 - Transmitter Subaudible Deviation Environmental Parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

3.4.18 Transmitter Squelch Tail Elimination Burst

3.4.18.1 Applicable method of measurement and definition are given in 2.4.18.

3.4.18.2 Standard

Table 77 - Transmitter Squelch Tail Elimination Burst

Squelch Tail Elimination System	**Timing Standards**
Reverse Burst CTCSS	150 to 200 ms
CDCSS Turn Off Code	150 to 200 ms

3.4.18.3 Environmental Parameters

Table 78 - Transmitter Squelch Tail Elimination Burst Environmental parameters

Environmental Parameter	**Specification Limit**	**Conditions**
Voltage	No DFS	±10%
Temperature	No DFS	-30 °C to +60 °C
Humidity	No DFS	90-95% @ 50 °C

4 CHANGE HISTORY

4.1 Chronology of revisions for TIA/EIA-603

. Table 79 – Change History

Date Adopted	New Issue	Section(s)	Description
21 January, 1997	TIA/EIA-603-1		Addendum to update requirements per FCC rule changes for narrowband equipment
15 June, 2001	TIA/EIA-603-A	1,2,3,4,5 and 6 Annex A Annex B	Consolidated Sections 4, 5 and 6 into Section 3. Added new subclauses 2.1.21, 2.1.22, 3.1.21 and 3.1.22. Included Addendum 603-1. Added limits for 15kHz spacing and revised interference limits due to use of 2 tone test signal. Added class A receiver limits. Eliminated previous Annex A, Frequency Bands. Updated measurement uncertainties and sample calculations and made these separate Annexes.
November 2002	TIA-603-B		Added test method and limits for 700 MHz band. Added 700 MHz information to 1.3.4.4 table. Added 2.2.12.3, Unwanted Emission : Radiated Spurious EIRP in the GGNSS band. Added 2.2.13.3, Unwanted Emission : Radiated Spurious Calculated EIRP in the GGNSS band. Changes to 2.2.14, Unwanted Emission: Adjacent Channel Power Ratio. Changes to 2.2.17, Radiated Output Power. Added 2.2.17.2, Effective Radiated Power (ERP). Section 3, modified limits to add 700 MHz.
December 2004	TIA-603-C		Changed method of measurement and requirements for section 2.1.3 and 3.1.3 power line conducted spurious output voltage to comply with FCC rules.
July 2010	TIA-603-D		Correction of typographical and format errors. Updated to latest FCC and NTIA frequency assignments.
October 2015	TIA-603-E		Allow the use of a low pass filter in the distortion meter when making measurements on equipment using Class-D audio amplifiers.

A ANNEX A (INFORMATIVE) - MEASUREMENT UNCERTAINTY

A.1 Introduction

Since two observers making measurements on the same Unit Under Test will not obtain the same results, it is important that the measurement uncertainties be understood by both observers and a consistent method of determining these uncertainties be used. This annex will not attempt to make a statement about the confidence level of the measurement uncertainties, but it will provide a consistent method that will allow two observers to compare their results. It also provides a method for evaluating and calculating the uncertainties when performing measurements to the limits specified in 3.1 through 3.4.

This annex contains a tutorial on the types of measurement errors that can occur and provides a mathematical method to quantify these errors.

Example calculations for the measurement methods in 2.1, 2.2, and 2.3 are provided in Annex B

These examples may be used without an understanding of the mathematical derivations in Section 3. The sources of errors listed in the example calculations may not include all the possibilities. Therefore, it is important that the observers identify all of the errors for their measurements and perform the analysis.

A.2 Definitions

A.2.1 Accuracy

The degree of closeness of a stated value to the actual or true value. While a commonly used term, its definition is not precise. Therefore, the term "uncertainty" will be used in preference to "accuracy" in this document.

A.2.2 Measurand

A quantity subject to measurement.

A.2.3 Error

The difference between the measured value and true value of a measurand.

A.2.4 Bias and Systematic Error

The difference between the expectation of the measured value and the true value of the measurand. The bias error is constant for a set of measurements performed on the same device, using the same measurement setup, performed within a reasonably short time frame. Bias error is the same as systematic error.

A.2.5 Random Error

The difference between the measured value and the limiting mean, or expectation, of those values; the difference between the measured value and the bias error. The random error is different each time a measurement is performed.

A.2.6 RSS Errors

Errors that are combined by calculating the square root of the sum of the square of the individual errors.

A.2.7 Precision

A measure of the reproducibility of the measurement results made under one set of conditions; a measure of the spread of random error. Precision is often expressed in terms of the standard deviation of the measurements, or in terms of a confidence limit. The standard deviation may be determined each time the measurement is performed, or just once, using a very large set of measurements, to arrive at a more reliable estimate as long as it doesn't change among measurement sets, e., as long as the measurement process is stationary. In some cases where the distribution of measured values about its mean is known theoretically from the nature of the measurement, the standard deviation may be determined *a prior.*

A.2.8 Uncertainty

An estimate characterizing the range of values within which the true value of a measurand lies.

A.2.9 Confidence Limits

Those values that the random component of error has some stated probability of being within; the random component of uncertainty.

A.3 Principles for Calculating Measurement Uncertainties

A.3.1 General

When calculating the over all measurement uncertainty for a given method of measurement, one has to identify all of the individual errors and sum these errors. There are several different methods discussed on the ways to sum the errors. This annex will use a method sufficient for transceiver test while providing a reasonable calculation.

A.3.2 Types of Errors

A.3.2.1 Random Errors

From Murphy [1969, p. 360]

Sometimes the precision is stated as ±2 standard deviations with the implication that approximately 95% of all the measurements of the measurement process will fall within two standard deviations of the long-run average for that process, whether that long-run average agrees with the reference level [e., true value] or not. In some cases people have used the multiple 1.96 rather than 2 in the hope that they will have obtained limits that more truly represent actual bounds within which 95% of the universe will lie. Usually such refinements are specious on two grounds: first, because the accuracy with which the standard deviation will be known is not consistent with distinguishing between multipliers of 2.00 and 1.96; second, too great a reliance on the figure of 95% is unjustifiable, anyway, since some measurement processes will yield a universe of observations of which perhaps only 90% may lie within the 2-standard-deviation limits. It is reasonable to suppose in most cases, however, that such limits will include 90% to 95% of the statistical universe of observations. Because of the uncertainty associated with this multiple, it might usually be better avoided in favor of other alternatives.

A.3.2.2 Bias Errors

The overall systematic or bias error of a measurement is generally composed of a number of individual systematic errors. From Eisenhart [1969, p. 43]:

Since the "known" systematic errors affecting a measurement process ascribable to specific origins are ordinarily determinate in origin only, their individual values ordinarily being unknown both with respect to sign and magnitude, it is not possible to evaluate their algebraic sum and thereby arrive at a value for the overall systematic error of the measurement process concerned. In consequence, it is necessary to arrive at bounds for each of the individual components of systematic error that may be expected to yield non-negligible contributions, and then from these bounds arrive at credible bounds to their combined effect on the measurement process concerned. Both of these steps are fraught with difficulties.

Determination of reasonable bounds to the systematic error likely to be contributed by a particular origin or assignable cause necessarily involves an element of judgment, and the limits cannot be set in exactitude. By assigning ridiculously wide limits, one could be practically certain that the actual error due to a particular cause would never lie outside of these limits. But such limits are not likely to be very helpful. The narrower the range between the assigned limits, the greater the uneasiness one feels that the assigned limits will not include whatever systematic error is contributed by the cause in question. But a decision has to be made; and on the basis of theory, other related measurements, a careful study of the situation in hand, especially its sensitivity so small changes in the factor concerned, and so forth, "the experimenter presently will feel justified in saying that he feels, or believes, or is of the opinion," that the systematic error due to the particular source in question does not exceed such and such limits, "meaning thereby, since he makes no claim to omniscience, that he has found no reason believing" that it exceeds these limits. In other words, "nothing has come to light in the course of the work to indicate" that the systematic error concerned lies outside the stated range.

Given the above statement, the problem remains how to combine individual sources of systematic error into one estimate of bias. The commonly used methods are:

a) Take the sum of the individual limits.
b) Take the square root of the sum of the squares of the individual limits that are expressed in fraction form of (delta X)/(X).
c) Assume a probability distribution for each of the individual systematic errors and calculate the probability distribution of their sum, assuming that the sources of error are independent. The estimated limits of the total bias error is then taken to be the points on the probability distribution function of the sum that encompass some fraction, typically 95%, of all the possible values.

Method a) is simple and often suitable when the number of individual sources of error is small, say 3 or less. It is probably overly pessimistic, however, when the number of errors is larger, as it seems very unlikely that all of the errors would be of the same sign and of the largest expected magnitude.

Method c) is initially attractive from a theoretical standpoint, though it can be computationally complex when the number of sources is not large and their limits are not of similar magnitude. Further, it suffers the problem that the underlying assumption of the applicability of the theory of error to the problem is not strictly valid. It assumes that the systematic errors actually do vary from one test setup to another according to the probability distribution function and that over a large number of such setups, some fraction of the systematic errors will lie within the limits given by that fraction of the distribution function. The assumption also implies that over a large number of such setups, the average systematic error will tend to zero. There is typically no evidence to support this assumption. There is no basis in statistical theory for assigning a confidence level to the bias error so determined. [Dorsey and Eisenhart 1969, p.50.]

Consequently, this standard will adopt method b) as the means of combining independent systematic errors since it provides a more reasonable estimate of the bias error limits than a), is commonly accepted, is computationally simpler than c) and does not lead one as easily to draw unsupported conclusions as the latter.
As a comparison between methods b) and c), it may be noted that the limits computed by b) encompass between 94 and 100% of the error distributions computed as in c), if the individual errors are assumed to be uniformly distributed between their limits. If limits are calculated per c) using a "confidence level" of 95%, the calculated limits are from 5% less to 13% greater than those calculated using b).

The effect of some systematic errors can be minimized by applying a correction factor to the measurement results when the value of the error and its effect on the measurement results are known. If the value of the systematic error itself is the result of a measurement, the errors in that measurement must be appropriately applied to the final uncertainty. An example of this is correcting modulation deviation measurements for the effect of residual noise.

A.3.3 Propagation of Errors

A.3.3.1 General

If some quantity z is calculated as a function of two other quantities x and y, then for some nominal or reference values x_0 and y_0,

$$z_0 = f(x_0 , y_0) \qquad (1)$$

and for small deviations from this nominal value,

$z_0 + dz = f(x_0 + dx, y_0 + dy).$ (2)

To a first-order approximation, good for dx and dy much smaller than x_0 and y_0, respectively,

$$z_0 + dz = f(x_0, y_0) + \frac{\partial f}{\partial x} dx\Big|_{\substack{x=x_0 \\ y=y_0}} + \frac{\partial f}{\partial y} dy\Big|_{\substack{x=x_0 \\ y=y_0}} \quad (3)$$

$$dz = \frac{\partial f}{\partial x} dx\Big|_{\substack{x=x_0 \\ y=y_0}} + \frac{\partial f}{\partial y} dy\Big|_{\substack{x=x_0 \\ y=y_0}} \quad (4)$$

If dx and dy are taken to represent errors in x and y, respectively, then dz is the error in z that results from those errors.

A.3.3.2 Propagation of Random Errors

If x and y are random variables, as for example measurements having random errors, then z is also a random variable, and to a first-order approximation,

$$\mu_z = f(\mu_x, \mu_y) \quad (5)$$

$$\sigma_z^2 = \left[\frac{\partial f}{\partial x}\right]^2 \sigma_x^2 + \left[\frac{\partial f}{\partial y}\right]^2 \sigma_y^2 + 2\rho_{xy} \frac{\partial f}{\partial x}\frac{\partial f}{\partial y}\sigma_x \sigma_y \quad (6)$$

for σ_x and σ_y sufficiently small that $f(x, y)$ is nearly linear in the vicinity of μ_x and μ_y. The square brackets signify that the derivatives within the brackets are to be evaluated at μ_x and μ_y.

If x and y are uncorrelated (usually true if they are independent), then the correlation coefficient ρ_{xy} is zero and the second equation reduces to

$$\sigma_z^2 = \left[\frac{\partial f}{\partial x}\right]^2 \sigma_x^2 + \left[\frac{\partial f}{\partial y}\right]^2 \sigma_y^2 \quad (7)$$

The extension to functions of more than two variables is straightforward.

A.3.4 Converting Power Errors Expressed in dB to Percentage

A bias error having [power] limits of $\pm\varepsilon$% may be expressed in dB using the relations

$$\delta_+ = 10 \log_{10}(1 + \varepsilon/100) \quad (8)$$

$$\delta_{-} = 10 \log_{10}(1 - \varepsilon/100) \qquad (9)$$

However, for small ε,

$$\delta_{\pm}(\text{dB}) \cong (10/\ln(10)) \times (\pm\varepsilon/100) = 0.04343 \times (\pm\varepsilon) \qquad (10)$$

The conversion formula of equation (10), and the equivalent for voltage bias errors, will be used in this document since it is sufficiently accurate for our purposes, avoids the problem of asymmetric error limits, and is consistent with other commonly-used approximations.

For example, error limits of ±0.22 dB may be converted to an equivalent power bias error of ±5.07% using our approximation, while the exact limits are +5.20, -4.94%. However, if a measurement result is calculated as the ratio of two measured values, each having error limits of ±5%, it is common to attribute ±5% of the error in the ratio to the error in the denominator, while the error in the denominator actually has a +5.26, -4.76% effect on the ratio. Hence the conclusion that our approximation is consistent with (and actually better than) others commonly used.

Since symmetric percentage error limits yield asymmetric limits in dB, and vice versa, it is prudent to express the total measurement uncertainty in the same units as the largest error contributions.

A.3.5 Mismatch Uncertainty and Mismatch Loss

When two instruments in a measurement configuration are connected, there will be a mismatch uncertainty of the signal passing through the connection. The mismatch uncertainty is described by the following equation:

$$M_u(\text{dB}) = 10 \log_{10}(r_g \times r_l)^2 \qquad (11)$$

If the mismatch uncertainty limits are given in percent deviation from unity rather than in dB, then the equation becomes:

$$M_u(\%) = 100 \left[(1 \pm r_l \times r_g)^2 - 1\right] \qquad (12)$$

Like equations (8) and (9) M_u is an asymmetric number; but, by applying equation (10) the following approximation can be used:

$$M_u(\text{dB}) \cong 8.686 \times r_g \times r_l \tag{13}$$

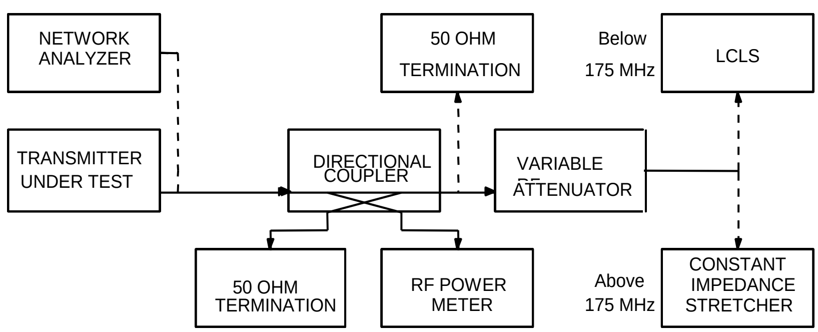
Where

r_l is the reflection coefficient of the load.
r_g is the reflection coefficient of the generator.

A.3.6 Sensitivity of Transmitter Output to Load

A transmitter is usually designed to work into a 50 Ω load. If the load is not exactly 50 Ω, then there will be an uncertainty in any measurements requiring a knowledge of the transmitter's output power. The following method of measurement will determine an effective output VSWR for the transmitter. For the examples in this annex we will use an effective transmitter VSWR of 2:1.and a standard load input VSWR of 2:1. This gives an uncertainty value of 0.26 dB for the transmitter output to standard load.

a) Connect the equipment as illustrated.



b) For frequencies up to 175 MHz, recommend using a lumped constant line stretcher (LCLS) as the variable load (see 5.25, 5.26 for the typical values of the inductors and capacitors).

c) For frequencies above 175 MHz, use constant impedance line stretcher with a RF short as the variable load.

d) Select the value for the attenuator to produce a VSWR of 3:1. The equivalent reflection coefficient is then r_l = 0.5.

e) Calibrate the variable load using the network analyzer at the frequencies of interest.

f) Key the transmitter into the 50 Ω load and measure the level at the RF power meter. Record this level as P_{z0}.

g) Key the transmitter into the variable load. Vary the phase of the load to find the maximum level into the RF power meter. Record this value as P_{fmax}.

h) Repeat step g) but vary the phase of the load to find the minimum level into the RF power meter. Record this value as P_{fmin}.

i) The output reflection coefficient (r_g) can be calculated from the maximum value of the following:

$$r_{g1} = \frac{1 - \sqrt{\dfrac{P_{z0}}{P_{f\max}}}}{r_1}$$

$$r_{g2} = \frac{1 - \sqrt{\dfrac{P_{z0}}{P_{f\min}}}}{r_1}$$

The maximum of r_{g1} and r_{g2} is r_g .

j) The effective output VSWR of the transmitter is now calculated as:

$$VSWR = \frac{1 + r_g}{1 - r_g}$$

A.3.7 Correcting rms Measurements for the Effects of rms Residuals

Because sinusoidal signals and random noise are uncorrelated, their mean-squared voltages add. Therefore, the measured rms value of a signal in the presence of noise will be:

$$V_T = \sqrt{V_S^2 + V_N^2}$$

where

V_s is the rms value of the signal and V_N is the rms value of the noise.

If the signal level does not influence the noise level (as it might if an AGC circuit was in the signal path), then a separate measurement of V_N may be made and used to correct the measurement of V_T to obtain a closer estimate of V_S. The estimate of V_S $(\hat{V}s)$ is then

$$\hat{V}_S = \sqrt{\hat{V}_T^{\,2} - \hat{V}_N^{\,2}}$$

Taking partial derivatives and applying the propagation of error formulas, we find that the normalized error in the measurement of V_S is:

$$\frac{dV_S}{V_S} = \frac{V_T^2}{V_T^2 - V_N^2}\,\frac{\delta V_T}{V_T} - \frac{V_N^2}{V_T^2 - V_N^2}\,\frac{\delta V_N}{V_N}$$

Example:

Let the measurement of the rms deviation of an FM signal in the presence of noise be 2.20 kHz and the measurement of residual noise alone be 100 Hz. Further, let the specified accuracy of the modulation meter be 2% of reading plus 10 Hz. Let us say that the measurements are stable so there is no need to include the effects of random errors.

The normalized (systematic) error in the measurement of the total deviation is 2% + 100x10/2200 = 2.45%; that of the residual noise is 2% + 100 x 10/100 = 12%. Therefore, taking the root-sum-square of the two components, the normalized error in the determination of the signal deviation is:

$$\sqrt{(1.00 \times 2.45)^2 + (0.00207 \times 12)^2} = 2.45\%$$

In this example the contribution of the error in the measurement of residual noise is negligible. It also turns out that the residual noise itself has a negligible effect on the measurement of the signal level--it only corrects the measurement by 2.3 Hz, or 0.1%. This example shows that residual noise typically has a very small effect on rms measurements at typical signal-to-noise ratios.

A.3.8 Correcting Peak Measurements for the Effects of Residuals

The response of a peak detector to noise and a signal plus noise depends, in a complicated fashion, on a number of factors beyond the control and knowledge of the typical user. It is not possible, therefore, to provide an accurate rule in the general case for correcting peak measurements for the effect of noise. The best that can be said is that it is very unlikely that a peak measurement of a signal made in the presence of noise will be less than that of the signal alone or greater than the sum of the signal and noise each measured alone.

A.4 Bibliography

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Dorsey, N. E. and Eisenhart, C. "On Absolute Measurement," NBS Special Publication 300, Vol. 1, February 1969, pp. 49-55.

Hewlett-Packard Application note 64-1 "Fundamentals of RF and Microwave Power Measurements" August 1977, pp. 29-34.

B ANNEX B (INFORMATIVE) - EXAMPLE CALCULATIONS

B.1 Example Calculations for Receiver Measurements

The examples in this section are for the limits in 3.1 based on the methods of measurement in 2.1 and the characteristics of equipment in 1.5. Conversion between decibels and percentage used herein utilize the symmetric approximation described in Equation 10 of Annex A.

B.1.1 Radiated Spurious Output Power

Uncertainty sources and estimates:

Test site and antenna	3 dB	69 %
Test cable	0.2 dB	4.6 %
Signal generator level	1 dB	23 %

Example calculation: $RSS_{error} = \sqrt{69^2 + 4.6^2 + 23^2} = 73\% = 3.2\ dB$

B.1.2 Conducted Spurious Output Power

Uncertainty sources and estimates:

Mismatch between the receiver input and the spectrum analyzer 8.686 x r_R x r_A = 8.686 x 0.33 x 0.091	0.26 dB	6 %
Spectrum analyzer amplitude log fidelity	2 dB	46 %

Example calculation: $RSS_{error} = \sqrt{6^2 + 46^2} = 46.4\% = 2\ dB$

B.1.3 Power Line Conducted Spurious Voltage

Uncertainty sources and estimates:

Line stabilization network response	1 dB	23 %
Spectrum analyzer amplitude log fidelity	2 dB	46 %
Mismatch between the line input stabilization network and the spectrum analyzer 8.686 x r_R x r_A = 8.686 x 0.33 x 0.091	0.26 dB	6 %

Example calculation: $RSS_{error} = \sqrt{23^2 + 46^2 + 6^2} = 51.8\% = 2.3\,dB$

B.1.4 Reference Sensitivity

Uncertainty sources and estimates:

Signal generator level	1 dB	23 %
Modulation level	0.15 dB	3.5 %
SINAD meter	0.5 dB	11.5 %
Impedance matching network and transmission line	0.2 dB	4.6 %
Signal generator and receiver mismatch, 8.686 x r_G x r_R = 8.686 x 0.091 x 0.33	0.26 dB	6 %

Example calculation: $RSS_{error} = \sqrt{23^2 + 3.5^2 + 11.5^2 + 4.6^2 + 6^2} = 27.8\% = 1.2\,\text{dB}$

B.1.5 Signal Displacement Bandwidth

Uncertainty sources and estimates (assuming a receiver with a 3 kHz signal displacement bandwidth):

Setting signal generator level	8.3 %
Reading SINAD meter	8.3 %
Signal generator frequency	16.7 %

Example calculation: $RSS_{error} = \sqrt{8.3^2 + 8.3^2 + 16.7^2} = 20.3\%$

B.1.6 Adjacent Channel Rejection

Uncertainty sources and estimates (assuming that reference sensitivity is first measured with the generator that is used as an interfering generator that prevents any uncertainty caused by differences in absolute level between the signal generators):

Reference level setting	0.5 dB	11.5 %
Interfering signal generator level	1 dB	23 %
Contribution due to interfering signal generator frequency	1 dB	23 %
SINAD meter	0.5 dB	11.5 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2 + 23^2 + 11.5^2} = 36.4\% = 1.6\,\text{dB}$

B.1.7 Offset Channel Selectivity

Uncertainty sources and estimates:

Reference level	0.5 dB	11.5 %
Signal generator level	1 dB	23 %
Signal generator frequency	2 dB	46 %
Interfering generator modulation	1 dB	23 %
SINAD meter	0.5 dB	11.5 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2 + 46^2 + 23^2 + 11.5^2} = 58.6\% = 2.5\,\text{dB}$

B.1.8 Spurious Response Rejection

Uncertainty sources and estimates (assuming that reference sensitivity is first measured with the generator that is used as an interfering generator that prevents any uncertainty caused by differences in absolute level between the signal generators):

Reference level setting	0.5 dB	11.5 %
Interfering signal generator level	1 dB	23 %
SINAD meter	0.5 dB	11.5 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2 + 11.5^2} = 28.2\% = 1.2\,\text{dB}$

B.1.9 Intermodulation Rejection

Uncertainty sources and estimates (assuming that reference sensitivity is first measured with the generator that is used as an interfering generator that prevents any uncertainty caused by differences in absolute level between the signal generators):

Reference level setting	0.5 dB	11.5 %
First interfering signal generator level	1 dB	23 %
Second interfering signal generator level	1 dB	23 %
SINAD meter	0.5 dB	11.5 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2 + 23^2 + 11.5^2} = 36.4\% = 1.6\,\text{dB}$

B.1.10 Audio Frequency Response

Uncertainty sources and estimates:

Reference reading		3 %
Reading at desired frequency		3 %
Signal generator modulator frequency response	0.5 dB	4.63 %

Example calculation: $RSS_{error} = \sqrt{3^2 + 3^2 + 4.6^2} = 4.9\% = 0.2\,\text{dB}$

B.1.11 Hum and Noise Ratio

Uncertainty sources and estimates:

Reference level setting	0.5 dB	1 %
Audio voltmeter reading	0.25 dB	5.8 %
Generator modulation level	0.3 dB	6.9 %

Example calculation: $RSS_{error} = \sqrt{1^2 + 5.8^2 + 6.9^2} = 9\% = 0.4\,\text{dB}$

B.1.12 Audio Distortion

Uncertainty sources and estimates:

Distortion analyzer	3 %
Power supply	10 %
Power setting uncertainty	20 %
Audio load uncertainty	20 %

Example calculation: $RSS_{error} = \sqrt{3^2 + 10^2 + 20^2 + 20^2} = 30.1\% = 1.3\,\text{dB}$

B.1.13 Audio Squelch

Uncertainty sources and estimates:

Signal generator level	1 dB	23 %
Squelch setting	1 dB	23 %
Impedance matching network & Transmission line	0.2 dB	4.6 %
Signal generator mismatch $8.686 \times r_G \times r_R$	0.26 dB	6.0 %

Example calculation: $RSS_{error} = \sqrt{23^2 + 23^2 + 4.6^2 + 6.0^2} = 33.4\% = 1.5\,\text{dB}$

B.1.14 Squelch Blocking

Uncertainty sources and estimates:

Setting signal generator level	
Setting signal generator to rated system deviation	

Example calculation: None is provided since the method of measurement only records the presence of squelch blocking.

B.1.15 Receiver Attack Time

Uncertainty sources and estimates:

Switch closure	10 ms	10 %

B.1.16 Receiver Closing Time

Uncertainty sources and estimates:

Switch opening	10 ms	10 %

Example calculation: $RSS_{error} = \sqrt{0.4^2 + 0^2 + 10^2} = 10\%$

B.1.17 Audio Sensitivity

Uncertainty sources and estimates:

Signal generator level	0.3 dB	6.9 %
Squelch setting	1 dB	23 %
Impedance matching network & transmission line	0.2 dB	4.6 %
Signal generator mismatch 8.686	0.26 dB	6.0 %

Example calculation: $RSS_{error} = \sqrt{6.9^2 + 23^2 + 4.6^2 + 6.0^2} = 25.2\% = 1.1\,\text{dB}$

B.1.18 Impulse Blanking Effectiveness

Uncertainty sources and estimates:

Signal generator at reference level	0.5 dB	11.5 %
Reading SINAD meter with blanker on	0.5 dB	11.5 %
Reading SINAD meter with blanker off	0.5 dB	11.5 %
Signal generator attenuator	1 dB	23 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 11.5^2 + 11.5^2 + 23^2} = 30.4\% = 1.3\text{ dB}$

B.1.19 Average Radiation Sensitivity

Uncertainty sources and estimates:

SINAD meter	0.5 dB	11.5%
Test antenna	1 dB	23 %
Spectrum analyzer level	2 dB	46 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2 + 43^2} = 52.8\% = 2.3\text{ dB}$

B.1.20 Acoustic Audio Output

Uncertainty sources and estimates (assuming a non-reflective path verified by observing a 6dB change on the sound level meter for a 1:2 change in separation distance):

Rated power setting	0.1 dB	2.3 %
Sound level meter	1 dB	23 %

Example calculation: $RSS_{error} = \sqrt{2.3^2 + 23^2} = 23.1\% = 1\text{ dB}$

B.1.21 Blocking Rejection

Uncertainty sources and estimates (assuming that reference sensitivity is first measured with the generator that is used as an interfering generator that prevents any uncertainty caused by differences in absolute level between the signal generators):

Reference level setting	0.5 dB	11.5 %
Interfering signal generator level	1 dB	23 %
Contribution due to interfering signal generator frequency	1 dB	23 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2 + 23^2} = 34.5\% = 1.5\ \text{dB}$

B.1.22 Receiver Opening Time After PTT

Uncertainty sources and estimates:

Oscilloscope, time base fidelity	2 %
Oscilloscope, amplitude fidelity	1 %

Example calculation: $RSS_{error} = \sqrt{2^2 + 1^2} = 2.2\%$

B.2 Example Calculations for Transmitter Measurements

The examples in this section are for the limits in 3.2, based on the methods of measurement in 2.2 and the characteristics of equipment in 1.5. Conversion between decibels and percentage used herein utilize the symmetric approximation described in Equation 10 of Annex A.

B.2.1 RF Output Power

Uncertainty sources and estimates for a 25-watt transmitter:

Power meter/sensor: reference level		2 %
Calibration mismatch 8.686 x r_g x r_l = 8.686 x 0.029 x 0.091	0.023 dB	0.5 %
Sensor calibration factor		2.3 %
Range-to-range change (one range change)	0.02 dB	0.5 %
Meter linearity	0.02 dB	0.5 %
Meter zero	0.02 dB	0.5 %
Mismatch transmitter → load 8.686 x r_{TX} x r_{LI} = 8.686 x 0.33 x 0.091	0.26 dB	6.0 %
Mismatch load → power sensor 8.686 x r_{LO} x r_{SI} = 8.686 x 0.091 x 0.091	0.072 dB	1.76 %
Load attenuation (can be reduced if the attenuator is calibrated at the transmitter's frequency)	0.5 dB	11.5 %
Power supply contribution, @ 13.8 V 0.25 dB/V x 0.007V	0.02 dB	0.5 %

Example calculation:

$$RSS_{error} = \sqrt{2^2 + 2.3^2 + 5 \times 0.5^2 + 6^2 + 1.7^2 + 11.5^2} = 13.5\% = 0.59\,\text{dB}$$

Note: RSS error = 13.4% (0.58 dB) for 25 mW (+14 dBm) into the power sensor.

B.2.2 Carrier Frequency Stability

Uncertainty sources and estimates based on a frequency of 550 MHz:

Timebase (based on counter calibration cycle of 30 days), timebase drift x 30 days x 550 MHz = 10-9 x 30 x 550x106	16.5 Hz
Counter resolution	30 Hz

Example calculation: $RSS_{error} = \sqrt{16.5^2 + 30^2} = 34.2$ Hz

B.2.3 Modulation Limiting

Uncertainty sources and estimates:

Test receiver	1 %

Example calculation: $RSS_{error} = \sqrt{1^2} = 1\%$

B.2.4 Carrier Attack Time

Uncertainty sources and estimates:

Delta timebase	410 µS	0.4 %
Oscilloscope resolution	50 pS	0 %
Switch closure	10 mS	10 %

Example calculation: $RSS_{error} = \sqrt{0.4^2 + 10^2} = 10.8\%$

B.2.5 Audio Sensitivity

Uncertainty sources and estimates:

Distortion meter used to measure the noise output at the standard receiver output	3% of reading
RMS voltmeter used to measure the audio noise source output	2% of reading

Example calculation: $RSS_{error} = \sqrt{3^2 + 2^2} = 3.6\%$ of reading

B.2.6 Audio Frequency Response

B.2.6.1 Uncertainty sources and estimates, Method 1:

DMM at reference level	2 %
DMM at measured level	2 %
Test receiver	1 %

Example calculation: $RSS_{error} = \sqrt{2^2 + 2^2 + 1^2} = 3\% = 0.1 \text{ dB}$

B.2.6.2 Uncertainty sources and estimates, Method 2:

Test receiver at reference level	1 %
Test receiver at measured level	1 %
Audio generator frequency reference	2.3 %

Example calculation: $RSS_{error} = \sqrt{1^2 + 1^2 + 2.3^2} = 2.7\% = 0.1 \text{ dB}$

B.2.7 Audio Distortion

Uncertainty sources and estimates:

Distortion analyzer	3%
Distortion of the audio frequency generator	1%
Distortion added by the test receiver	1%

Example calculation: $RSS_{error} = \sqrt{3^2 + 1^2 + 1^2} = 3.3\%$

B.2.8 FM Hum and Noise Ratio

Uncertainty sources and estimates:

Uncertainty of the test receiver, DEV_{TOTAL}	1 %
Resolution of the test receiver, DEV_{TOTAL}	0.5 %
Test receiver	5 %
Resolution of the receiver for the DEV_{NOISE}	4.8 %

Example calculation: $RSS_{error} = \sqrt{1^2 + .5^2 + 5^2 + 4.8^2} = 8.6\%$

B.2.9 AM Hum and Noise Ratio

Uncertainty sources and estimates:

DMM	0.5%
Oscilloscope	1%

Example calculation: $RSS_{error} = \sqrt{.5^2 + 1^2} = 1.1\%$

B.2.10 Acoustic Microphone Sensitivity

Uncertainty sources and estimates:

Sound level meter	1 dB	11.5 %
Modulation level		1 %

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 1^2} = 11.5\%$

B.2.11 Sideband Spectrum

Uncertainty sources and estimates error:

Spectrum analyzer resolution bandwidth and frequency response flatness	0.6 dB	13.8 %
Spectrum analyzer amplitude log fidelity	2 dB	46 %

Example calculation: $RSS_{error} = \sqrt{13.8^2 + 46^2} = 48.1\% = 2.1\,\text{dB}$

B.2.12 Undesired Emissions: Radiated Spurious

Uncertainty sources and estimates:

Substitution antenna position and gain	1 dB	23 %
RF signal generator absolute level	1 dB	23 %
Mismatch between the signal generator output and the substitution antenna 8.686 x r_{SO} x r_{AT} = 8.686 x 0.091 x 0.33	0.26 dB	6.0 %
Standard radiation test site	3.0 dB	69 %

Example calculation: $RSS_{error} = \sqrt{23^2 + 23^2 + 6.0^2 + 69^2} = 76.6\% = 3.3\,\text{dB}$

Note: The uncertainty of the carrier power measurement needs to be included if the results were recorded as spurious emission attenuation rather than spurious emission power.

B.2.13 Undesired Emissions: Conducted Spurious

Uncertainty sources and estimates for a 10-watt transmitter:

Load power coefficient: (assume output VSWR = 2.0:1 into a 30 dB ±0.5 dB load with power factor 0.001 dB/dB x 10W)	0.3 dB	6.9 %
Mismatch transmitter → load 8.686 x r_{TX} x r_{LI} = 8.686 x 0.33 x 0.091	0.26 dB	6.0 %
Mismatch load → notch filter 8.686 x r_{LO} x r_{FI} = 8.686 x 0.091 x 0.091	0.07 dB	1.7 %
Mismatch notch filter→ spectrum analyzer 8.686 x r_{FO} x r_{AI} = 8.686 x 0.091 x 0.20	0.16 dB	3.6 %
signal generator level	1 dB	23 %
Signal generator → load 8.686 x r_{SO} x r_{LI} = 8.686 x 0.20 x 0.091	0.16 dB	3.6 %
Mismatch load→ notch filter 8.686 x r_{LO} x r_{FI} = 8.686 x 0.091 x 0.091	0.07 dB	1.7 %
Mismatch notch filter → spectrum analyzer 8.686 x r_{FO} x r_{AI} = 8.686 x 0.091 x 0.20	0.16 dB	3.6 %

Example calculation:

$$RSS_{error} = \sqrt{6.9^2 + 6^2 + 1.7^2 + 3.6^2 + 23^2 + 3.6^2 + 1.7^2 + 3.6^2} = 25.6\% = 1.1\,\text{dB}$$

Note: Uncertainty of the carrier power measurement needs to be included if the results were recorded as spurious attenuation.

B.2.14 Undesired Emissions: Adjacent Channel Power Ratio

B.2.14.1 Uncertainty sources and estimates for Method 1 (spectrum analyzer):

Spectrum analyzer frequency response flatness	0.6 dB	13.8 %
Spectrum analyzer amplitude log fidelity	1 dB	23 %

Example calculation: $RSS_{error} = \sqrt{13.8^2 + 23^2} = 26.8\% = 1.2\,\text{dB}$

B.2.14.2 Uncertainty sources and estimates for Method 2 (measuring receiver):

Relative power measurement	0.5 dB	11.5%
Filter bandwidth	1 dB	23%

Example calculation: $RSS_{error} = \sqrt{11.5^2 + 23^2} = 25.7\% = 1.1\,\text{dB}$

B.2.15 Low Pass Filter Response

Uncertainty sources and estimates:

Relative frequency flatness	0.6 dB	13.8 %
Log fidelity	1 dB	23 %
Output flatness of audio frequency generator	0.2 dB	2.3 %

Example calculation: $RSS_{error} = \sqrt{13.8^2 + 23^2 + 2.3^2} = 27\% = 1.2\,\text{dB}$

B.2.16 Intermodulation Attenuation

Uncertainty sources and estimates:

Power measurement (see clause on RF Output Power uncertainty)	0.59 dB	13.5%
20 dB attenuator	0.5 dB	11.5 %
Coupler loss	0.5 dB	11.5 %
10 dB attenuator	0.5 dB	11.5 %
(The above three could be reduced if the path were calibrated)		
Interfering signal to the transmitter:		
Mismatch of interfering source→ 20 dB attenuator 8.686 x r_{INT} x r_{20} = 8.686 x 0.33 x 0.046	0.13 dB	3.0 %
Mismatch of 20 dB att → coupler 8.686 x r_{20} x $r_{cplthru}$ = 8.686 x 0.046 x 0.166	0.07 dB	1.5 %
Mismatch uncertainty of coupler → 10 dB atten. 8.686 x $r_{cplthru}$ x r_{10} = 8.686 x 0.166 x 0.046	0.07 dB	1.5 %
Mismatch uncertainty of 10 dB att → transmitter 8.686 x r_{10} x r_{TX} = 8.686 x 0.0.046 x 0.33	0.13	3.0 %
Assume that the above uncertainty in the interfering signal will have a 1 dB/ 1 dB effect on the intermodulation product.		
Signals to the spectrum analyzer:		
Mismatch of transmitter → 10 dB attenuator 8.686 x r_{TX} x r_{10} = 8.686 x 0.33 x 0.046	0.13 dB	3.0 %

Mismatch of 10 dB att → coupler 8.686 x r_{10} x $r_{cplthru}$ = 8.686 x 0.046 x 0.166	0.07 dB	1.5 %
Mismatch of coupler → spectrum analyzer 8.686 x r_{cplau} x r_A = 8.686 x 0.23 x 0.20	0.4 dB	9.2 %
Spectrum analyzer frequency response flatness	0.6 dB	13.8 %
Spectrum analyzer log fidelity amplitude	2 dB	46.1 %

Example calculation:

$$RSS_{error} = \sqrt{13.5^2 + 3\times 11.5^2 + 3\times 3.0^2 + 3\times 1.5^2 + 9.2^2 + 13.8^2 + 46.1^2} = 54.9\% = 2.4\,\text{dB}$$

B.2.17 Average Radiated Power Output

Uncertainty sources and estimates:

Substitution antenna position and gain	1 dB	23 %
Mismatch between the signal generator output and the substitution antenna 8.686 x r_{SO} x r_{AT} = 8.686 x 0.091 x 0.33	0.26 dB	6.0 %
RF signal generator absolute level	1 dB	23 %
Radiation test site	3.0 dB	69 %

Example calculation: $RSS_{error} = \sqrt{23^2 + 6.0^2 + 23^2 + 69^2} = 76.6\% = 3.3\,\text{dB}$

B.2.18 Transmitter Stability into VSWR

Uncertainty sources and estimates:

Mismatch of signal generator → load 8.686 x r_{SO} x $r_{CPLR/TERM}$ = 0.686 x 0.091 x 0.091	0.07 dB	1 %
Signal generator	1 dB	23 %

Example calculation: $RSS_{error} = \sqrt{1.7^2 + 23^2} = 23.1\% = 1.0\,\text{dB}$

B.2.19 Transient Frequency Behavior

Uncertainty sources and estimates (assuming a 25mS timing measurement):

Oscilloscope timebase	410 µS	1.6 %
Demodulator capture	1 mS	20 %

Example calculation: $RSS_{error} = \sqrt{16^2 + 20^2} = 21.6\%$

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