



Active Antenna Amplifier Electrical Characteristics Tests

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. The purpose of this test is to determine certain operating performance characteristics for active antenna modules/bases operating in the Amplitude Modulation (AM) (530 kHz to 1710 kHz), Frequency Modulation (FM) (76.0 MHz to 107.9 MHz, Region Dependent), Terrestrial Digital Audio Broadcast/Terrestrial Digital Multimedia Broadcast (T-DAB/T-DMB) (174 MHz to 240 MHz), Remote Function Receiver (RFR) (314.9 MHz and 433.92 MHz), China Digital Television (CDTV) (470 MHz to 798 MHz), BeiDou/Galileo/Global Position Satellite (GPS)/Global Navigation Satellite System (GLONASS) (1568 MHz to 1608 MHz, System Dependent) collectively referred to herein as Global Navigation Satellite System (GNSS), and Satellite Digital Audio Radio Service (SDARS) (2320 MHz to 2345 MHz) bands such as, but not limited to, amplifier gain, amplifier noise figure, amplifier linearity, amplifier bandwidth, and passive antenna element isolation. Refer to 7.1 for definitions.

This document specifies requirements and test procedures for verification of active antenna system performance for all General Motors vehicles marketed and sold around the world. This document applies to passenger vehicles, light duty trucks, and medium duty trucks. In this document, an active antenna is defined as an antenna system where any part of it requires electrical power from the vehicle or receiver. A passive antenna does not require electrical power from the vehicle or receiver.

1.2 Applicability. This test procedure shall apply to active antennas. This procedure is applicable to the development and validation of antenna systems for new vehicle programs as well as design changes for current vehicles.

1.3 Remarks. The requirements stated in this document supersede all Component Technical Specifications (CTS), Subsystem Technical Specifications (SSTS), and Vehicle Technical Specifications (VTS) that pertain to AM/FM, T-DAB/T-DMB, RFR, CDTV, GNSS, and SDARS antenna systems until MY2022, after which all requirements will reside in Dynamic Object Oriented Requirements System (DOORS).

For active antenna technologies not specifically described in this document, the requirements of the nearest frequency band shall apply. Refer to applicable CTS/SSTS/VTS/Global Infotainment Standard (GIS) documents for further clarification.

Note: This document is one out of a series of five global antenna documents, which specify antenna test and validation requirements. The complete series consists of the following documents: GMW15648, GMW15649, GMW15650, GMW16039, and GMW16261. Additional antenna information can be found in the Infotainment Global Subsystem Leadership Team (GSSLT) documents GIS-24, GIS-46, GIS-90A, GIS-92, GIS-93(A), GIS-94(A), GIS-98 and GIS-99(A).

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ISO 17025 SX-9845-0105

2.2 GM Standards/Specifications.

GMW15648 GMW15650 GMW16039 GMW16261

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2.3 Additional References.

- Applicable antenna Component Technical Specification (CTS)
- Applicable antenna Subsystem Technical Specification (SSTS)
- Applicable antenna Vehicle Technical Specification (VTS)
- CG4926 Active Antenna Amplifier Performance Report External Supplement to GMW15649
- Infotainment Global Subsystem Leadership Team (GSSLT) documents GIS-24, GIS-46, GIS-90A, GIS-92, GIS-93(A), GIS-94(A), GIS-98 and GIS-99(A)
- K&L Microwave Low Pass Filter 6L120-816/T2000-O/O available at; <http://www.klmicrowave.com/>
- Keysight Noise Source 346B available at; <http://www.keysight.com/en/pd-1000001299%3Aeapsg%3Apro-pn-346B/noise-source-10-mhz-to-18-ghz-nominal-enr-15-db?nid=-536902744.536880068&cc=US&lc=eng>
- MiniCircuits BLP-100+ available at; http://www.minicircuits.com/products/filters_coax_low.shtml
- MiniCircuits ZFBT-4R2GW+ available at; http://www.minicircuits.com/products/bias_tees_coax.shtml
- MiniCircuits ZSC-2-1+ and ZN2PD2-50-S+ available at; www.minicircuits.com/products/psc_coax_2_0.shtml
- Miteq AU-1332 Amplifier available at; <https://miteq.com/docs/MITEQ-AU-1332-E2810.PDF>
- North Hills Impedance Adapter NH16448 available at; <http://www.nhsignal.com/pdf/products-wb-coaxial-adapters.pdf>
- Rohde and Schwarz EZ-12 Antenna Impedance Converter, SMW200A Vector Signal Generator (VSG), SMBV100A VSG, FSW8 Vector Spectrum Analyzer (VSA), ZNB8 Vector Network Analyzer (VNA), ZN-Z51 Calibration Unit, and NRP-Z91 Power Meter available at; http://www.rohde-schwarz.com/en/home_48230.html

3 Resources

3.1 Facilities. All measurements for the Antenna under Test (AUT) active module shall be done with the active module located in a shielded box or chamber with a minimum 80 dB isolation.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment. External calibration laboratories that are accredited to ISO 17025 shall be used to calibrate applicable equipment that is used for the testing outlined in this procedure. For antenna amplifiers that require nominal "5 Volt" power, the supply voltage for all tests is $5.0\text{ V} \pm 0.1\text{ V}$. For antenna amplifiers that require nominal "12 Volt" power, the supply voltage for all tests is $12.3\text{ V} \pm 0.1\text{ V}$ for Phantom Feed units and $13.8\text{ V} \pm 0.1\text{ V}$ for all other units unless otherwise specified. Phantom power voltage levels shall be set at the output of the three-port network (bias T) with module/base connected.

3.2.1 Amplifier Gain Related Tests. These tests require:

3.2.1.1 Network analyzer/VNA or Radio Frequency (RF) generator/VSG and spectrum analyzer/ VSA/receiver capable of covering the frequency range of 50.0 kHz to 3000 MHz.

3.2.1.2 Rohde and Schwarz EZ-12 Impedance Converter.

3.2.1.3 Bias T(s) capable of covering the frequency range of 500 kHz to 3000 MHz.

3.2.1.4 A 300 Ω unbalanced to 50 Ω unbalanced transformer for AM measurements only (e.g., North Hills Impedance Adapter Model NH16448).

3.2.1.5 Two (2) supplier-provided passive impedance transformers/matching networks (optional).

3.2.2 Amplifier Gain Variation with Supplied Voltage. This test requires a power supply capable of 7.5 V to 16.0 V, in addition to the equipment listed in 3.2.1.

3.2.3 Amplifier Gain Variation with Temperature. This test requires a temperature chamber capable of -40 °C to +85 °C, in addition to the equipment listed in 3.2.1.

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3.2.4 Amplifier Noise Figure (NF). This test requires:

3.2.4.1 Amplifiers ≤ 10 MHz (mandatory) and Amplifiers 10 MHz to 450 MHz (optional).

3.2.4.1.1 Spectrum analyzer or receiver capable of covering the frequency range of 0.5 MHz to 450 MHz.

3.2.4.1.2 Low Noise Amplifier (LNA) capable of covering the frequency range of 0.5 MHz to 450 MHz and sufficient gain to provide a sensitivity of -174 dBm/Hz (e.g., Miteq model number AU-1332 has a minimum gain of 45 dB with a noise figure of 1.4 dB).

3.2.4.1.3 A 300 Ω unbalanced to 50 Ω unbalanced transformer for AM measurements only (e.g., North Hills Impedance Adapter Model NH16448).

3.2.4.2 Amplifiers > 10 MHz (mandatory).

3.2.4.2.1 Noise Figure Meter or RF Signal Analyzer with Noise Figure Application and an appropriate noise source capable of covering the frequency range of 10 MHz to 3000 MHz.

3.2.4.3 Bias T(s) capable of covering the frequency range of 0.5 MHz to 3000 MHz.

3.2.5 Amplifier Linearity Related Tests. These tests require:

3.2.5.1 Amplifiers ≤ 450 MHz.

3.2.5.1.1 Two (2) RF generators/VSGs capable of covering the frequency range of 500 kHz to 450 MHz with an output power of +17 dBm. Any AM Band second harmonic shall be ≥ 55 dB down from the fundamental at +17 dBm output level. Any FM Band 2nd harmonic shall be ≥ 55 dB down from the fundamental at +17 dBm output level.

3.2.5.1.2 A 300 Ω unbalanced to 50 Ω unbalanced transformer for AM measurements only (e.g., North Hills Impedance Adapter Model NH16448).

3.2.5.2 Amplifiers ≥ 450 MHz.

3.2.5.2.1 Two (2) RF generators/VSGs capable of covering the frequency range of 450 MHz to 6000 MHz with an output power of $\geq +20$ dBm.

3.2.5.3 Spectrum analyzer or receiver capable of covering the frequency range of 500 kHz to 6000 MHz.

3.2.5.4 Two (2) Way combiner(s) with ≥ 23 dB typical port isolation and ≤ 4 dB typical insertion loss covering the frequency range of 500 kHz to 6000 MHz. **Note:** This requirement may require the use of separate combiners depending on the test condition.

3.2.5.5 Bias T(s) capable of covering the frequency range of 500 kHz to 3000 MHz.

3.2.6 Antenna Isolation. This test requires a VNA capable of covering the range of 450 MHz to 6000 MHz.

3.2.6.1 Straight-edge 1 m ground plane with appropriate antenna mounting hole/adapter

3.2.7 Bandwidth Related Tests. This test requires a VNA or RF generator/VSG and spectrum analyzer/receiver capable of covering the frequency range of 250 MHz to 3000 MHz.

3.2.7.1 Bias T capable of covering the frequency range of 300 MHz to 450 MHz if not a part of the network analyzer.

3.2.8 Active Current Draw. This test requires a milliammeter capable of 0.1 mA resolution.

3.3 Test Vehicle/Test Piece. The tests described herein shall be performed on Design Validation (DV) and Product Validation (PV) AUT. The AUT is comprised of any of the following: Passive matching network (passive module), active matching network (active module), input interconnects, and the antenna element(s).

3.4 Test Time.

Calendar time: (2 to 3) d

Test time: 28 h

Coordination time: 6 h

3.5 Test Required Information. The minimum test information shall contain the antenna manufacturer, the AUT module part number, serial number and version (DV or PV) and date tested.

3.6 Personnel/Skills. Test personnel shall have a working knowledge of spectrum analyzers, network analyzers, test receivers, milli-ohmmeters, antennas, and other RF equipment. A working knowledge of computers and data spreadsheets is also required.

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4 Procedure

4.1 Preparation. All test equipment shall be turned on for a minimum of 30 minutes before any AUT measurements begin.

4.2 Conditions.

4.2.1 Environmental Conditions. Equipment and AUT should be at a room temperature of $+23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$, and a relative humidity of 25% to 75%, unless otherwise specified.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.2.2.1 Care shall be taken to avoid overload conditions when using a spectrum analyzer to measure 2nd Order Intermodulation (IM2), 3rd Order Intermodulation (IM3), and Harmonic signals. Filters may be required on the spectrum analyzer input to ensure accurate measurements.

4.2.2.2 Care shall be taken to ensure that the input direct current (DC) voltage(s) at any bias T are adjusted to compensate for the current draw of the base/module and that the voltage at the bias T RF+DC port matches the specified DC voltage(s) for the particular test.

4.2.3 AUT Conditions. Except where otherwise noted, AUT modules or bases $\leq 450\text{ MHz}$ with an input wire or contact shall have the input wire or contact replaced with either a Sub Miniature version A (SMA), Sub Miniature version B (SMB) connector soldered directly onto the circuit board or a Bayonet Neill-Concelman (BNC) connector and a short length of RG-174 coaxial cable (not to exceed 5 cm total) soldered directly onto the circuit board. Optionally, RG-58 coaxial cable with a length of 5 m may be added to the output of the amplifier to simulate vehicle coaxial loss. For AUT modules or bases $\geq 450\text{ MHz}$, the antenna element shall be replaced with an SMA connector soldered directly onto the circuit board at the antenna element input. The circuit board(s) shall be mounted in the AUT housing as intended for mounting on a vehicle.

4.2.3.1 For all SDARS measurements, the antenna shall be submitted to SiriusXM (SXM) for Type Acceptance according to the latest revision of SX-9845-0105 and the Type Acceptance Test Report (TATR) shall be submitted to General Motors along with the GMW15649 data. Successful completion of the SXM antenna type acceptance for SXM frequencies will be evaluated against SDARS requirements contained in this document for compliance, and subject to additional testing by General Motors (GM).

4.2.3.2 AUT AM amplifier measurements shall have network analyzer port one or RF generator connected to a network comprised of a $50\text{ }\Omega$ termination with a $1\text{ k}\Omega$ resistor in series with the input of the module or base input. When using a $300\text{ }\Omega$ to $50\text{ }\Omega$ transformer, thru-calibration of the network analyzer shall include the connection cables only. The bias T (if necessary) and the $300\text{ }\Omega$ to $50\text{ }\Omega$ transformer losses shall be measured separately. If it is necessary to use a Rohde and Schwarz EZ-12, thru-calibration of the network analyzer shall include the resistor network, bias T (if necessary), and the EZ-12. All measurements and requirements assume these configurations

4.2.3.3 AUT FM, T-DAB/T-DMB, GNSS, SDARS, CDTV, and RFR amplifiers that require the use of a bias T shall include the bias T in the network analyzer thru-calibration. An AUT supplier may, at their discretion, provide two (2) passive impedance transformers/matching networks or a Touchstone S2P file to be used in the event the AUT module or base is not nominally $50\text{ }\Omega$. The loss of each transformer/matching network shall be determined by performing an S21 measurement at each test frequency on the two (2) transformers/matching networks end-to-end and dividing the result by two (2). The transformer/matching network loss shall be compensated for in the amplifier gain measurement. All measurements and requirements are assumed to be in a $50\text{ }\Omega$ system and failure to provide a passive impedance transformer/matching network or a Touchstone S2P file for systems that are not $50\text{ }\Omega$, does not constitute a deviation when requirements are not met.

4.3 Instructions.

4.3.1 AM Amplifier Measurements.

4.3.1.1 AM Amplifier Active Gain Requirements. The AM Amplifier Active Gain shall meet the requirements as shown in Table 1.

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Table 1: AM Amplifier Gain Requirements

Frequency (kHz)	Gain (dB)	Attenuation (dB)
77.5	n/a	≥ 15
530 to 1710	≤ 13	n/a

Note: n/a = Not applicable.

4.3.1.1.1 Test Method.

- Connect the AUT and equipment as shown in Figure 1 utilizing the 300 Ω to 50 Ω transformer on the amplifier output. The VNA Port 1 shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. **Note:** It is the responsibility of entity performing the test to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- Set the DC Power Supply to 12.3 V $\pm$ 0.1 V for phantom powered/13.8 V $\pm$ 0.1 V for direct powered AUTs.
- Set up the VNA for an S21 measurement with start frequency = 500 kHz, stop frequency = 1720 kHz, source power = -40 dBm.
- Perform a 2-port calibration with the appropriate calibrate path illustrated in Figure 1. Thru-calibration of the network analyzer shall include the connection cables only. The bias T (if necessary) and the 300 Ω to 50 Ω transformer losses shall be measured separately.
- Insert the module/base under test and record the respective gain values required in CG4926.
- Replace the VNA with the VSG/signal generator and spectrum analyzer.
- Configure the VSG/signal generator for 77.5 kHz Continuous Wave (CW) output at 0 dBm at the input network.
- Configure the spectrum analyzer for a Center Frequency = 77.5 kHz, span = 10 kHz, reference level = 10 dBm, attenuator = auto, dB/div = 10, Resolution Bandwidth (RBW) = 1 kHz, Video Bandwidth (VBW) = auto and preamp gain = 0 dB.
- Measure the output of the VSG/signal generator and adjust for a 0 dBm input at the AM Input Network using the spectrum analyzer.
- Disconnect the VSG/signal generator from the spectrum analyzer and connect it to the AM Input Network of the AUT.
- Measure the output of the AUT with the spectrum analyzer and calculate the 77.5 kHz gain: VSG/signal generator output level (dBm) – spectrum analyzer measured level (dBm) = AUT 77.5 kHz Attenuation (dB).

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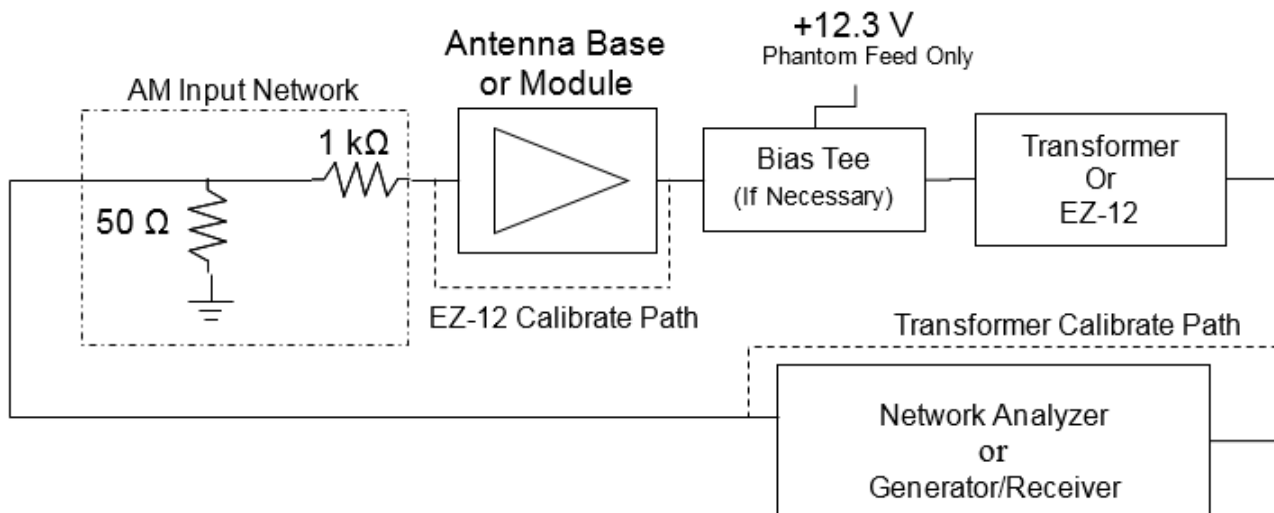
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Figure 1: AM Amplifier Gain Equipment Configuration



4.3.1.2 AM Amplifier Active Gain Requirements with Voltage Variation. The AM Amplifier Active Gain with Voltage Variation shall not exceed ± 1 dB from the gain values measured at 12.3 V for the minimum and maximum operating voltages of 7.5 V and 14.5 V for phantom power supplied amplifiers and at 9.0 V and 16.0 V for direct battery powered amplifiers from 530 kHz to 1710 kHz.

4.3.1.2.1 Test Method.

- Connect the AUT and equipment as shown in Figure 1 utilizing the 300 Ω to 50 Ω transformer on the amplifier output. The VNA Port 1 shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. **Note:** It is the responsibility of entity performing the test to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- Set the DC Power Supply to 7.5 V $\pm$ 0.1 V for phantom powered/9.0 V $\pm$ 0.1 V for direct powered.
- Set up the VNA for an S21 measurement with start frequency = 500 kHz, stop frequency = 1720 kHz, source power = -40 dBm.
- Perform a 2-port calibration with the appropriate calibrate path illustrated in Figure 1. Thru-calibration of the network analyzer shall include the connection cables only. The bias T (if necessary) and the 300 Ω to 50 Ω transformer losses shall be measured separately.
- Insert the module/base under test and record the respective gain values required in CG4926.
- Repeat the gain measurement with the DC Power Supply set to 14.5 V $\pm$ 0.1 V for phantom powered/16.0 V $\pm$ 0.1 V for direct powered.

4.3.1.3 AM Amplifier Active Gain Requirements with Temperature Variation. The AM Amplifier Active Gain with Temperature Variation shall not exceed ± 2 dB from the gain values measured at 12.3 V and nominal temperature across the temperature range of -40 $^{\circ}$ C to +85 $^{\circ}$ C from 530 kHz to 1710 kHz.

4.3.1.3.1 Test Method.

- Connect the AUT and equipment as shown in Figure 1 utilizing the 300 Ω to 50 Ω transformer on the amplifier output. The VNA Port 1 shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. The AUT, Input Network, Bias Tee, Transformer and Inductor shall be located inside the thermal chamber. **Note:** It is the responsibility of the entity performing the test to ensure these devices do not degrade or enhance the gain measurement due to temperature variations. In addition, it is the responsibility of the entity performing the test to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- Set the DC Power Supply to 12.3 V $\pm$ 0.1 V for phantom powered/13.8 V $\pm$ 0.1 V for direct powered AUTs.

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- c. Set up the VNA for an S21 measurement with start frequency = 500 kHz, stop frequency = 1720 kHz, source power = -40 dBm.
- d. Perform a 2-port calibration with the appropriate calibrate path illustrated in Figure 1. Thru-calibration of the network analyzer shall include the connection cables only. The bias T (if necessary) and the 300 Ω to 50 Ω transformer losses shall be measured separately. Ensure that the cables used in the test are stable over the operating temperature range of the test.
- e. Insert the module/base under test along with the appropriate input network, output network and power filters/bias tee into the temperature chamber.
- f. Set the temperature chamber to $-40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, and remove power from the AUT (unpowered cold soak).
- g. After the thermal chamber has stabilized at the test temperature, and the AUT soaked for 1 h, power the unit and record the respective gain values required in CG4926.
- h. Set the temperature chamber to $85\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, and maintain power to the AUT (powered hot soak).
- i. After the thermal chamber has stabilized at the test temperature, and the AUT soaked for 1 h with power applied, record the respective gain values at required in CG4926.

4.3.1.4 AM Amplifier Active Gain Requirements with and without 1 k Ω Series Input Resistor. The AM Amplifier Active Gain difference with and without a 1 k Ω series input resistor shall not exceed ± 0.5 dB at 530 kHz and ± 1.0 dB at 1710 kHz.

4.3.1.4.1 Test Method.

- a. Connect the AUT and equipment as shown in Figure 1 utilizing the EZ-12 on the amplifier output. The VNA Port 1 shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. **Note:** It is the responsibility of entity performing the test to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- b. Set the DC Power Supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- c. Set up the VNA for an S21 measurement with start frequency = 500 kHz, stop frequency = 1720 kHz, source power = -40 dBm.
- d. Remove the 1 k Ω resistor, keeping the 50 Ω termination and perform a thru-port calibration with the appropriate calibrate path illustrated in Figure 1. Thru-calibration of the network analyzer shall include the connection cables and the EZ-12 with the input 50 Ω termination. The bias T (if necessary) losses shall be measured separately.
- e. Insert the module/base under test and record the respective gain values at 530 kHz and 1710 kHz.
- f. Place the 1 k Ω resistor back into the input path as shown in Figure 1, and record the respective gain values at 530 kHz and 1710 kHz.

4.3.1.5 AM Amplifier Noise Figure Requirements. The AM Amplifier Noise Figure shall not exceed 20 dB from 530 kHz to 1710 kHz.

4.3.1.5.1 Test Method.

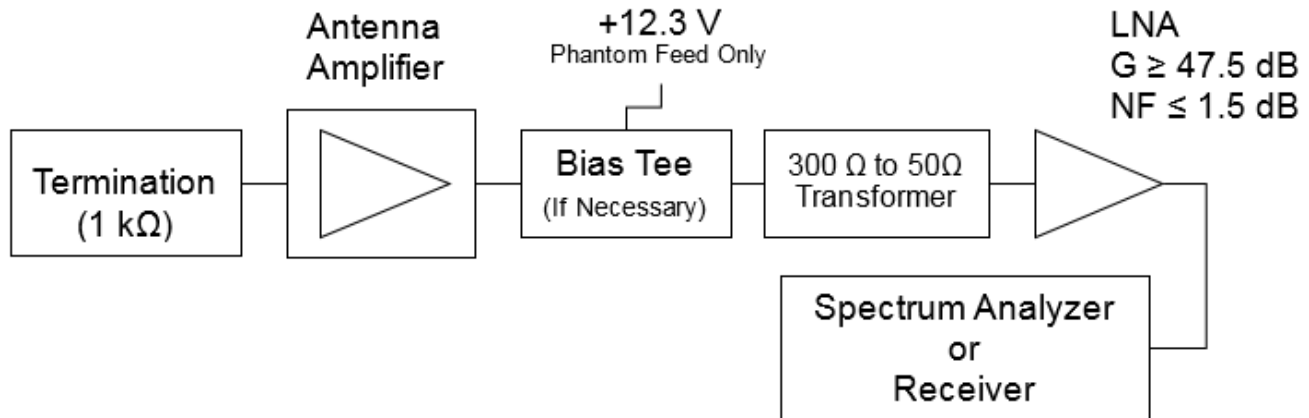
- a. Connect the AUT and equipment as shown in Figure 2 utilizing the 300 Ω to 50 Ω transformer and Miteq Amplifier on the amplifier output. The input shall be terminated with a 1 k Ω (The AM Input Matching Network may be used in lieu of a single 1 k Ω resistor across the input). All references to AUT gain are those gain values measured in 4.3.1.1 on the same AUT. **Note:** It is the responsibility of tester to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- b. Set the DC Power Supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- c. Set up the spectrum analyzer for center frequency = 530 kHz, span = 2 kHz, amplitude units = dBm, attenuator = 0 dB, dB/div = 10, RBW = 1 kHz, VBW = 300 Hz, preamp gain = (30 dB bandwidth correction + Miteq AU-1332 gain: 47.8 dB typical), and video average = 100.
- d. Adjust the reference level in 10 dB increments so that the trace is located around the 5th graticule.
- e. Activate the video average and place trace in view after 100 video averages are completed.
- f. Place the marker at the center frequency and record the amplitude value as the measured noise level and calculate the noise figure according to the following formula:

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- g. $NF = 174 + (\text{measured noise level in dBm}) - (10 \log (\text{measurement bandwidth in Hz})) - \text{LNA gain} - \text{AUT gain} + 300 \Omega \text{ to } 50 \Omega \text{ transformer loss} + \text{bias T loss}$ (e.g., measurement bandwidth of 1 kHz equals 30 dBHz).
- h. Change the center frequency to 1710 kHz and repeat steps c through f.
- i. This procedure shall be used for any frequency in the AM band regardless of region.

Figure 2: AM Noise Figure Equipment Configuration



Note: G = Gain, NF = Noise Figure.

4.3.1.6 AM Amplifier Second Order Intermodulation Product (IM2) Requirements. The AM IM2 product shall be ≥ 30 dB below the input signal level.

4.3.1.6.1 Test Method.

- a. Connect the AUT and equipment as shown in Figure 3 utilizing the 300 Ω to 50 Ω transformer on the amplifier output. The common port of the power combiner shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. **Note:** It is the responsibility of tester to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- b. Configure the spectrum analyzer for center frequency = 1100 kHz, span = 10 kHz, reference level = 30 dBm, attenuator = auto, dB/div = 10, RBW = 1 kHz, VBW = RBW and preamp gain = 0 dB.
- c. Configure the VSG/signal generator to source 610 kHz and 1710 kHz Continuous Wave (CW) from the RF output ports.
- d. Configure the amplitude of each VSG/signal generator port for a 114 dBuV (+7 dBm) test signal level, as measured on the output of the power combiner. The spectrum analyzer shall be used for this measurement set to the appropriate source frequency and utilizing all the other settings as stipulated in step b.
- e. Verify the equipment setup and ensure the spectrum analyzer is configured for center frequency = 1100 kHz.
- f. If the test frequency is not on the spectrum analyzer screen, decrease the reference level until the test frequency is between the first and second graticule. Care should be taken not to overload the input of the spectrum analyzer.
- g. Record the amplitude at 1100 kHz from the spectrum analyzer.
- h. The requirement level is determined by subtracting the spectrum analyzer value from the test signal level of 114 dBuV (+7 dBm).
- i. **Note:** In lieu of the VSG/signal generators and spectrum analyzer, a VNA with Intermodulation Measurement Options may be used to perform the intermodulation measurement.

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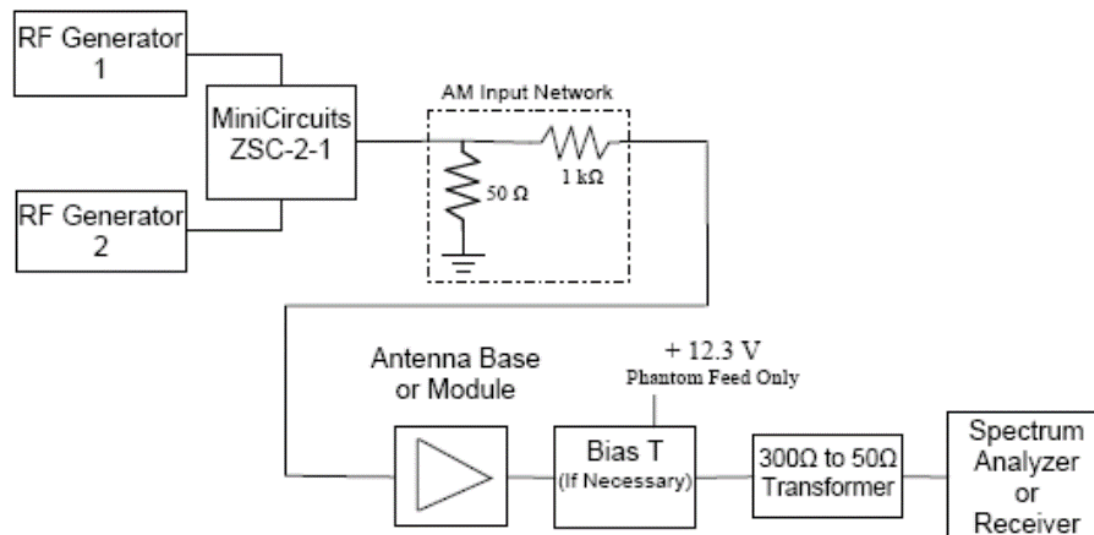
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Figure 3: AM IM2 and IM3 Measurement Equipment Configuration



Note: Filters may be required on the RF Generators and/or spectrum analyzer for maximum accuracy.

4.3.1.7 AM Amplifier Third Order Intermodulation Product (IM3) Requirements. The AM IM3 product shall be ≥ 45 dB below the input signal level.

4.3.1.7.1 Test Method.

- Connect the AUT and equipment as shown in Figure 3 utilizing the 300 Ω to 50 Ω transformer on the amplifier output. The common port of the power combiner shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. **Note:** It is the responsibility of tester to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- Configure the spectrum analyzer for center frequency = 900 kHz, span = 10 kHz, reference level = 30 dBm, attenuator = auto, dB/div = 10, RBW = 1 kHz, VBW = RBW and preamp gain = 0 dB.
- Configure the VSG/signal generator to source 600 kHz and 750 kHz CW from the RF output ports.
- Configure the amplitude of each VSG/signal generator port for a 114 dBuV (+7 dBm) test signal level, as measured on the output of the power combiner. The spectrum analyzer shall be used for this measurement set to the appropriate source frequency and utilizing all the other settings as stipulated in step b.
- Verify the equipment setup and ensure the spectrum analyzer is configured for center frequency = 900 kHz.
- If the test frequency is not on the spectrum analyzer screen, decrease the reference level until the test frequency is between the first and second graticule. Care should be taken not to overload the input of the spectrum analyzer. Record the amplitude at 900 kHz from the spectrum analyzer.
- The requirement level is determined by subtracting the spectrum analyzer value from the test signal level of 114 dBuV (+7 dBm).
- Note:** In lieu of the VSG/signal generators and spectrum analyzer, a VNA with Intermodulation Measurement Options may be used to perform a swept intermodulation measurement.

4.3.1.8 AM Amplifier Current Draw. The DC Current draw shall not exceed 100 mA.

4.3.1.8.1 Test Method.

- Connect the AUT and equipment as shown in Figure 1 utilizing the 300 Ω to 50 Ω transformer on the amplifier output. The VNA Port 1 shall be connected to a network comprised of a 50 Ω termination with a 1 k Ω resistor in series with the input of the AUT. **Note:** It is the responsibility of tester to ensure that there is sufficient isolation between the DC power supply and the AUT output so as not to introduce additional bias tee insertion loss.
- Place a milliammeter in series with the DC power supply.

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- c. Set the DC power supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- d. Set up the VNA for an S21 measurement with start frequency = 500 kHz, stop frequency = 1720 kHz, source power = -40 dBm.
- e. Measure and record the current draw using the series milliammeter.

4.3.2 FM Amplifier Measurements.

4.3.2.1 FM Amplifier Active Gain Requirements. The FM Amplifier Active Gain shall meet the requirements for the respective regional FM Bands as shown in Table 2.

Table 2: FM Amplifier Gain Requirements

Frequency (MHz)			Gain (dB)		Attenuation (dB)	
Japan	International	Brazil	Shark Fin	All Others	Receive Only	w/TX Ant ^{Note}
76.1 to 89.9	87.9 to 107.9	76.1 to 107.9	≤ 16	≤ 13	n/a	n/a
900			n/a	n/a	≥ 30	≥ 40
1800			n/a	n/a	≥ 25	≥ 40

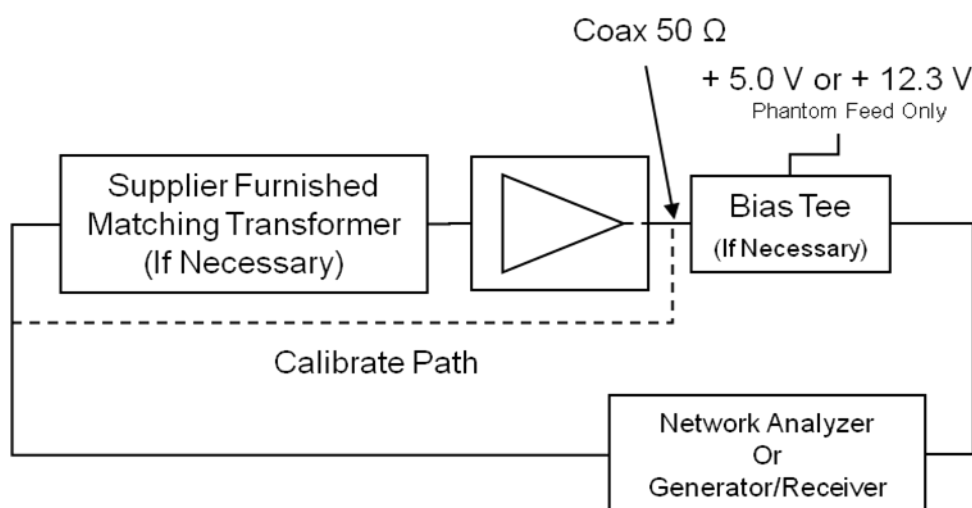
Note: The term "w/TX Ant" is defined as multiband units with transmit antennas located in the same physical package.

Note: n/a = Not applicable

4.3.2.1.1 Test Method.

- a. Connect the AUT and equipment as shown in Figure 4.
- b. Set the DC Power Supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- c. Configure the VNA for an S21 measurement with start frequency = 76 MHz, stop frequency = 108 MHz, source power = -40 dBm. Set the markers for the frequencies listed in CG4926 for the AUT region.
- d. Perform a 2-port calibration on the VNA with the appropriate calibrate path illustrated in Figure 4.
- e. Insert the module/base under test and record the respective gain values at the marker frequencies required for the AUT region listed in CG4926.

Figure 4: Amplifier Gain and RFR Bandwidth Equipment Configuration



Note: Coax = Coaxial.

4.3.2.2 FM Amplifier Active Gain Requirements with Voltage Variation. The FM Amplifier Active Gain with Voltage Variation shall not exceed $\pm 1\text{ dB}$ from the gain values measured at 12.3 V for the minimum and

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maximum operating voltages of 7.5 V and 14.5 V for phantom power supplied amplifiers and at 9.0 V and 16.0 V for direct battery powered amplifiers in the regional FM band under test as defined in Table 2.

4.3.2.2.1 Test Method.

- Connect the AUT and equipment as shown in Figure 4.
- Set the DC Power Supply to $7.5\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $9.0\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- Configure the VNA for an S21 measurement with start frequency = 76 MHz, stop frequency = 108 MHz, source power = -40 dBm. Set the markers for the frequencies listed in CG4926.
- Perform a 2-port calibration on the VNA with the appropriate calibrate path illustrated in Figure 4.
- Insert the module/base under test and record the respective gain values at the marker frequencies required for the AUT region in CG4926.
- Repeat the gain measurement with the DC power supply set to $14.5\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $16.0\text{ V} \pm 0.1\text{ V}$ for direct powered.

4.3.2.3 FM Amplifier Active Gain Requirements with Temperature Variation. The FM Amplifier Active Gain with Temperature Variation shall not exceed $\pm 2\text{ dB}$ from the gain values measured at 12.3 V and nominal temperature across the temperature range of $-40\text{ }^{\circ}\text{C}$ to $+85\text{ }^{\circ}\text{C}$ in the regional FM band under test as defined in Table 2.

4.3.2.3.1 Test Method.

- Connect the AUT and equipment as shown in Figure 4.
- Set the DC Power Supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- Configure the VNA for an S21 measurement with start frequency = 76 MHz, stop frequency = 108 MHz, source power = -40 dBm. Set the markers for the frequencies listed in CG4926.
- Perform a 2-port calibration on the VNA with the appropriate calibrate path illustrated in Figure 4.
- Insert the module/base under test into the temperature chamber.
- Set the temperature chamber to $-40\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, and remove power from the AUT (unpowered cold soak).
- After the thermal chamber has stabilized at the test temperature, and the AUT soaked for 1 h, power the unit and record the respective gain values at the marker frequencies required for the AUT region in CG4926.
- Set the temperature chamber to $85\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, and maintain power to the AUT (powered hot soak).
- After the thermal chamber has stabilized at the test temperature, and the AUT soaked for 1 h with power applied record the respective gain values at the marker frequencies required for the AUT region in CG4926.

4.3.2.4 FM Amplifier Noise Figure Requirements. The FM Amplifier Noise Figure shall not exceed 5 dB in the regional FM band under test as defined in Table 2.

4.3.2.4.1 Test Method.

- Connect the AUT and equipment as shown in Figure 5.
- Set the DC Power Supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- Disconnect the Noise Source, and calibrate the Noise Source with the Noise Figure Measuring Device.
- Reconnect the equipment as shown in Figure 5 and record the Noise Figure at frequencies required for the AUT region in CG4926.
- Note:** If Noise Figure is performed as a swept measurement, the plot should also be included in the appropriate worksheet in CG4926.

4.3.2.4.2 Alternate Test Method.

- Connect the AUT and equipment as shown in Figure 2 with the exception of the $300\text{ }\Omega$ to $50\text{ }\Omega$ transformer. Connect the Miteq Amplifier on the amplifier output. The input shall be terminated with amplifier characteristic impedance and not $1\text{ k}\Omega$. All references to AUT gain are those gain values measured in 4.3.2.1 on the same AUT.
- Set the DC power supply to $12.3\text{ V} \pm 0.1\text{ V}$ for phantom powered/ $13.8\text{ V} \pm 0.1\text{ V}$ for direct powered AUTs.
- Set up the spectrum analyzer for center frequency = 88 MHz, span = 2 kHz, amplitude units = dBm, attenuator = 0 dB, dB/div = 10, RBW = 1 kHz, VBW = 300 Hz, preamp gain = (30 dB bandwidth correction + Miteq AU-1332 gain: 47.8 dB typical), and video average = 100.

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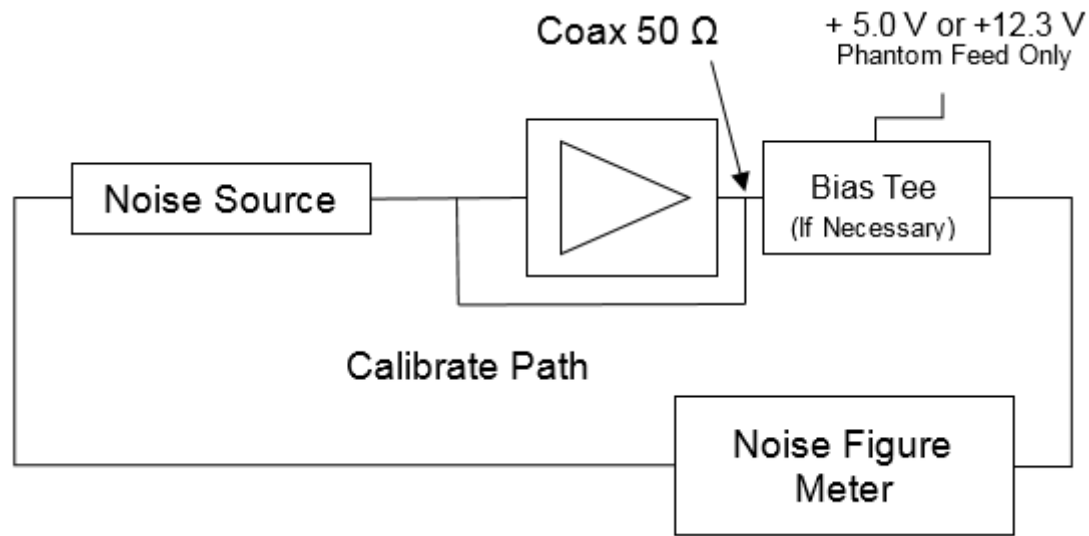


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- d. Adjust the reference level in 10 dB increments so that the trace is located around the 5th graticule.
- e. Activate the video average and place trace in view after 100 video averages are completed.
- f. Place the marker at the center frequency and record the amplitude value as the measured noise level and calculate the noise figure according to the following formula:
- g. $NF = 174 + (\text{measured noise level in dBm}) - (10 \log(\text{measurement bandwidth in Hz})) - \text{LNA gain} - \text{AUT gain} + \text{bias T loss}$ (e.g., measurement bandwidth of 1 kHz equals 30 dBHz).
- h. Change the center frequency to the next frequency required for the AUT region in CG4926 and repeat steps c through f, until all the required frequencies are tested.

Figure 5: Noise Figure Equipment Configuration



4.3.2.5 FM Amplifier Automatic Gain Control (AGC) Requirements. The FM Amplifier AGC shall limit the output of the FM Amplifier to a maximum of 100 dBuV (-7 dBm) for input signal levels below and including 121 dBuV (+14 dBm) in the regional FM band under test as defined in Table 2.

4.3.2.5.1 Test Method.

- a. Connect the AUT and equipment as shown in Figure 6.
- b. Measure and record the RF losses of all elements and cables in the signal path from the AUT output and the spectrum analyzer.
- c. Configure the VSG/signal generator for a CW Signal at 98.1 MHz and an output of 85 dBuV (-22 dBm).
- d. Configure the spectrum analyzer for center frequency = 98.1 MHz, span = 10 kHz, reference level = 10 dBm, attenuator = auto, dB/div = 10, RBW = 1 kHz, VBW = RBW and preamp gain = 0 dB.
- e. Disconnect the VSG/signal generator Output at the AUT Input, and connect it to the input of the Spectrum analyzer.
- f. Adjust the VSG/signal generator output until the spectrum analyzer measures 85 dBuV (-22 dBm).
- g. Reconnect the VSG/signal generator to the AUT input, measure the AUT output on the spectrum analyzer output, add any losses measured in preceding step b, and record this as the AUT output level in CG4926.
- h. Repeat steps f and g at every 3 dB increments until the input level reaches 121 dBuV (+14 dBm).
- i. **Note:** In lieu of the VSG/signal generators and spectrum analyzer, a VNA with Power/Gain Sweep Measurement Options may be used to perform a swept gain measurement.

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