



Vehicle AM/FM, T-DAB/T-DMB, RFR, Gain, Directionality, and Impedance Test

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 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 (T-DAB)/Terrestrial Digital Multimedia Broadcasting (T-DMB) (174 MHz to 240 MHz) and Radio Frequency Remote (RFR) (314.9 MHz and 433.92 MHz) system gain, directionality, impedance, and feedline cable shield resistance. Gain refers to the ratio of the intensity of an antenna radiation pattern compared to that of a reference antenna. Directionality refers to the uniformity of an antenna radiation pattern.

This standard specifies requirements and test procedures for verification of AM, FM, T-DAB/T-DMB, and RFR antenna system performance for all GM vehicles marketed and sold around the world. This standard applies to passenger vehicles, light duty trucks, and medium duty trucks. In this standard, an active antenna is defined as an antenna system where any part of it requires electrical power from the vehicle. A passive antenna does not require electrical power from the vehicle.

Additionally, an optional active antenna noise test may be performed to gain insight into the system's emissions performance. (See Appendix B.)

1.2 Applicability. This test procedure shall apply to all passive and 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 standard supercede all Component Technical Specifications (CTS), Subsystem Technical Specifications (SSTS), and Vehicle Technical Specifications (VTS) that pertain to antenna systems mentioned herein until model year 2022, after which, all requirements will reside in Dynamic Object Oriented Requirements System (DOORS).

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

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

2 References

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

2.1 External Standards/Specifications.

ISO/IEC 17025

2.2 GM Standards/Specifications.

GMW3091

GMW3172

GMW15648

GMW15649

GMW3097

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2.3 Additional References.

- Applicable antenna CTS
- Applicable antenna SSTS
- Applicable antenna VTS
- CAPCON Electromagnetic Interference (EMI) suppressant tubing or equivalent available at Uniform Resource Locator (URL): <http://www.capconemi.com/>.
- ETS Model 3121 Roberts Dipole Antenna available at URL <http://www.ets-lindgren.com>
- GIS-24
- GIS 46
- GIS-90A
- GIS-92
- GIS-98
- GM Antenna Part Number 22876544 available to order at any GM brand dealership
- Mini-Circuits ZFBT-4R2G available at URL: <http://www.minicircuits.com/homepage/homepage.html>
- Rohde and Schwarz EZ-12 Antenna Impedance Converter available at URL http://www.rohde-schwarz.com/en/home_48230.html
- TEGAM Model 253 Impedance Meter available at URL: <http://www.tegam.com/>
- Yagi-Uda Antenna available at URL www.yagi-uda.com

3 Resources

3.1 Facilities. Facilities must be compliant with ISO/IEC 17025.

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.

3.1.3 The AM Gain test facility shall be an open air environment with a minimum 100 m radius clear space around the Vehicle Under Test (VUT). The test site shall be 10 km from any AM/FM transmitting station > 10 kW. Regional spectrum usage permission may be required for AM transmission (if required).

3.1.4 The FM, T-DAB/T-DMB, and RFR Gain test facility shall be an open air environment with a minimum 100 m radius clear space around the VUT. The test site shall be 10 km from any AM/FM transmitting station > 10 kW. Regional spectrum usage permission may be required for FM transmission.

3.2 Equipment.

3.2.1 AM Gain. This test requires:

3.2.1.1 Spectrum Analyzer or Receiver with a minimum frequency range of 0.5 MHz to 2 MHz.

3.2.1.2 Rohde and Schwarz EZ-12 Antenna Impedance Converter available at Uniform Resource Locator (URL) http://www.rohde-schwarz.com/en/home_48230.html.

3.2.1.3 AM Reference consisting of a rod antenna 775 mm in length with a feedline of RG62U modified cable 2000 mm in length (GM part number 22876544). The antenna shall be mounted on an aluminum box with the following dimensions; 432 mm (length) × 254 mm (width) × 102 mm (height) (Hammond model 1444-33 box with 1434-30 cover, or equivalent) onto the 432 mm (length) × 254 mm (width) surface, i.e., the largest side.

3.2.1.4 Battery capable of providing power to the spectrum analyzer or receiver for 30 minutes (minimum).

3.2.1.5 Direct Current (DC) to Alternating Current (AC) Inverter that is capable of powering the spectrum analyzer. This item is not necessary if the spectrum analyzer or receiver is capable of operation on direct battery power. The emissions for the DC to AC inverter and test equipment should be measured according to GMW3097, for each test band, to avoid injecting Electromagnetic Compatibility (EMC) noise into the antenna measurements.

3.2.2 FM Gain and Directionality. This test requires:

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3.2.2.1 Transmit antenna(s) to cover the frequency range 76 MHz to 108 MHz with a Voltage Standing Wave Ratio (VSWR) < 2.5:1. Transmit antenna type should be a log periodic, BiConiLog, or a Yagi-Uda type (URL: www.yagi-uda.com).

3.2.2.2 Reference antennas (dipole, folded dipole, or log periodic antennas only) to cover the frequency range 76 MHz to 108 MHz with a VSWR < 2.0:1. All gain values shall be normalized to a tunable dipole, e.g., ETS Model 3121 Roberts Dipole (URL: <http://www.ets-lindgren.com/>). Normalization can be done by either using calibrated antenna factors, or by deriving a correction factor by measuring the received power difference between the reference antenna and the tunable dipole (Roberts Dipole).

3.2.2.3 Spectrum Analyzer, Receiver, or Network Analyzer with a minimum frequency range of 70 MHz to 110 MHz.

3.2.2.4 Radio Frequency (RF) Signal Generator with a minimum frequency range of 70 MHz to 110 MHz (not needed when using a Network Analyzer).

3.2.2.5 Dual Channel RF Power Meter (not needed when using a Network Analyzer).

3.2.2.6 Dual Directional Coupler (not needed when using a Network Analyzer).

3.2.2.7 Two 3 dB Port Power Splitter or equivalent directional coupler.

3.2.2.8 A 50 Ω , 3 dB attenuator on the receive path.

3.2.2.9 Receive test feedline cable (connecting the Antenna Under Test (AUT) or reference antenna to the spectrum analyzer/receiver) consisting of a 2.5 m to 10 m length of RG58 coaxial cable covered full length with CAPCON Electromagnetic Interference (EMI) suppressant tubing or equivalent (URL: <http://www.capconemi.com/>).

3.2.2.10 Vehicle turntable with a positioning accuracy of 1 degree minimum resolution.

3.2.2.11 Turntable covering structure (optional). If any structure is used to cover the vehicle turntable, it shall exhibit a through loss (S21) of ≤ 0.5 dB.

3.2.3 T-DAB/T-DMB Gain and Directionality. This test requires:

3.2.3.1 Transmit antenna(s) to cover the frequency range 174 MHz to 240 MHz with a VSWR < 2.5:1. Transmit antenna type should be a log periodic or BiConiLog type.

3.2.3.2 Reference antennas (dipole, BiConiLog or log periodic antennas only) to cover the frequency range 174 MHz to 240 MHz with a VSWR < 2.5:1. All gain values shall be normalized to a tunable dipole, i.e., ETS Model 3121 Roberts Dipole. Normalization can be done by either using calibrated antenna factors or by deriving a correction factor by measuring the received power difference between the reference antenna and the tunable dipole (Roberts Dipole).

3.2.3.3 Spectrum Analyzer, Receiver, or Network Analyzer with a minimum frequency range of 150 MHz to 300 MHz.

3.2.3.4 RF Signal Generator with a minimum frequency range of 150 MHz to 300 MHz (not needed when using a Network Analyzer).

3.2.3.5 Dual Channel RF Power Meter (not needed when using a Network Analyzer).

3.2.3.6 Dual Directional Coupler (not needed when using a Network Analyzer).

3.2.3.7 A 50 Ω , 3 dB attenuator on the receive path.

3.2.3.8 Receive test feedline cable (connecting the AUT or reference antenna to the spectrum analyzer/receiver) consisting of a 2.5 m to 10 m length of RG58 coaxial cable covered full length with CAPCON EMI suppressant tubing or equivalent.

3.2.3.9 Vehicle turntable with a positioning accuracy of 1 degree minimum resolution.

3.2.3.10 Turntable covering structure (optional). If any structure is used to cover the vehicle turntable, it shall exhibit a through loss (S21) of ≤ 0.5 dB.

3.2.4 RFR Gain and Directionality. This test requires:

3.2.4.1 Transmit antenna(s) to cover the frequencies of 314.9 MHz and 433.92 MHz with a VSWR < 2.5:1. Transmit antenna type should be a log periodic, BiConiLog, or a Yagi-Uda type.

3.2.4.2 Reference antennas (dipole, folded dipole, or log periodic antennas only) to cover the frequencies of 314.9 and 433.92 MHz with a VSWR < 2.0:1. All gain values shall be normalized to a tunable dipole, i.e., ETS

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Model 3121 Roberts Dipole. Normalization can be done by either using calibrated antenna factors or by deriving a correction factor by measuring the received power difference between the reference antenna and the tunable dipole (Roberts Dipole).

3.2.4.3 Spectrum Analyzer, Receiver, or Network Analyzer with a minimum frequency range of 300 MHz to 500 MHz.

3.2.4.4 RF Signal Generator with a minimum frequency range of 300 MHz to 500 MHz (not needed when using a Network Analyzer).

3.2.4.5 Dual Channel RF Power Meter (not needed when using a Network Analyzer).

3.2.4.6 Dual Directional Coupler (not needed when using a Network Analyzer).

3.2.4.7 A 50 Ω , 3 dB attenuator on the receive path.

3.2.4.8 Receive test feedline cable (connecting the AUT or reference antenna to the spectrum analyzer/receiver) consisting of a 2.5 m to 10 m length of RG58 coaxial cable covered full length with CAPCON EMI suppressant tubing or equivalent.

3.2.4.9 Vehicle turntable with a positioning accuracy of 1 degree minimum resolution.

3.2.4.10 Turntable covering structure (optional). If any structure is used to cover the vehicle turntable, it shall exhibit a through loss (S21) of ≤ 0.5 dB.

3.2.5 AM Impedance. This test requires a Network Analyzer, Voltage Impedance Meter, or Impedance Analyzer capable of covering the frequency range of 0.5 MHz to 2 MHz.

3.2.6 FM Impedance. This test requires a Network Analyzer, Voltage Impedance Meter, or Impedance Analyzer capable of covering the frequency range of 70 MHz to 120 MHz.

3.2.7 T-DAB/T-DMB Impedance. This test requires a Network Analyzer, Voltage Impedance Meter, or Impedance Analyzer capable of covering the frequency range of 150 MHz to 250 MHz.

3.2.8 RFR Impedance. This test requires a Network Analyzer, Voltage Impedance Meter, or Impedance Analyzer capable of covering the frequency range of 325 MHz to 450 MHz.

3.2.9 Shield Resistance. The unit shall be a four-wire system using Kelvin clips, operating at 1 kHz, with immunity to ground currents (≤ 5 m Ω difference), and with 1.8 m minimum test leads. A TEGAM Model 253 Impedance Meter (URL: <http://www.tegam.com/>) meets these requirements.

3.3 Test Vehicle/Test Piece.

3.3.1 The AUT shall be in a production ready state and have passed all other applicable component-level, i.e., GMW3172, and vehicle level electrical tests, i.e., GMW3091, GMW3097. The AUT is comprised of any of the following: Receiver feedline cable, passive matching network (passive module), active matching network (active module), coaxial cable interconnects, and the antenna element(s).

3.3.2 If a vehicle has a switched diversity antenna system, then the supplier shall provide a modified module that allows manual selection of each antenna input. The manually switched diversity antenna module shall be constructed from a production intent module.

3.3.3 Multi-element antenna systems shall have amplifiers with a gain difference not exceeding 1 dB at a given test frequency as measured per GMW15649. Amplifiers with a gain difference > 1 dB must have usage approval from the appropriate General Motors Bill of Materials Family Owner (BFO).

Note: Care shall be taken to ensure all on-glass antennas are mounted with production urethane.

3.4 Test Time. Times shown are typical for antenna tests at the GM regional facilities listed. Times may vary for antenna tests in other facilities.

Calendar time:	General Motors Korea (GMK): 4 d General Motors North America (GMNA) 2 d to 3 d
Test time:	GMK 12 h GMNA 4 h
Coordination time:	GMK 8 h GMNA 8 h

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3.5 Test Required Information.

3.5.1 The minimum test information shall contain: GM Vehicle Number, antenna manufacturer, AUT module and coaxial cable feedline part numbers and serial numbers, hardware revision description, software revision (if applicable).

3.5.2 The minimum test site information shall contain: test site software revision, name of test site, date tested, time tested, and precipitation conditions.

3.5.3 Supplier facilities shall provide test equipment and setup information, in addition to the information required in 3.5.1 and 3.5.2.

3.6 Personnel/Skills. Test personnel shall have a working knowledge of spectrum analyzers, network analyzers, test receivers, milliohm meters, antennas, antenna range protocol, and other RF equipment. A working knowledge of computers and data spreadsheets is also required.

4 Procedure

4.1 Preparation.

4.1.1 All test equipment shall be turned on for a minimum of 15 minutes before any reference or AUT measurements begin.

4.1.2 Ensure that coherent test equipment RF emissions, for the AM Gain test frequencies, are not > 10 dB above the receiver noise floor as determined with the EZ-12 and AM reference antenna connected in test configuration inside a shielded room or other suitable AM station-free environment (if required).

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 AM Gain measurements shall not be conducted before 1 h after sunrise and not later than 1 h before sunset.

4.2.1.2 Test signals generated on site must be 40 dB minimum above the ambient noise floor of the test spectrum analyzer or receiver when measured with the reference antenna.

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 Test signal transmit antennas shall be mounted on a fiberglass/plastic structure with the axis located 2 m to 4 m above the range surface and positioned between 50 m to 250 m from the center of the turntable with a bore sight angle of < 5 degrees.

4.2.2.2 Passive AUT may be tested with the vehicle off. Active antennas without feedline (phantom) power feed shall be tested with the vehicle in accessory mode or vehicle running. Active antennas with feedline (phantom) power feed shall be tested with power supplied by an appropriate DC source and Bias T (Mini-Circuits ZFBT-4R2G or equivalent URL: <http://www.minicircuits.com/homepage/homepage.html>). Multiple modules attached to the same antenna element structure shall all be in the correct power state and their outputs terminated during testing. Ensure all unnecessary vehicle functions are turned off.

4.2.2.3 The AUT vehicle shall be in a customer usable state (meaning seats shall be in their upright positions, trim pieces installed, as appropriate). For vehicles equipped with movable roof structures, the standard test condition is convertible top up, targa roof sections installed, or sun roof sections closed. The presence and state of such roof sections shall be noted in the test data.

4.2.2.4 Test equipment default connection for all tests shall be at the AUT feedline connection to the vehicle receiver. Deviations from the default shall be noted in the test documentation.

4.3 Instructions.

4.3.1 Reference Antenna(s) ≥ 25 MHz.

4.3.1.1 Reference antenna amplitude measurements shall be made for each polarity (horizontal and vertical) at all test frequencies.

4.3.1.2 Care shall be taken to perform reference antenna measurements with the same range conditions (rain, snow, etc.) as the AUT measurements. The reference antenna(s) shall be mounted on a fiberglass/plastic structure. The reference antenna(s) shall be located on the range centerline $1.75 \text{ m} \pm 0.25 \text{ m}$ in front of the

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turntable and 1.5 m $\pm$ 0.05 m above the turntable surface. The reference antenna shall be oriented normal to the range centerline. See Appendix A, Figure A1.

4.3.1.3 The test feedline cable shall be used to connect the reference antenna to the Spectrum Analyzer or Receiver and supported 1.50 m $\pm$ 0.25 m above the turntable surface using a foam block or fiberglass tripod for 1 m minimum, behind (downrange) the reference antenna. The spectrum analyzer and any associated equipment shall be located on the turntable surface 2.5 m minimum, behind (downrange) the reference antenna. Connection shall be made to the reference antenna using a 3 dB attenuator.

4.3.1.4 If additional equipment is needed to activate the diversity system, then the equipment shall be included in the reference antenna path.

4.3.1.4.1 Reference measurements, for diversity antenna systems that require vehicle receiver connection during measurement, shall be made with a power splitter or a directional coupler at the antenna end of the test feedline cable in place of the 3 dB attenuator. The common or input port shall be attached to the reference antenna. With a splitter, one output port shall be terminated and the other attached to the test feedline cable routed to the Spectrum Analyzer or Receiver. With a coupler, the through port shall be terminated and the coupled port attached to the test feedline cable routed to the Spectrum Analyzer or Receiver.

4.3.1.4.2 If the AUT requires the use of a Bias T, it shall be connected to the test feedline cable at the spectrum analyzer or receiver and remain in place for all reference and AUT measurements.

4.3.2 AM Gain.

4.3.2.1 Measurements shall be made using AM band broadcast stations, as the signal source, testing a minimum of four frequencies across the AM band. AM carrier amplitude, as measured using the reference antenna, shall be at least 26 dB greater than the spectrum analyzer or receiver ambient noise floor $\pm$ 5 kHz from each station center frequency.

4.3.2.2 Spectrum Analyzer and Receiver Settings.

4.3.2.2.1 Spectrum Analyzers shall be set to 20 kHz frequency span, 3 kHz maximum resolution bandwidth (300 Hz preferred), and 3 kHz video bandwidth. Set the unit to peak detection mode and ensure the maximum value is captured. Measurement averaging shall be employed to remove modulation effects from the signal over a minimum of 10 measurements per test frequency.

4.3.2.2.2 Receivers shall be set to an intermediate frequency bandwidth of 10 kHz using average detection mode. Allow the receiver to acquire 5 s worth of data.

4.3.2.3 Ensure that no cables exit the AUT vehicle and make contact with any other surface or item under or around the vehicle. No power connections shall be made between the vehicle and the measurement equipment. All vehicle doors shall be closed during measurements.

4.3.2.4 Both the reference antenna and the AUT shall be connected to the Rohde and Schwarz EZ-12 Impedance Matching Unit. Any adapters used between the antenna feedline cable and the EZ-12 shall not be $>$ 5 cm in length. If phantom power is needed, the Bias T shall only be used for the vehicle AUT measurement and the Bias T output shall be connected directly to the EZ-12 input. The Bias T DC cable length shall be kept as short as practical and the addition of a 1 mH Inductor on the Bias T DC port is preferred. The Bias T, inductor and battery shall not be used with the AM reference antenna. The RF cable length between the EZ-12 and the spectrum analyzer shall be as short as practical and shall not be changed between reference antenna and AUT measurements. See Appendix A, Figure A2.

4.3.2.5 The reference measurements shall be made with the reference antenna centered as nearly as possible on the vehicle roof, avoiding any roof obstructions, e.g., sunroof or targa roof, roof rack equipment. If the vehicle has a non-metallic roof, testing shall be done with the reference antenna placed on the roof of the vehicle.

4.3.2.6 AUT measurements shall be made by connecting to the AUT feedline cable at the vehicle receiver and shall be conducted within 10 minutes of the reference measurement for the particular frequency.

4.3.3 FM, T-DAB/T-DMB, RFR Gain and Directionality.

4.3.3.1 Test Frequencies.

4.3.3.1.1 International FM Band measurements shall be made at the following 10 frequencies minimum: 88.0 MHz, 90.0 MHz, 92.0 MHz, 94.0 MHz, 96.0 MHz, 100.0 MHz, 102.0 MHz, 104.0 MHz, 106.0 MHz, and 107.8 MHz (all values $\pm$ 0.5 MHz). Japanese FM Band measurements shall be made at the following 8 frequencies, minimum: 76.0 MHz, 78.0 MHz, 80.0 MHz, 82.0 MHz, 84.0 MHz, 86.0 MHz, 88.0 MHz, and

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90.0 MHz (all values ± 0.5 MHz). Brazilian FM Band measurements shall be made at the following 17 frequencies, minimum: 76.0 MHz, 78.0 MHz, 80.0 MHz, 82.0 MHz, 84.0 MHz, 86.0 MHz, 88.0 MHz, 90.0 MHz, 92.0 MHz, 94.0 MHz, 96.0 MHz, 98 MHz, 100.0 MHz, 102.0 MHz, 104.0 MHz, 106.0 MHz, and 107.8 MHz (all values ± 0.5 MHz). Connection to the AUT shall be at the vehicle receiver.

4.3.3.1.2 FM Diversity AUT measurements that require vehicle receiver connection shall be made at six (6) channel frequencies minimum, spread across the FM band. All other FM antenna types shall use the frequencies specified in 4.3.3.1.1.

4.3.3.1.3 T-DAB/T-DMB Test Frequencies. T-DAB/T-DMB Band measurements shall be made at the following 10 frequencies, minimum: 174 MHz, 180 MHz, 186 MHz, 192 MHz, 198 MHz, 204 MHz, 210 MHz, 216 MHz, 234 MHz and 240 MHz (all values ± 2.0 MHz). Connection to the AUT shall be at the vehicle receiver.

4.3.3.1.4 RFR Test Frequencies. RFR band measurements shall be made at the following two (2) frequencies 314.9 MHz or 433.92 MHz, as applicable. Connection to the AUT shall be at the vehicle RFR receiver.

4.3.3.2 Spectrum Analyzer and Receiver Settings.

4.3.3.2.1 Spectrum Analyzers shall be set to 20 kHz frequency span, 10 kHz resolution bandwidth and 10 kHz video bandwidth. Set the unit to peak detection mode and ensure the maximum value is captured.

4.3.3.2.2 Receivers shall be set to 9 kHz intermediate frequency bandwidth using average detection mode and ensure that the maximum value is captured.

4.3.3.3 For diversity AUT measurements, that require vehicle receiver connection, the test signal amplitude, as measured using the reference antenna(s) and AUT shall be at least 30 dB greater than any ambient station signal. Using the vehicle receiver, listen to each test frequency as the vehicle rotates 360 degrees, to ensure there is no station intrusion onto the test signal. The 3 dB termination on the splitter/coupler used during reference measurements, is replaced with as short a feedline cable as practical and connected to the vehicle receiver. The common or input port is connected to the AUT feedline cable.

4.3.3.4 AUT amplitude measurements shall be made for each polarity (horizontal and vertical) at all test frequencies. Data shall be taken at a minimum of one degree increments for the complete 360 degree rotation.

4.3.3.5 The test vehicle shall be positioned on the turntable so that the AUT is located as near to the center of the turntable as possible.

4.3.3.6 Antenna feedline cables or power cables exiting the vehicle shall be RF isolated with a covering of CAPCON EMI suppressant tubing or have a minimum of three (3) Type-73 ferrite cores installed on the cable with care taken to suspend the cores between the vehicle and the turntable deck.

4.3.3.7 Vehicles with a rear glass antenna and a rear glass sunshade option shall perform a gain and directionality test for the appropriate band(s) with the sunshade deployed in addition to the sunshade stowed state.

4.3.4 AM, FM, T-DAB/T-DMB, and RFR Impedance.

4.3.4.1 Network Analyzer Setup.

4.3.4.1.1 Network Analyzers shall be calibrated for an S11 measurement with minimal adapter changes between calibration and measurement.

4.3.4.1.2 AM Band impedance magnitude and phase measurements shall be made beginning at 500 kHz and ending at 1800 kHz with a step size not > 50 kHz.

4.3.4.1.3 International FM Band impedance magnitude and phase measurements shall be made beginning at 80 MHz and ending at 120 MHz with a step size not > 0.2 MHz. International Band VSWR reporting frequencies shall be 88 MHz to 108 MHz in 2 MHz steps. Ninety-eight (98) MHz may be omitted.

4.3.4.1.4 Japanese FM Band impedance magnitude and phase measurements shall be made beginning at 70 MHz and ending at 100 MHz with a step size not > 0.2 MHz. Japanese FM Band VSWR reporting frequencies shall be 76 MHz to 90 MHz in 2 MHz steps.

4.3.4.1.5 Brazilian FM Band impedance magnitude and phase measurements shall be made beginning at 70 MHz and ending at 120 MHz with a step size not > 0.2 MHz. Brazilian FM Band VSWR reporting frequencies shall be 76 MHz to 108 MHz in 2 MHz steps.

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4.3.4.1.6 T-DAB/T-DMB Band impedance magnitude and phase measurements shall be made beginning at 164 MHz and ending at 244 MHz with a step size not exceeding 0.4 MHz. T-DAB/T-DMB Band VSWR reporting frequencies shall be the test frequencies called out in 4.3.3.2.1.

4.3.4.1.7 RFR Band impedance magnitude and phase measurements shall be made beginning at 310 MHz to 320 MHz and 430 MHz to 440 MHz with a step size not > 0.02 MHz. International Band VSWR reporting frequencies shall be 314.9 MHz or 433.92 MHz as applicable.

4.3.4.2 The test feedline cable connecting the Network Analyzer to the AUT shall not exceed 3 m in length. The total length of any adapter(s) and/or extension cable used to connect the Network Analyzer test cable or Vector Impedance Meter (VIM) probe to the AUT feedline cable shall not exceed 8 cm in length. Any electrical delay differences between calibration and measurement shall be compensated in the measurement data.

4.3.4.3 The test vehicle shall be located in a clear area with a minimum 3 m distance (including vertical) from any surface of the vehicle to a surrounding object. All doors, roof panels, and decklids shall be closed and the vehicle shall be in a customer usable state. All test equipment shall be kept a minimum 1 m distance away from the AUT. Connection to the AUT shall be at the vehicle receiver.

4.3.4.4 Impedance measurements on all active antenna systems shall be performed with the AUT powered off and on. While there is no requirement for power off, this test mode is required to ensure that the active components of the AUT are operating.

4.3.4.5 A VIM or Impedance Analyzer should be used to make AM band impedance magnitude measurements > 500 Ω unless the Network Analyzer specifications explicitly state that capability. A Network Analyzer may be used for measurements exceeding 500 Ω but there may be degradation in performance.

4.3.5 Resistance.

4.3.5.1 Ensure that all wiring, except the AM/FM AUT feedline cable, is disconnected from the receiver and does not come in contact with the receiver chassis at any time during measurement. Some milliohm meters are affected by ground currents. If ground current sensitivity cannot be verified, the battery negative lead shall be disconnected from the vehicle battery.

4.3.5.2 Measure the resistance from the battery negative to the receiver chassis.

4.3.5.3 The resistance between the antenna mount and the vehicle negative battery is called R_{MB} . R_{MB} is measured as follows (with the AM/FM coaxial cable disconnected at the receiver):

4.3.5.3.1 For antennas with built in amplifiers, the measurement of R_{MB} is made from the mounting bolt to the vehicle battery.

4.3.5.3.2 For antennas with external amplifiers, i.e., external antenna modules, housed in a non-metallic case, the measurement of R_{MB} is made from the ground wire attached to the ground mounting tab to the vehicle battery. Care must be taken to ensure the measurement lead does not touch sheet metal during the measurement.

4.3.5.3.3 For antennas with external amplifiers housed in a metallic case, the measurement of R_{MB} is made from the case to the vehicle battery. It may be necessary to scratch the case surface to ensure bare metal contact.

4.3.5.4 Measure the resistance from the battery negative to any metal part of the receiver case with all power wiring connected and all antenna feedline cables disconnected.

4.3.5.5 If the AUT is a power mast, measure the resistance from the mast tip to the mast base at a point not > 1 cm above the vehicle surface.

5 Data

5.1 Calculations.

5.1.1 AM Gain. For each test frequency, gain is calculated by subtracting the Reference Antenna (RA) amplitude measurement (in dBm or dB μ V) from the AUT amplitude measurement (in dBm or dB μ V).

$$\text{Gain} = \text{Amplitude}_{\text{AUT}} - \text{Amplitude}_{\text{RA}}$$

The results are compared to the requirements in 5.2.1.

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