



AM/FM Tuner Performance Requirements

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. This document specifies static requirements and test procedures for verification of Amplitude Modulation/Frequency Modulation (AM/FM) tuner performance for all General Motors vehicles marketed and sold around the world.

The requirements stated in this document supercede all Component Technical Specifications (CTS), Subsystem Technical Specifications (SSTS), and Vehicle Technical Specifications (VTS) that pertain to AM/FM tuner components until Model Year (MY) 2022 (MY2022), after which all requirements will reside in Dynamic Object Oriented Requirements System (DOORS).

1.2 Applicability. This document is applicable to the development and validation of AM/FM tuner components for new vehicle programs as well as design changes for current components.

1.3 Remarks. This document specifies the static tuner Radio Frequency (RF) hardware requirements and test procedures for verification. Other documents, such as the radio Human Machine Interface (HMI) and End of Line (EOL) programming requirements may drive other tuner hardware behavior requirements not covered in the document.

2 References

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

2.1 External Standards/Specifications.

EN 62106 ISO 17025

2.2 GM Standards/Specifications.

GMW3059	GMW3097	GMW15648	GMW15650
GMW3091	GMW3103	GMW15649	GMW17201

2.3 Additional References.

- Applicable antenna Component Technical Specification (CTS)
- Applicable antenna Subsystem Technical Specification (SSTS)
- Applicable antenna Vehicle Technical Specification (VTS)
- CG2510 Test Result Template
- CG3476 Recommended Region Programming
- RX_CERT_3727 and RX_CERT_3727 document by XPERI Corporation

3 Test Preparation and Evaluation

3.1 Resources.

3.1.1 Facilities.

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

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3.1.1.2 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.

3.1.2 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.

- MiniCircuits ZSC-2-1+ available at; <https://www.minicircuits.com/pdfs/ZSC-2-1.pdf>
- Keysight 34465A Digital Multimeter available at; <http://www.keysight.com/en/pd-2519397-pn-34465A/digital-multimeter-6-digit-performance-truevolt-dmm?nid=-536902435.1119130&cc=US&lc=eng>
- Rohde and Schwarz SFE-100 Broadcast Test Transmitter, SMBV100A Vector Signal Generator (VSG), UPV Audio Analyzer, ZNB8 Vector Network Analyzer (VNA) and FSW8 Vector Spectrum Analyzer (VSA) available at; http://www.rohde-schwarz.com/en/home_48230.html
- Kikusui PBZ20-20 Programmable DC Power Supply available at; <http://www.kikusuiamerica.com/product/detail.php?IdFamily=0105>
- Tektronix DPO7254C Oscilloscope available at; <https://www.tek.com/oscilloscope>

3.1.3 Test Vehicle/Test Piece. The tests described herein shall be performed on Design Validation (DV), Product Validation (PV), or any current production AM/FM Tuners.

3.1.4 Test Time.

Calendar time:	5 d
Test time:	35 h
Coordination time:	5 h

3.1.5 Test Required Information. See 3.7.1.

3.1.6 Personnel/Skills. Test personnel shall have a working knowledge of radio frequency/radio data system (RF/RDS) signal generators, network analyzers, pulse generators, AM/FM tuners including calibration and other RF equipment. A working knowledge of computers and data spreadsheets is also required.

3.2 Preparation. Not applicable.

3.3 Conditions.

3.3.1 Environmental Conditions. All tuner measurements shall be taken at $-40^{\circ}\text{C} \pm 2^{\circ}\text{C}$, $+23^{\circ}\text{C} \pm 2^{\circ}\text{C}$, and $+85^{\circ}\text{C} \pm 2^{\circ}\text{C}$, all with a relative humidity of 30% to 70%, unless otherwise specified. The tuner shall be powered and soaked at the high test temperature, unpowered and soaked at the low test temperature at least 1 h prior to commencing any tests. If there is an external amplifier required for tuner operation, the amplifier shall remain outside any thermal chamber at room temperature.

3.3.2 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.

Deviations from the requirements of this standard shall have been agreed upon utilizing the appropriate Problem Resolution and Tracking System (PRTS) and Engineer Work Order (EWO) Deviation process.

- Unless otherwise specified, all receiver performance tests shall be performed with the single frequency audio tone with the balance, and fade controls set to center (neutral) position.
- Volume shall be set to standard output levels when tuned on the station and measured at the left front audio output, unless otherwise specified.
- Speed compensated volume controls shall be disabled during tests.
- HD Radio mode, if available, shall be disabled during all tests

3.3.2.1 Operating voltage Nominal test voltage at room temperature shall be $13.8\text{ V} \pm 0.1\text{ V}$, nominal test voltage at cold temperature shall be $9.0\text{ V} \pm 0.1\text{ V}$ and nominal test voltage at hot temperature shall be $16.0\text{ V} \pm 0.1\text{ V}$ unless otherwise specified. Voltage levels shall be set at the output of the power supply with ripple voltage $< 0.1\text{ V}$ Peak to Peak, and monitored utilizing a digital multimeter as required.

All audio frequency measurements shall be made in V_{rms} units.

3.3.2.2 Audio Output Configuration and Loading.

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- Internal power amplifier for speakers: Each speaker audio output shall be connected to a 4 Ω power resistor.
- The Internal power amplifier shall have a flat audio equalization
- External power amplifier for speakers (Radio connected to the ext. amplifier): Each amplifier speaker audio output shall be connected to the corresponding power resistor according to specification (e.g., 2 Ω , 4 Ω , etc.)
 - The external amplifier shall have flat Audio equalization and maximum gain.
 - If the measurements are necessary with a tuned audio frequency response (e.g., snapshot testing before a test-ride) there might be the need to change the audio tone from 1 kHz down to 400 Hz due to a notch in the frequency response of the amplifier.
 - If an external power amplifier is not available, the radio analog line level outputs shall be terminated with a 2 k Ω resistor.
 - In all cases of digital audio output from the tuner, the external amplifier shall be used in all tests cases.

3.3.2.3 AM Mono Standard Test Conditions.

- a. Frequency: 1080 kHz
- b. Audio Tone: 1 kHz
- c. Modulation: 30% of full level
- d. Mode: Mono
- e. RF Level (E' using AM dummy): 60 dB μ V. See 6.1 for E' definition.
- f. Audio Filter: 15 kHz low pass filter

3.3.2.4 FM Mono Standard Test Conditions.

- a. Frequency: 98.1 MHz
- b. Audio Tone: 1 kHz
- c. Modulation: 22.5 kHz deviation with the corresponding FM Pre-emphasis.
- d. Mode: Left (L) = Right (R) (Mono)
- e. RF Level (E' using FM dummy): 60 dB μ V
- f. Audio Filter:
 - 15 kHz low pass filter with 19 kHz notch
 - Attenuation at 15 kHz < 3 dB
 - Attenuation slope > 18 dB/octave
 - Attenuation at 19 kHz > 30 dB (notch filter)

3.3.2.5 FM Stereo Standard Test Conditions.

- a. Frequency: 98.1 MHz
- b. Audio Tone: 1 kHz
- c. Modulation: 22.5 kHz deviation with the corresponding FM Pre-emphasis and in addition 6.75 kHz deviation to the pilot tone according to Appendix C.
- d. Pilot: 6.75 kHz deviation
- e. Mode: L = R
- f. Stereo System: GE-Zenith (Federal Communications Commission)
- g. RF Level (E' using FM dummy): 60 dB μ V
- h. Audio Filter:
 - 15 kHz low pass filter with 19 kHz notch
 - Attenuation at 15 kHz < 3 dB
 - Attenuation slope > 18 dB/octave
 - Attenuation at 19 kHz > 30 dB (notch filter)

3.3.2.6 FM RDS Standard Test Conditions.

- a. Frequency: 98.1 MHz

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- b. Audio Tone: 1 kHz
- c. Modulation: 31.25 kHz deviation, which includes 22.5 kHz deviation with the corresponding FM Pre-emphasis, 6.75 kHz allocated to the pilot tone and 2 kHz to RDS modulation according to Appendix C and EN 62106 (Specification of the Radio Data System (RDS) for VHF/FM sound broadcasting in the frequency range from 87.5 MHz to 108.0 MHz).
 - 1 kHz Level: 22.5 kHz deviation with the corresponding FM Pre-emphasis
 - Pilot Level: 6.75 kHz deviation
 - RDS Level: 2 kHz deviation
- d. RF Level (E' using FM dummy): 60 dBμV
- e. Audio Filter:
 - 15 kHz low pass filter with 19 kHz notch
 - Attenuation at 15 kHz < 3 dB
 - Attenuation slope > 18 dB/octave
 - Attenuation at 19 kHz > 30 dB
- f. RDS Parameters:
 - Alternate frequencies: 98.1 MHz, 99.1 MHz
 - Frequency deviation: 2 kHz
 - RDS phase: 0 degrees
 - Program service name: The program service name shall be left as a null field
 - Radio text: The radio text shall be left as a null field
 - Music/Speech: Music
 - Traffic announcement: OFF
 - Traffic program: ON
 - Clock time: OFF
 - PI code: 8035
 - Group types: "0A" and "2A"
 - Decoder information: Stereo
 - Program type: 1 (News)
 - Message: None

3.3.2.7 "0 dB" Audio Reference Level Setup.

- a. Connect audio analyzer to the left-front (or desired) output.
- b. Configure the RF signal generator using the AM Mono or FM Standard Test Conditions as applicable.
- c. Adjust the tuner to the desired frequency that the RF signal generator is configured for.
- d. Using the properly loaded audio outputs, adjust the volume of the audio output to $1.4 \text{ V} \pm 140 \text{ mV}$ or ± 1 volume detent if the detent stepsize is too large.
- e. Measure the actual audio output level. This measured value is the 0 dB audio reference level (0 dBr).

3.3.2.8 RF Voltage Specification Measurement Location. All RF testing shall be performed with the standard AM and FM antenna dummy loads.

All RF Levels (E') in this document are RF generator levels when using the standard antenna dummy circuits as specified. The effects of the antenna dummy circuits as shown are included in this document.

The antenna dummy circuits shall adhere to the technical requirements according to Appendix B.

Measurements that involve changing the RF signal generator level to produce a specified effect shall use level increments of $\leq 0.1 \text{ dB}\mu\text{V}$.

3.3.2.9 AM Active Dummy Antenna. This AM dummy antenna circuit (see Figure 1) and test setup shall be used in the measurement of all AM RF specifications and shall be considered the reference AM dummy circuit.

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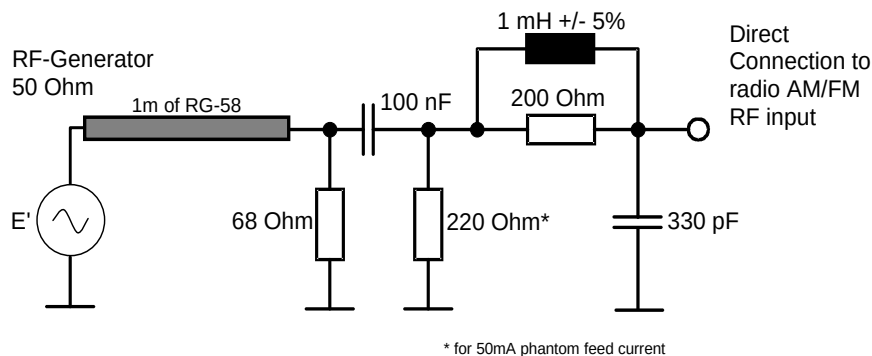


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The reference test setup connects the output of the AM dummy circuit directly to the tuner RF input connector and is connected to the 50 Ω RF signal generator output with 1 m of RG-58 type coax.

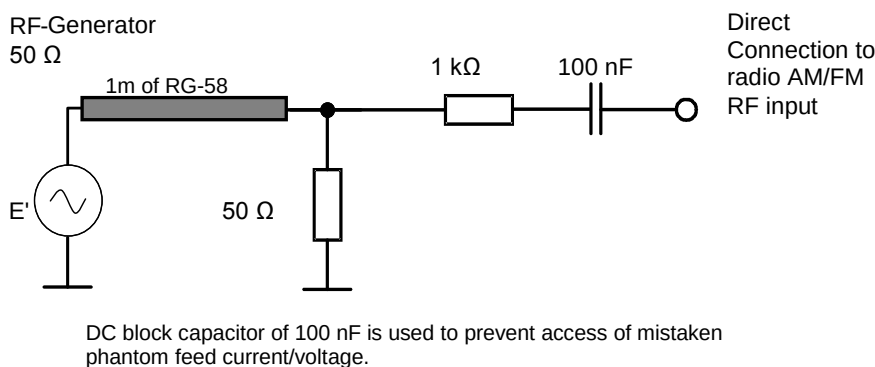
Note that this circuit is an attenuator, and that the RF levels specified in this document are signal generator levels which include the effect of this circuit.

Figure 1: AM Active Dummy Antenna Circuit



3.3.2.9.1 AM Passive Dummy Antenna. This AM dummy antenna circuit (see Figure 2) and test setup shall be used for the measurements “receivers with passive rod antenna” according to the applicable tests that require passive antenna measurements for the AM/MW band.

Figure 2: AM Passive Dummy Antenna Circuit



3.3.2.10 FM Dummy Antenna. This FM dummy antenna circuit (see Figure 3) and test setup shall be used in the measurement of all FM RF specifications and shall be considered the reference FM dummy circuit.

The reference test setup connects the output of the FM dummy circuit directly to the tuner RF input connector and is connected to the 50 Ω RF signal generator output with 1 m of RG-58 type coax.

Note that this circuit is a 6 dB attenuator, and that the RF levels specified in this document are signal generator levels which include the effect of this circuit.

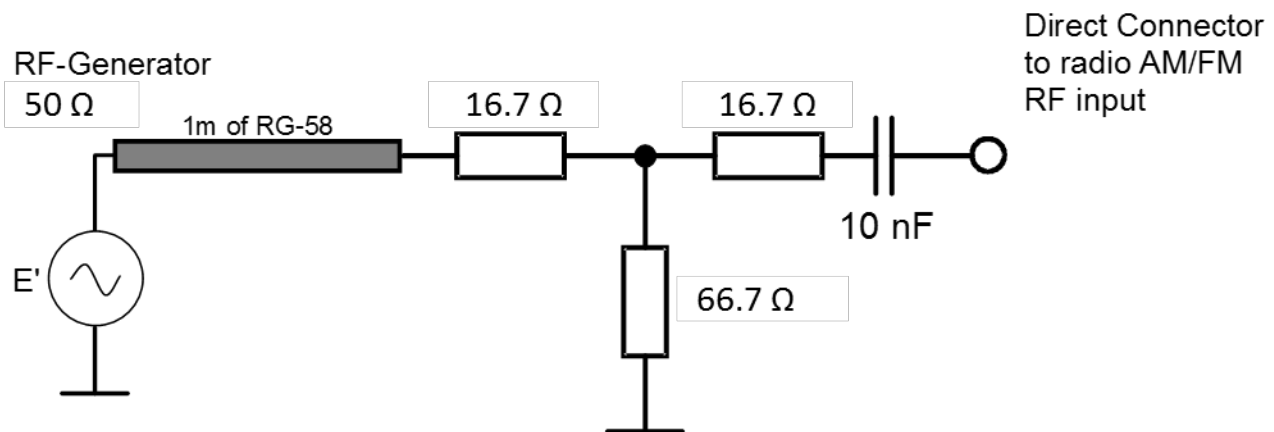
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Figure 3: FM Dummy Antenna Circuit



3.4 Instructions. Not applicable.

3.5 Data. Not applicable.

3.6 Safety.

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

3.7 Documentation. Samples of components or material released to this standard shall be tested for conformity with the requirements of this standard and approved by the responsible GM Department prior to the start of delivery of production level components or materials.

Any change to the component or material, e.g., design, function, properties, manufacturing process and/or location of manufacture requires a new release of the product. It is the sole responsibility of the supplier to provide the customer, unsolicited, with documentation of any change or modification to the product/process, and to apply for a new release.

If not otherwise agreed to, the entire verification test shall be repeated and documented by the supplier prior to start of delivery of the modified or changed product. In some cases, a shorter test can be agreed to between the responsible GM department and the supplier.

3.7.1 Test Results. The measurement results shall be noted in the separately available "GMW16273 Test Result Template (CG2510)" with all plots included. The plots shall conform to the examples in Appendix E, Figures E1 thru E15.

For GM employees, the download of the actual version of the Test Result Template is available in Global Document Management (GDM) system. For Suppliers, CG2510 is available with GMW purchase. All tests and test methods shall be executed if not otherwise stated. Results, and the radio tested shall be provided to GM, without any hardware or software modification, as requested by GM to support validation milestones.

3.7.1.1 General Guidelines for Completing CG2510 Test Result Template.

3.7.1.1.1 Prior to performing the tests, the tester should become familiar with GMW16273. This test results template does not include any test descriptions.

3.7.1.1.2 The Supplier shall use the Test Result Template (CG2510) and not a different format.

3.7.1.1.3 The test results shall be entered using the same word processing tools as GM.

3.7.1.1.4 The Supplier shall not change the acceptance criteria.

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3.7.1.1.5 All tests shall be performed. If a test is not possible or not applicable, the Supplier shall provide the reason why the test was not performed.

3.7.1.1.6 The Supplier shall enter the actual result of the test in the "Test Result" column, (e.g., FMAuto1 = 36 dBμV), and not simply OK, Not OK (NOK) or left blank.

3.7.1.1.7 Plots of the Frequency Response, Signal to Noise measurement, High Cut Frequency Response, an Input Output Diagram, Selectivity, Loudness-Frequency Response, etc., shall be added to the test report where indicated. The plots shall conform to the examples in Appendix E.

4 Requirements and Procedure

4.1 Integration Requirements.

4.1.1 Tuner Performance over Temperature. The tuner shall meet all requirements over the operating temperature and voltage range unless otherwise specified.

4.1.2 Tuner Performance over All Supported Frequencies. The tuner shall meet all requirements over the entire selectable frequency range in each band.

4.1.3 Tuner Calibration. Design Validation (DV) tests may be performed using a supplier calibration override or development calibration as agreed upon with GM Design and Validation Engineering. All Production Validation (PV) tests shall be performed using a GM originated production calibration.

4.1.4 Tuner Performance on Separate Audio Channels. The tuner shall meet all requirements on all audio channels according to all audio specifications.

4.1.5 Auxiliary FM Tuner (Dual Tuner) Requirements. An auxiliary FM tuner may be included in radios for particular regions requiring Radio Data Service-Traffic Message Channel (RDS-TMC) traffic data processing, which has special requirements to improve radio reception performance. The auxiliary FM tuner shall be in addition to the primary audio tuner.

4.1.5.1 Antenna Sharing. The primary antenna may be shared as a wideband sampling input with a single front end that is shared with up to four (4) station outputs before an additional RF front-end is added to the system.

4.1.5.2 Performance. All tuned channels shall meet performance requirements, by band, of the primary tuned channel.

4.1.5.3 Compatibility with the Primary Tuner. The auxiliary tuner shall not interfere with primary tuner.

4.1.5.4 Functions of the Auxiliary Tuner(s). The auxiliary tuners shall be shared for tasks including, but not limited to the following:

- RDS-TMC traffic data for both free and subscription data services
- FM band memory for improved RDS alternate frequency (AF) station switching performance
- FM band scanning for a user table display of all available frequencies

4.1.5.5 Diversity Antenna System Compatibility. When the primary radio output is diversity FM, the antenna signals shall be processed using phase diversity signal processing.

4.1.6 Dynamic Tuner Performance. Prior to executing an AF switch, a second tuner output will be tuned to the alternate frequency prior to the switch, so performance and audio correlation can be verified a priori. Single tuner AF checks and AF switches are not permitted. The supplier shall provide all configuration/API parameters programmed either directly or via calibration value at the request of GM Validation Engineering.

4.1.7 Input Impedance. The tuner RF input circuitry shall be able to interface with the antenna technologies shown in 4.1.9 such as fixed mast antennas and active antennas.

4.1.8 Tuner Measurement Mode Configuration. The tuner shall not be tested using any special software/development modes. A development screen for tuner parameter and/or RDS status reporting is allowed. All tests shall commence in normal vehicle operating mode.

4.1.9 Compatibility with Antenna Interfaces. The tuner shall support the following antenna interface features:

- a. Passive masts (capacitive AM) and active AM antennas with AM impedance according to GMW15649 and GMW15650.
- b. Active FM antennas.

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- c. Phantom Direct Current (DC) power supply to an active antenna.
- d. Active antenna power using Remote Enable output as applicable.

4.1.10 Regional Programming. CG3476 along with the corresponding DOORS/GIS requirements shall define the regional configurations for the tuner. The supplier shall work with the GM Design Responsible Engineer to comprehend this requirement.

4.1.11 Digital IF Feature. The tuner shall provide a Digital low Intermediate Frequency (IF) that shall not exceed ± 1 MHz from Zero IF utilizing a single digital mix.

4.1.12 Time to Produce Audio. The time to produce audio after power on shall be defined in the appropriate GM DOORS/Global Infotainment Standard (GIS) requirements and adhered to by the tuner.

4.1.13 High Definition (HD) Radio.

4.1.13.1 HD Radio Certification. At the DV sample stage all HD compatible tuners shall be pre-certified by XPERI Corporation (formerly iBiquity). At the PV sample stage all HD compatible tuners shall be certified by XPERI Corporation (formerly iBiquity). Evidence of certification shall be provided to GM that includes at a minimum:

- a. All FM Receiver Sensitivity and Bit Error Rate (BER) Performance testing specified in the latest version of RX_CERT_3727 document provided by XPERI Corporation.
- b. All FM Receiver Sensitivity and BER Performance testing specified in the latest version of RX_CERT_3727 document by XPERI Corporation.
- c. For receivers with Maximal Ratio Combining (MRC) feature all FM Receiver Sensitivity and BER Performance testing specified in the latest version of RX_CERT_3850 document provided by XPERI Corporation
- d. The receiver sensitivity and BER performance testing shall be measured using the iBiquity sensitivity measurement procedure specified in the latest version of RX_CERT_3727 and/or RX_CERT_3850 document from XPERI Corporation.

The radio shall fulfill the requirements according to GMW15648 and GMW17201.

4.1.14 Maximum RF Input Voltage. The Radio shall fulfill the requirements according to GMW3091, GMW3097 and GMW3103.

4.1.15 Strong Signal Protection. The tuner shall be able to prevent RF overload with all supported antenna types. In addition, the radio shall fulfill the requirements according to GMW15648.

4.1.16 Diagnostics HMI. The radio supplier shall provide the necessary steps to enable and display the tuner diagnostic screens for purposes of test and monitoring as required.

4.2 Tuner General Requirements.

4.2.1 AM Frequency Range.

4.2.1.1 Requirements. Configuration of the tuner to multiple frequency ranges shall be possible. The lower and upper limits specify the center frequency of the first and last tunable channel.

The tuner shall NOT provide support for the Long Wave (LW) broadcast band of (153 to 279) kHz.

If the tuner has AM calibrated off due to a country/regional Regulatory Advisory, no AM tests are required for that configuration.

4.2.1.2 Test Method.

- a. Verify the tuner programming per CG3476.
- b. Adjust the tuner manually to all listed lower and upper limits defined in CG3476 for the regional programming under test. Ensure that tuning range and HMI is aligned and that functionality of the radio with the corresponding frequency of the RF signal generator is given through the entire range.
- c. Record the lower and upper values for the AM Frequency Range.

4.2.2 FM Programmable Frequency Ranges and FM De-emphasis.

4.2.2.1 Requirements. Configuration of the tuner to multiple frequency ranges shall be possible. The lower and upper limits specify the center frequency of the first and last tunable channel.

The specified FM De-emphasis shall be paired with the specified FM frequency ranges as specified in CG3476.

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4.2.2.2 Test Method.

- Verify the tuner programming per CG3476.
- Adjust the tuner manually to all listed lower and upper limits defined in CG3476 for the regional programming under test. Ensure that tuning range and HMI is aligned and that functionality of the radio with the corresponding frequency of the RF signal generator is given through the entire range.
- Record the lower and upper values for the FM Frequency Range. The specified FM De-emphasis shall be paired with the specified FM frequency ranges as specified in CG3476.

4.2.3 AM Tuning Steps.

4.2.3.1 Requirements. The tuner shall support AM seek, manual and direct (keypad) tune functionality with the frequency stepsize calibrations specified in CG3476.

The tuner shall support the channel bandwidths which are connected to the tuning seek calibration.

4.2.3.2 Test Method.

- Verify the tuner programming per CG3476. Adjust the tuner to the lower limit of the corresponding Frequency Range.
- Adjust the RF signal generator for an output level of 60 dB μ V and frequency matching to the corresponding Step-Size as specified in CG3476 (e.g., for AMSTEP1: 1020 kHz - frequency will not be tuned by the radio with a Step-Size of 9 kHz).
- All listed functionalities shall be verified. For seek manual, and direct (keypad) tuning both directions shall be tested. Ensure functionality of the radio with the corresponding frequency of the RF signal generator.
- Record the tuning steps for each programmable AM Tuning Step.

4.2.4 FM Tuning Steps.

4.2.4.1 Requirements. The tuner shall support FM seek, manual and direct (keypad) tune functionality with the frequency stepsize calibrations specified in CG3476.

The tuner shall support the channel bandwidths which are connected to the tuning seek calibration.

4.2.4.2 Test Method.

- Verify the tuner programming per CG3476.
- Adjust the tuner to the lower limit of the corresponding Frequency Range.
- Adjust the RF signal generator for an output level of 60 dB μ V and the frequency matching to the corresponding Step-Size as specified in CG3476 (e.g., for FM_STEP2: 97.6 MHz - frequency will not be tuned by the radio with a Step-Size of 200 kHz).
- All listed functionalities shall be verified. For seek manual, and direct (keypad) tuning both directions shall be tested. Ensure functionality of the radio with the corresponding frequency of the RF signal generator.
- Record the tuning steps for each programmable FM Tuning Step.

4.2.5 AM Seek Threshold Configuration.

4.2.5.1 Requirements. See Table 1. The AMSeek value is a calibration parameter. The value in the table is meant solely for bench testing to demonstrate the tuner can be set to a specified RF Level within an acceptable tolerance band. Each unique vehicle/antenna combination will result in a unique value for that vehicle platform.

The seek function shall perform the same for both the seek-up and seek-down function.

4.2.5.2 Test Method.

- Configure the RF signal generator using the AM Mono Standard Test Condition.
- Adjust the tuner to a channel at least ten (10) channels below the target test frequency of 1080 kHz.
- Adjust the RF signal generator for an output level at least 5 dB μ V below the high seek threshold.
- Increase the generator level using a minimum of 1 dB μ V steps until the tuner stops on the target test frequency when using the seek-up function. If the tuner does not stop at the target test frequency, interrupt the seek function or use a second signal generator at 60 dB μ V on the starting channel to stop the seek function so that the tuner will not switch to the low seek threshold. If using two generators, all RF levels are specified WITHOUT the loss of the combiner.

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- e. Record the signal generator's output level as the High-Level-Seek Threshold. The final value shall be recorded in 0.1 dB μ V resolution.
- f. Adjust the tuner to a channel at least ten (10) channels below the target test frequency of 1080 kHz.
- g. Adjust the RF signal generator to an output level at least 5 dB μ V below the low seek threshold.
- h. Increase the generator level using a minimum of 1 dB μ V steps until the tuner stops on the target test frequency during the low seek/second seek when using the seek-up function. If the tuner has a low seek timer, wait beyond the time-out before incrementing the RF signal generator output level and starting again. Record the signal generator's output level as the Low-Level-Seek Threshold. The final value shall be recorded in 0.1 dB μ V resolution.

Table 1: AM_SEEK

Band	Frequency	High Level	Low Level	Limit
AMSeek	1080 kHz	38 dB μ V	20 dB μ V	± 3 dB

4.2.6 FM Seek Threshold Configuration.

4.2.6.1 Requirements. See Table 2. FMSeek value is a calibration parameter. The value in the table is meant solely for bench testing to demonstrate the tuner can be set to a specified RF Level within an acceptable tolerance band. Each unique vehicle/antenna combination will result in a unique value for that vehicle platform. The seek function shall perform within the limits over the entire worldwide FM band of (76 to 108) MHz.

4.2.6.2 Test Method.

- a. Configure the RF signal generator using the FM Mono Standard Test Condition.
- b. Adjust the tuner to a channel at least ten (10) channels below the target test frequency of 98.1 MHz.
- c. Adjust the RF signal generator for an output level at least 5 dB μ V below the high seek threshold.
- d. Increase the generator level using a minimum of 1 dB μ V steps until the tuner stops on the target test frequency when using the seek-up function. If the tuner does not stop of the target test frequency, interrupt the seek function or use a second signal generator at 60 dB μ V on the starting channel to stop the seek function so that the tuner will not switch to the low seek threshold. If using two generators, all RF levels are specified WITHOUT the loss of the combiner.
- e. Record the signal generator's output level as the High-Level-Seek Threshold. The final value shall be recorded in 0.1 dB μ V resolution.
- f. Adjust the tuner to a channel at least ten (10) channels below the target test frequency of 98.1 MHz.
- g. Adjust the RF signal generator to an output level at least 5 dB μ V below the low seek threshold.
- h. Increase the generator level using a minimum of 1 dB μ V steps until the tuner stops on the target test frequency during the low seek/second seek when using the seek-up function. If the tuner has a low seek timer, wait beyond the time-out before incrementing the RF signal generator output level and starting again.
- i. Record the signal generator's output level as the Low-Level-Seek Threshold. The final value shall be recorded in 0.1 dB μ V resolution.

Table 2: FM_SEEK

Band	Frequency	High Level	Low Level	Limit
FMSeek	98.1 MHz	36 dB μ V	15 dB μ V	± 3 dB

4.2.7 AM Selectivity.

4.2.7.1 Requirements. See Table 3.

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4.2.7.2 Test Method.

Setup: Use the MiniCircuits ZSC-2-1+ or equivalent to combine two signal generators. All RF levels specified are WITHOUT the loss of the combiner.

- Configure the desired station's RF signal generator using the AM Mono Standard Test Condition, Adjust the desired station's RF generator output level to $E' = 30 \text{ dB}\mu\text{V}$.
- Configure the alternate station generator RF and modulation off.
- Establish the 0 dB audio reference level using the RF levels specified in preceding step a.
- Turn off desired station's modulation.
- Turn on the alternate station's RF generator at or below 0 dB μV .
- Adjust alternate station's generator frequency to $f_{\text{desired}} \pm df$ (one test at a time) and turn on the modulation at 30% (same as AM Mono Standard Test Condition).
- Increase the alternate station's level from a low value until the audio output level measures -26 dB compared to the 0 dB level measured in step a with a measurement delay; settling time of at least 250 ms.
- A selectivity graph shall be provided in CG2510 demonstrating the selectivity characteristics with a $\pm df$ from 0 Hz to 100 kHz utilizing a minimum of 1 kHz resolution as shown in Appendix E.
- Calculate Selectivity as the ratio of the desired and alternate station RF output levels.
- A plot of selectivity response shall be provided in CG2510 as shown in Appendix E.

Table 3: AM Selectivity

df	Limit
$\pm 10 \text{ kHz}$	> 80 dB
$\pm 20 \text{ kHz}$	> 85 dB
$\pm 100 \text{ kHz}$	> 90 dB

4.2.8 FM Selectivity.

4.2.8.1 Requirements. See Table 4.

4.2.8.2 Test Method.

Setup: Use the MiniCircuits ZSC-2-1+ or equivalent to combine two signal generators. All RF levels specified are WITHOUT the loss of the combiner.

- Configure the RF signal generator using the FM Mono Standard Test Condition.
- Adjust the RF generator output level to $E' = 26 \text{ dB}\mu\text{V}$.
- Configure the alternate station generator RF and modulation off.
- Establish the 0 dB audio reference level using the RF levels specified in preceding step b.
- Turn off desired station's modulation.
- Turn on the alternate station's RF generator at or below 0 dB μV .
- Adjust alternate station's generator frequency to $f_{\text{desired}} \pm df$ (one test at a time) and turn on the modulation at 22.5 kHz deviation (same as FM Mono Standard Test Condition).
- Increase the alternate station's level from a low value until the audio output level measures -26 dB compared to the 0 dB level measured in step b with a measurement delay/settling time of at least 250 ms.
- A selectivity graph shall be provided demonstrating the selectivity characteristics with a $\pm df$ from 0 Hz to 600 kHz utilizing a minimum of 1 kHz resolution as shown in Appendix E.
- Calculate Selectivity as the ratio of the desired and alternate station RF output levels
- A plot of selectivity response shall be provided in CG2510 as shown in Appendix E.

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Table 4: FM Selectivity

Receiver Type	df	Limit
200 kHz spacing	± 200 kHz	> 70 dB
	± 300 kHz	> 70 dB
	± 400 kHz	> 70 dB
	± 600 kHz	> 80 dB
100 kHz spacing	± 75 kHz	15 dB $\pm$ 10 dB
	± 80 kHz	30 dB $\pm$ 10 dB
	± 85 kHz	= 40 dB $\pm$ 15 dB
	$\geq +150$ kHz ≤ -150 kHz	> 70 dB

4.2.9 FM Deviation Sensitivity.

4.2.9.1 Requirements. See Table 5. This requirement applies to all audio system configurations regardless of internal or external amplifier utilizing a 13.8 VDC $\pm$ 0.1 V supply at all test temperatures.

4.2.9.2 Test Method.

- Configure the RF signal generator using the FM Mono Standard Test Condition.
- Establish the 0 dB audio reference level.
- Adjust the radio volume to maximum.
- Adjust the RF signal generator FM deviation to 0 Hz.
- Increase the generator's FM deviation setting until the 0 dB audio reference level is reached utilizing 0.1 kHz resolution allowing at least a 1 s measurement delay/settling time between deviation steps. Record the RF signal generator's FM deviation level.

Table 5: FM Deviation Sensitivity

Audio Output Circuit	Nominal	Limit
Audio Amplifier	2.6 kHz	± 0.6 kHz

4.2.10 FM Output vs. Deviation.

4.2.10.1 Requirements. See Table 6. This requirement applies to all audio system configurations with an internal amplifier utilizing a 13.8 VDC $\pm$ 0.1 V supply at all test temperatures.

4.2.10.2 Test Method.

- Configure the RF signal generator using the FM Mono Standard Test Condition with the 0 dB reference set to 0.5 W $\pm$ 0.05 W instead of 1.4 W.
- Adjust RF signal generator FM deviation according to Table 6 allowing at least a 1 s measurement delay/settling time between deviation steps.
- Record the FM output level of the radio to two decimal places.

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Table 6: FM Output vs. Deviation

FM Deviation in kHz	Output for a Radio using the Internal Power Amplifier – Variable Level Output in W at 13.8 VDC $\pm$ 0.1 V	
0	0.00	$\pm$ 0.01
5	0.03	$\pm$ 0.01
10	0.11	$\pm$ 0.02
15	0.25	$\pm$ 0.03
20	0.45	$\pm$ 0.05
22.5	0.50	$\pm$ 0.1
25	0.69	$\pm$ 0.1
30	1.00	$\pm$ 0.1
35	1.36	$\pm$ 0.2
40	1.77	$\pm$ 0.3
45	2.25	$\pm$ 0.3
50	2.78	$\pm$ 0.4
55	3.35	$\pm$ 0.5
60	4.00	$\pm$ 0.5
65	4.69	$\pm$ 0.5
70	5.44	$\pm$ 0.5
75	6.23	$\pm$ 0.8

4.2.11 Distortion.

4.2.11.1 Requirements. See Table 7. This requirement applies to all audio system configurations regardless of internal or external amplifier utilizing a 13.8 VDC $\pm$ 0.1 V supply at all test temperatures.

4.2.11.2 Test Method.

- Configure the RF signal generator using the AM Mono or FM Mono Standard Test Condition as applicable.
- Establish the 0 dB audio reference level.
- Adjust the RF generator modulation or deviation level using the table.
- Perform a swept total harmonic distortion (THD) measurement for the audio frequencies specified in Table 7.
- Find the highest (peak) level of distortion for the swept frequencies.
- Record that peak level as the distortion.

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Table 7: Distortion Measurement

Frequency	Audio Level	Audio Frequency	Maximum Distortion
1080 kHz	30% mod.	50 Hz to 2.5 kHz	1.5%
1080 kHz	80% mod.	50 Hz to 2.5 kHz	2.0%
98.1 MHz	11 kHz	1 kHz to 15 kHz	1.0%
98.1 MHz	22.5 kHz	40 Hz to 1 kHz	1.0%
98.1 MHz	75 kHz	40 Hz to 1 kHz	4.5%

4.2.12 Audio Frequency Response.

4.2.12.1 Requirements. See Table 8 for Audio Frequency Response. The Left/Right channel amplitude imbalance shall not exceed 0.5 dB at all frequencies inclusive of the test frequencies listed in Table 8.

Table 8: Audio Frequency Response

Band	Audio Frequency Range	Nominal	Limit
FM	40 Hz	-3 dBr	± 1 dB
	15 kHz	-3 dBr	± 1 dB
AM/MW	100 Hz	-3 dBr	± 2 dB
	2.5 kHz	-3 dBr	± 1 dB

4.2.12.2 Test Method. Perform this test on both left and right channels

- Configure the RF signal generator using the AM Mono or FM Mono Standard Test Condition as applicable. For FM measurements, adjust the generator's FM deviation to 11.0 kHz instead of 22.5 kHz to establish 0 dBr.
- Establish the 0 dB audio reference level utilizing the left channel.
- Adjust the audio frequency as directed by the table.
- Measure the resulting audio output of both the left and right channels in dBr.
- Record the audio output as the difference between the 0 dB reference level (Step c) and the measured audio level (step d).
- A plot of audio frequency response shall be provided in CG2510 as shown in Appendix E.

4.2.13 FM Pilot Rejection Ratio.

4.2.13.1 Requirements. See Table 9.

Table 9: FM Pilot Rejection Ratio

Pilot Frequency	Limit
19 kHz	> -85 dBr
38 kHz	> -85 dBr
57 kHz	> -85 dBr

4.2.13.2 Test Method.

- Configure the RF signal generator using the FM RDS Standard Test Condition.

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- b. Adjust the generator's FM deviation to 11.0 kHz instead of 22.5 kHz to establish the 0 dB audio reference level.
- c. Establish the 0 dB audio reference level.
- d. Turn off the 1 kHz audio modulation on the RF signal generator.
- e. Measure and record the audio output using a selective filter adjusted to each pilot frequency Listed in Table 9, relative to 0 dBr utilizing a 3% Bandpass filter at each measurement frequency.

4.2.14 Station Tuning Frequency Error.

4.2.14.1 Requirements. See Table 10.

4.2.14.2 Test Method.

- a. Configure the RF signal generator using the AM Mono or FM Mono Standard Test Conditions as applicable.
- b. Establish the 0 dB audio reference level. Adjust the RF signal generator to a 28 dBμV output level.
- c. Set the RF signal generator frequency to $f_{wanted} - df$.
- d. Increase RF signal generator frequency with a measurement delay/settling time of at least 1 s until audio output level is -3 dBr.
- e. Record RF generator frequency as f_1 .
- f. Set RF generator to frequency to $f_{wanted} + df$.
- g. Decrease RF generator frequency with a measurement delay/settling time of at least 1 s until audio output level is -3 dBr Record RF generator frequency as f_2 .
- h. Calculate Station Frequency Tuning Error = $|(f_1 + f_2)/2 - f_{wanted}|$
- i. This test may be omitted if the supplier can show evidence that the tuner crystal meets the following characteristics:
 - Initial drift $< \pm 25$ ppm
 - Maximum drift over time $< \pm 5$ ppm/year
 - Maximum drift over the operating temperature range $< \pm 30$ ppm

Table 10: Station Tuning Frequency Error

Band	f_{wanted}	Generator Setting	df	Limit
MW	1080 kHz	28 dBμV	10 kHz	< 0.3 kHz
FM	98.1 MHz	28 dBμV	200 kHz	< 5 kHz

4.2.15 FM Stereo Separation.

4.2.15.1 Requirements. See Table 11. The maximum stereo separation shall not exceed 35 dB, and there shall be no channel cross-over at 0 dB separation. The Left/Right channel amplitude imbalance shall not exceed 0.5 dB. The stereo separation curve characteristics shall not be impacted due changes in audio equalization.

4.2.15.2 Test Method.

- a. Configure the RF signal generator using the FM Stereo Standard Test Condition.
- b. Establish the 0 dB audio reference level (utilizing the left channel).
- c. Turn off the right audio channel's modulation.
- d. Set the RF signal generator to 0 dBμV and increment the RF signal generator in 1 dB steps with a measurement delay/settling time of at least 1 s until reaching 60 dBμV. Determine the E' needed for the required separation from the left to the right channel for the points listed in Table 11.
- e. Repeat this test by turning on the right audio channel and turning off the left audio channel and recording the RF generator's output level as the RF threshold level for right to left separation.
- f. Repeat steps c, d, and e but instead begin the test at 60 dBμV and end at 0 dBμV for left to right and right to left channel separation.

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- g. Plots showing the left to right and right to left stereo separation from 0 dB μ V to 60 dB μ V and 60 dB μ V to 0 dB μ V shall be included in CG2510.

Table 11: FM_SEPARATION

Name	Desired Channel Separation	Nominal RF Level	Limit
All Regions except Korea	< 3 dB	≤ 26 dB μ V	NA
	3 dB	29 dB μ V	± 3 dB
	6 dB	31 dB μ V	± 3 dB
	9 dB	33 dB μ V	± 3 dB
	12 dB	36 dB μ V	± 3 dB
	20 dB	39 dB μ V	± 3 dB
	30 dB	42 dB μ V	± 3 dB
Korea 1 kHz	0 dB	25 dB μ V	± 3 dB
	4 dB	30 dB μ V	± 3 dB
	7 dB	35 dB μ V	± 3 dB
	22 dB	50 dB μ V	± 3 dB
	25 dB	55 dB μ V	± 3 dB
	27 dB	60 dB μ V	± 3 dB
	30 dB	65 dB μ V	± 3 dB
	30 dB	70 dB μ V	± 3 dB
Korea 10 kHz	0 dB	25 dB μ V	± 3 dB
	0 dB	30 dB μ V	± 3 dB
	0 dB	35 dB μ V	± 3 dB
	8 dB	50 dB μ V	± 3 dB
	12 dB	55 dB μ V	± 3 dB
	18 dB	60 dB μ V	± 3 dB
	30 dB	65 dB μ V	± 3 dB
	30 dB	70 dB μ V	± 3 dB

4.2.16 Broadcast Audio Change Timing.

4.2.16.1 Requirements The requirements shown are the maximum allowed values. See Table 12. This measurement is performed as an audio dropout time between a frequency change using a preset, for start-up of the radio, and for a source change between FM and AM.

The tuner shall use this behavior during an audio dropout time between a preset frequency change.

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