APPENDIX

E

Mobile Installation Standards and Techniques

E.1 Introduction

The information contained in this appendix has been prepared for use by persons installing mission critical two-way mobile radio equipment and associated accessories in vehicles. It has been prepared according to current engineering principles and generally accepted practices. These guidelines are intended to supplement, but not to be used in place of, detailed instructions from the manufacturers of mission critical mobile equipment. Because it is not possible to cover all possible installations of mission-critical mobile equipment, Motorola Solutions, Inc. cannot be held responsible for incidental or consequential damages arising from the use of the information contained herein.

This Appendix contains information on the following topics:

- “Referenced Publications for Mobile Installations” on page E-2
- “Safety Requirements for Mobile Installations” on page E-2
- “Mobile Installer Training and Certification” on page E-4
- “Vehicle Considerations” on page E-5
- “Planning for Mobile Installations” on page E-5
- “Transceiver Preventive Maintenance and Inspection” on page E-6
- “Pre-Install and Post-Install Checklist” on page E-6
- “Tools for Mobile Installation” on page E-7
- “Installation of Mobile Equipment” on page E-8
- “Power Wiring for Mobile Installations” on page E-16
- “Joining Conductors for Mobile Installations” on page E-26
- “Bonding Requirements for Mobile Installation” on page E-29
- “Conductor Tapping and Soldering” on page E-30
- “Electrical Tape and Heat Shrink Tubing” on page E-31
- “Antenna Installation and Testing” on page E-32
- “Effective Receiver Sensitivity Testing” on page E-42
- “Radio Transmit Noise Testing” on page E-46
- “Installation of Miscellaneous Equipment” on page E-47
- “Motorcycle Installations” on page E-49
- “Marine Installations” on page E-51
- “Aircraft Installations” on page E-52
- “Example of Installation Checklist” on page E-52



IMPORTANT: The information contained in this appendix is intended to supplement the equipment installation manual provided by the manufacturer. The specific equipment installation manual **shall** be followed.

E.2 Referenced Publications for Mobile Installations

The following publications were used in this Appendix and should be referred to for more information.

- Chrysler Corporation: Radio Communication Equipment Installation Recommendations
- FCS1362:2022: UK Code of Practice for the Installation of Mobile Radio and Related Ancillary Equipment in Land Based Vehicles
- ETA International (ETA®): Mobile Communications & Electronics Installer
- Ford Motor Company: Mobile Radio Installation Guidelines
- IEEE CH2944-7/91/0000/0866 Vehicle mobile radio installation guidelines
- General Motors: Radio Telephone / Mobile Radio Installation Guidelines
- General Motors Upfitter Integration, UI Bulletin #119: Info - Radio Telephone/Mobile Radio (Transceiver) Installation and Troubleshooting Guidelines; All GM Passenger Cars and Trucks, Model Years 2000 and beyond. Revision date August 14, 2014
- Motorola Solutions, Inc.: APX™ Mobiles Installation Manual (part number 6878215A01)
- Motorola Solutions, Inc.: RF Energy Exposure Training and Product Safety Information for Mobile Two-Way Radios installed in Vehicles or as Fixed Site Control Stations (part number 6881095C99)
- National Institute of Justice: Guide to Test Methods, Performance Requirements, and Installation Practices for Electronic Sirens Used on Law Enforcement Vehicles (NIJ Guide 500-00)
- SAE J1128_202508: Surface Vehicle Standard - Low Voltage Primary Cable
- SAE J1849: Surface Vehicle Standard - Emergency Vehicle Sirens
- SAE J378:201802: Surface Vehicle Standard - Marine Propulsion System Wiring

E.3 Safety Requirements for Mobile Installations



WARNING: Ensure adequate ventilation when running the vehicle.



WARNING: The installer SHALL receive proper training regarding the safety hazards of the following: supplemental restraint systems (airbags) and related equipment (see FCS1362:2022), high voltage in electric and/or hybrid vehicles, and compressed gas vehicles.



CAUTION: Before installing any electrical equipment, check the vehicle manufacturer's user manual and/or dealership for warnings and/or recommendations.

The following safety requirements **shall** be followed:

- To help ensure suitable and safe conditions for the installer, installation work **shall** take place in a suitable dry and well illuminated location and/or facility, as practicable (see FCS1362:2022, section 2.4.1).
- The installer **shall** read all equipment instruction manuals prior to installation.
- The installer **shall** receive proper training regarding the safety hazards associated with supplemental restraint systems (airbags) and associated equipment.
- The installer **shall** receive proper training regarding the safety hazards associated with high voltage in electric and/or hybrid vehicles.

NOTE: The high voltage (up to 900 volts) cables in hybrid and electric vehicles are typically orange or blue in color (Figure E-1 is an example). Check with the specific vehicle manufacturer's documentation. See FCS1362:2022 section 2.9.1 for more information.

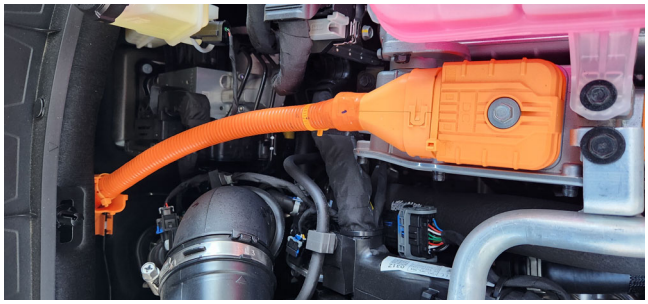


Figure E-1. Hybrid Vehicle High Voltage Cables Example

- The installer **shall** receive proper training regarding the safety hazards associated with compressed gas vehicles.
- The installer **shall** ensure the safety of the vehicle has not been compromised as a result of the mobile radio equipment installation (see FCS1362:2022).
- The installer **shall** ensure the safety of the vehicle has been maintained once work to fit the equipment has been completed (see FCS1362:2022).
- The installer **shall** take due consideration to ensure that safety is not compromised by any customer demands (see FCS1362:2022).
- Any modification to the vehicle **shall** be performed in such a way that it does not create a condition where danger is likely to be caused to the driver, passengers, or other road users (see FCS1362:2022).
- Before drilling or using self-drilling/tapping screws, check for vehicle system components (for example: batteries, wiring, fuel lines, brake lines, air conditioning lines, and so on) that may be damaged.
- There **shall** be no rough, sharp, or protruding edges that could be impacted by the vehicle's occupants in a collision (see FCS1362:2022).
- Excess lengths of any cable ties **shall** be cut flush with its locking mechanism to avoid leaving sharp and potentially dangerous projections (FCS1362:2022).
- The controls, displays, and cabling, including any microphone/handset lead of the installed equipment, **shall not** obscure nor obstruct instruments, vehicle controls or the swept area of the windscreen (windshield); neither should their operation distract or impede the driver (see FCS1362:2022).
- If the driver is the prime user of the equipment, all necessary controls should be positioned within reach of the driver but not in such a way that the driver's attention is distracted from the road or that the view of the road is obscured. See FCS1362:2022 for more information.
- The installer **shall** follow all equipment installation requirements as specified by the equipment manufacturer.
- The installer **shall** follow all installation and safety requirements published by the vehicle manufacturer related to aftermarket mobile radio equipment installations.
- Appropriate tools **shall** be used during installation, and the tools **shall** be used appropriately. See “Tools for Mobile Installation” on page E-7.
- Appropriate safety equipment (for example: safety glasses and gloves) **shall** be used during installation.
- Installers **shall** remove metallic rings and other jewelry that can come in contact with vehicle voltages.
- Appropriate hearing protection **shall** be used when running a vehicle siren.
- See FCS1362:2022 for additional safety information.

E.3.1 Requirements for Compliance with RF Energy Exposure Safety Standards

CAUTION: See the specific transceiver manufacturer instruction manual (or equivalent) for information regarding Radio Frequency (RF) energy exposure safety standards and warnings.

To ensure compliance with radio frequency (RF) Energy Safety Standards:

- Install only manufacturer approved antennas and accessories.
- Install equipment according to the manufacturer's instructions.
- Install the antenna(s) according to “Antenna Installation” on page E-33 and the radio’s Installation Manual.
- Provide any Operator’s Manual, Product Safety and RF Safety Booklets provided with the radio to the end user.

See FCS1362:2022, section 2.8 for more information.

E.3.2 Vehicle Battery Disconnect Recommendations

Before beginning mobile radio and electronics installations, Motorola Solutions recommends disconnecting the negative battery cable from the battery (12V battery systems).

If removing a seat that contains airbags, seat belt pre-tensioners, or other Supplemental Restraint System (SRS), the vehicle battery should be disconnected for safety. Before unplugging connectors associated with the seat wiring, time must be allowed after disconnecting the battery to ensure that any capacitors in the airbag or SRS circuitry have fully discharged. Check with the vehicle manufacturer’s guidelines.

All disconnected wiring must be reconnected prior to restoring the vehicle battery or turning the ignition on.

See FCS1362:2022 for more information.

E.4 Mobile Installer Training and Certification

Mission Critical Mobile Installers **shall** be properly trained in mobile installations, including the following: Land Mobile Radio (LMR), basic electricity, basic electronics, vehicle mechanics, safety, and other applicable disciplines (for example: emergency lighting and sirens). A Mobile Installer **shall** be certified in mobile installations by an industry recognized certification organization. Such certifications include, but are not limited to, the following:

- ETA International (ETA®): Mobile Communications and Electronics Installer
- Certification Systems Technology Company™: Mobile Electronics Certified Professional (MECP)

Additional certification from the Automotive Service Excellence (ASE®) in Electrical/Electronic Systems (A6) is recommended.

In addition to the certifications listed above, one or both of the following certifications are recommended for marine installers:

- National Marine Electronics Association (NMEA®): Marine Electronics Installer
- American Boat & Yacht Council (ABYC®): Marine Electrical

E.5 Vehicle Considerations

Adding emergency equipment (e.g., lights, sirens, and communications equipment) increases the current demand on the vehicle's charging system. To ensure adequate charging capacity, the vehicle's alternator must be adequately sized to accommodate the additional current draw. Vehicles ordered specifically for emergency operations typically have an alternator designed to meet the additional demand.

If the vehicle was not ordered as an emergency vehicle with a higher-capacity alternator, ensure the emergency equipment does not exceed the capacity of the vehicle's charging system. This may require the assistance of an Installation Engineer or vehicle dealership. If the charging system is determined to be inadequate, a higher-capacity alternator will be required.

E.6 Planning for Mobile Installations

NOTE: The following information primarily applies to projects and/or fleet installations. As applicable, the information should be used as general guidance for all installations.

Mission critical land mobile radio installations **shall** be properly planned, engineered, and documented. The customer **shall** approve the final installation plan. Mission-critical installation planning should include all members of the project team as follows (as applicable):

- Customer representative with decision making authority
- Project manager
- Project system engineer
- Project field engineer or system technologist
- Project maintenance technician and/or system manager
- Project installation contractor

Installation planning **shall** be documented for each vehicle type (for example: Police, Fire, Public Works, and so on), for each vehicle make/model (for example: Ford Explorer, Chevy Tahoe, Dodge Charger, Ladder Truck, Engine, Aid Unit, and so on). The installation documentation **shall minimally** include the following:

- Radio transceiver mounting location
- Radio control head mounting location
- Radio microphone mounting location
- Radio speaker mounting location
- Siren speaker mounting location
- Antenna mounting location
- Radio power and earth/ground connection locations
- Radio cable routing
- Third-party audio interface (for example: headset or PA) requirements
- Existing equipment removal and/or relocation requirements
- Power distribution and fuse locations

IMPORTANT: Ensure the antenna type and mounting location match the engineered system design. Changing the antenna type and/or mounting location without engineering approval can negatively impact the mobile radio's intended coverage footprint and/or can violate licensing limitations.

E.6.1 Vehicle Protection

The Mobile Installer **shall** exercise due care to avoid vehicle damage. Such care includes, but is not limited to, the following (see FCS1362:2022, section 2.4.3):

- Wearing nothing sharp that can scratch a vehicle or cause damage to the interior.
- Using a fender cover where applicable.
- Using drop cloths or blankets on seats.
- Avoid putting tools in back pockets that could gouge or tear the interior of the vehicle.
- Ensuring no grease, oil, or dirt is present on hands, clothing, shoes, and so on when getting in a vehicle.

E.7 Transceiver Preventive Maintenance and Inspection

Prior to installation, the radio transceiver **shall** be tested for proper operation according to the manufacturer's recommendations and jurisdictional requirements (for example: frequency, modulation, power output, and receiver sensitivity). All applicable measurements **shall** be documented. See FCS1362:2022, section 3.3 for more information.

Inspection should include a firmware upgrade (if applicable) as needed according to the manufacturer's instructions (such as Product Service Bulletins or Technical Notifications). The inspection **shall** be made by an appropriately certified and/or licensed technician.

All test equipment used for the transceiver preventive maintenance **shall** be in known good working order and **shall** be within national and/or factory calibration standards. The test equipment calibration records **shall** be maintained and made available as requested.

IMPORTANT: The transceiver output power **shall** be set according to the manufacturer's requirements and according to the system design requirements. Some specific system designs may call for a transmitter power output of something less than the maximum rated output power. Exceeding the specific system design rated power may be in violation of licensing limitations and/or may create undesired RF interference at the system infrastructure receivers.

NOTE: Receiver sensitivity should be recorded in dBm.

E.8 Pre-Install and Post-Install Checklist

Mission critical installations **shall** be planned and documented as described in “Planning for Mobile Installations” on page E-5. A pre-install and post-install checklist **shall** also be included.

The pre/post-install checklist should minimally include the following (see FCS1362:2022 and Section E.23 for example forms):

- A basic outline of the vehicle for quick indication of non-functioning lights, damage to the vehicle, and equipment location.
- A checklist pass/fail should include the following: running lights, headlights, dash lights, interior lights, LED lights and bars, strobes, sirens, wig-wags, vehicle horn, reverse lights, alley lights, brake and turn signal lights, gun release, RADAR, existing radios, intercom, and so on.
- Room for additional comments.
- Radio receiver sensitivity.
- Radio effective receiver sensitivity (see “Effective Receiver Sensitivity Testing” on page E-42).

- Radio transmit power output.
- Antenna VSWR or Return Loss (see “Antenna VSWR Testing” on page E-39).
  - Forward and reflected power.
- Voltage at radio transmitter when radio is keyed.

An example form is located at the end of this Appendix in “Example of Installation Checklist” on page E-52.

E.9 Tools for Mobile Installation

All installation tools and equipment used **shall** be functional, suitably maintained, and calibrated (if required). All measurement devices and meters should be regularly checked for accuracy. If accurate electrical measurements are required, the relevant test equipment **shall** be regularly checked and calibrated against a recognized national standard according to the manufacturer's requirements.

IMPORTANT: The appropriate tool **shall** be used, and the tool **shall** be used according to the manufacturer's instructions.

The suggested installation tools and equipment include, but are not limited to, the following (see FCS1362:2022 and ETA® International publication, *Mobile Communications & Electronics Installer*):

- A good quality general tool kit including screwdrivers, spanners, socket set, pliers, and so on
- Any specialist tools relative to the type of vehicle and products undergoing installation
- Correct equipment and tools for removal of panels and trim should be used as appropriate
- VSWR meter (see “Antenna VSWR Testing” on page E-39)
- Antenna analyzer (see “Antenna VSWR Testing” on page E-39)
- Coax strippers
- RF connector ratchet crimp tool
- Wire strippers
- DC connector ratcheting crimp tool (see “Electrical Ring Terminals, Lugs, Splices, and Similar Devices” on page E-27)
- Digital Voltmeter (DVM)
- Measuring tape
- Power drill kit
- Hole saw kit
- Hole saw specifically designed for antenna mounts (typically contain a collar to prevent damage to vehicle headliner)
- Portable soldering iron
- Heat gun (required for heat shrink materials and connectors)
- Vehicle trim removal tools
- Radio removal keys
- Specialized screw or security driver bits
- Seat, panel, and fender covers to protect the vehicle during installation procedures (see “Vehicle Protection” on page E-6)
- Storage for any parts, screws, or hardware (fixings) removed during installation for later reassembly

WARNING: DO NOT use old-style test lights (test probes) on vehicles with supplemental restraint systems (airbags). Inadvertently testing the wrong wire with the test light can deploy the airbag system, possibly resulting in injury or death to the installer and severe damage to the vehicle. Airbag-safe test lights are commercially available.

IMPORTANT: When crimping RF connectors (such as mini-UHF), the appropriate, manufacturer-approved, crimping tool **shall** be used. DO NOT attempt to crimp RF connectors with the wrong crimper, or other improper tools (such as pliers).

IMPORTANT: When crimping wire connectors and lugs, the appropriate, manufacturer-approved, crimping tool **shall** be used. DO NOT attempt to crimp connectors and lugs with the wrong crimper, or other improper tools (such as pliers).

E.10 Installation of Mobile Equipment

This section provides general guidelines and requirements for installation of mobile equipment:

- See “Safety Requirements for Mobile Installations” on page E-2.
- An equipment location **shall** be selected that provides a solid mounting point that does not interfere with the vehicle operator controls and provides adequate ventilation.

WARNING: DO NOT mount any transceiver, microphone, speaker, or any other item in the deployment path of the airbag system.

- The equipment and associated cables **shall not** be subject to damage during use.
- Ventilation for the equipment **shall** be maintained (see manufacturer installation instructions).
- Equipment **shall not** be located where it is subject to water damage.
- Equipment **shall not** be located where it is subject to heat damage.
- Connections to the equipment **shall** be easily accessible for maintenance purposes.
- If radio equipment is installed under the instrument panel, ensure there is no interference with the operation of the foot controls. Mount the control head or front panel (especially the microphone cable) so that it is clear of the steering wheel and column controls and passenger airbag.
- If screws penetrate the floor, the underbody projections **shall** be sealed. This will help keep moisture out of the carpet and insulation, and will forestall rust in this area.

WARNING: Under no circumstances SHALL installed equipment be left loose in the vehicle. All equipment SHALL be securely mounted. See FCS1362:2022, section 2.5 for more information.

IMPORTANT: Local jurisdictional regulations regarding windshield (windscreen) obstruction **shall** be followed.

E.10.1 Mounting Systems for Mobile Electronics

Numerous third-party mounting systems are available for mounting mobile electronics in emergency vehicles. Some of the benefits of the mounting systems are as follows:

- Safe and secure mounting of mobile electronics.
- Convenient mounting of mobile electronics.
- Space saving mounting of mobile electronics.
- Fold away design for space savings and convenient servicing of the equipment.

Mounting systems are available for several applications, such as the following:

- Passenger compartment area center console (see Figure E-2)
- Trunk sliding tray (see Figure E-3)
- Trunk fold away (see Figure E-4)
- Sport Utility Vehicle (SUV) rear fold away (see Figure E-5)

Motorola Solutions, Inc. does not endorse specific mobile electronics mounting systems. Requirements for mobile electronics mounting systems are as follows:

- The mounting system **shall** be designed for the application.
- The mounting system **shall** be designed for the specific vehicle.
- The mounting system **shall** be installed according to the manufacturer's requirements.



Figure E-2. Example of Center Console Mounting System

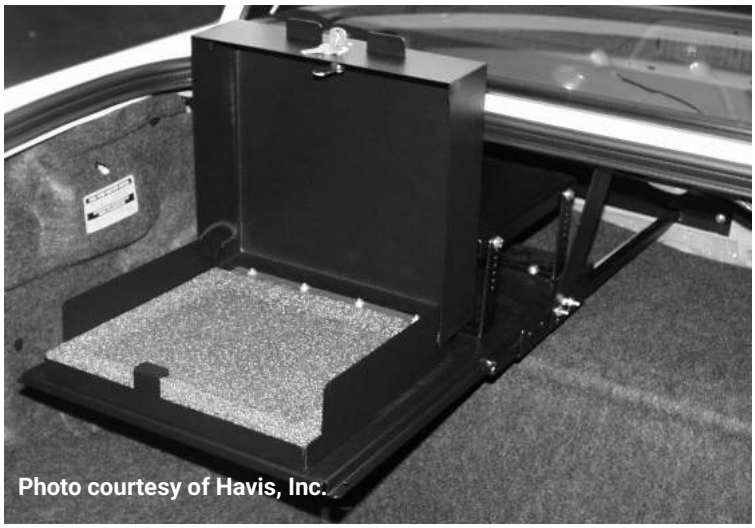


Figure E-3. Example of Sliding Trunk Mount System



Figure E-4. Examples of Trunk Fold-away Mounting System



Figure E-5. Example of SUV Fold Away Mounting System

E.10.2 Securing Hardware for Mobile Installation

Hardware to secure equipment may include the following (see FCS1362:2022, section 2.6.1.2):

- Screws or bolts with locking nuts or plain nuts with shake-proof washers are the preferred hardware for securing equipment, particularly where the equipment is heavy and/or where the equipment may be subjected to vibration.
  - This method may not always be practicable unless both sides of the holding surface are accessible.
- Rivet nuts offer a stronger solution than self-drilling/tapping screws. Rivet nuts come in various types and provide a blind nut or a threaded stud. See Figure E-6 for an example.
  - Rivet nuts often require special tools for fitting.
- Self-drilling/tapping screws are acceptable where a strong and secure surface is available to screw in to, and the back of the screw does not protrude into an accessible area leaving a sharp point that may cause injury or damage. See Figure E-7 for an example.
  - Be aware that self-drilling/tapping screws can work loose.
  - Self-drilling/tapping screws are not recommended for heavy loads.
  - Self-drilling/tapping screws are not recommended for equipment mounted to the underside of a shelf (or equivalent).
- Rivets provide a more permanent mounting. Therefore, consideration **shall** be given regarding the servicing needs of the equipment.
  - Not generally suitable for use for this reason.

Precautions **shall** be taken on all of the above to avoid the hardware working loose with vibration. The use of shake proof washers, locking nuts or flat nuts is recommended.

Corrosion resistant fastenings (for example, stainless steel nuts and bolts) should always be used in areas exposed to the elements.

WARNING: The shortest practicable screw or bolt SHALL be used to help prevent unintended contact with vehicle components (for example: EV batteries, wiring, fuel lines, or brake lines).

WARNING: To reduce risk of injury, installed hardware SHALL NOT be left with sharp protrusions.



Figure E-6. Example of Rivet Nut



Figure E-7. Example of Self-Drilling Screws

E.10.3 Routing, Protection and Securing of Conductors and Cabling

E.10.3.1 Routing of Conductors and Cabling for Mobile Installations

- Where practicable, all cables and conductors should pass under carpets and through trim or moldings in such a way as to ensure that any panels do not trap, crush, or distort the cable when refitted. Use sleeving or cable protection and cable ties where required. See FCS1362:2022, section 4.3.1 for more information.
  - Cables and conductors installed under carpets **shall** be routed away from areas of normal foot traffic, as practicable.
- Cable and conductor lengths **shall** provide sufficient slack for equipment to be easily tested and maintained while still connected.
- Cables and conductors **shall** be routed and supported so they avoid the following (see FCS1362:2022, section 4.3.3):
  - Sharp edges
  - Continual bending
  - Stress or strain
  - Abrasion
  - Extreme temperature
  - Sharp bends
  - Creating a hazard or distraction to the occupants of the vehicle
  - Running parallel to power cables in electric/hybrid vehicles, as practicable
  - Running in parallel with equipment's antenna cables, as practicable
- Route and secure all under-hood wiring away from heat and mechanical hazards, such as exhaust manifolds and moving parts (including the steering shaft, throttle linkage, fans, and so on).
  - The use of split loom or similar is required. This is important for aesthetics, as it ensures against wire chafing and protects against heat and oil damage.
  - Split loom installed in the engine space **shall** be rated for the temperature.
- Avoid routing cables and conductors near vehicle moving parts (for example: steering column, pedals, controls, and so on). See FCS1362:2022, section 4.3.3 for more information.
- Maintain as great a distance as practicable between mobile radio power conductors and the vehicle's electronic modules and wiring.
- If practicable, avoid running power conductors in parallel with vehicle wiring over long distances.
- Avoid routing the antenna cable (coax) in parallel with vehicle wiring over long distances, as practicable.
- Use caution when routing wires between the passenger and engine compartments to avoid chafing or pinching of wires.

E.10.3.2 Protection of Conductors and Cabling for Mobile Installations

NOTE: High-temperature split loom that is rated up to 149° C (300° F) is readily available. UV-rated split loom is readily available.

- Cabling open to the elements, such as power conductors installed in the engine area for connection to the battery, **shall** be protected using split loom (or equivalent) (FCS1362:2022). See Figure E-8 for an example.



Figure E-8. Example of Split Loom

- Cabling easily accessible within the passenger area **shall** be protected using split loom (or equivalent) (FCS1362:2022).
- Under-hood cabling and conductors **shall** be protected from damage and **shall** be installed in split loom (or equivalent).
- Split loom (or equivalent) used in the engine area, or other high temperature areas, **shall** be rated for the temperature.
- Split loom (or equivalent) normally exposed to UV **shall** be UV-rated.
- Grommets **shall** be used for aesthetics, safety, and cable protection whenever cabling passes through a firewall, bulkhead, or other partition. See Figure E-9 for an example.



Figure E-9. Example of Grommet Use

- Penetrations through the firewall **shall:**
  - Use grommets for cable protection (see Figure E-9).
  - Be sealed from dirt, fumes, and water. Sealing the firewall penetration may help reduce the amount of sound transmitted from the engine area to the passenger area.

E.10.3.3 Securing of Conductors and Cabling for Mobile Installations

- Cabling and conductors **shall** be secured as required to keep them in place and provide adequate strain relief.
- Cabling and conductors **shall not** be secured to movable parts under the dash, in the trunk, or in the engine compartment (for example: brake pedal, steering column, and so on).
  - Secure wires to a trunk lid arm only if mounting equipment to the trunk lid (such as antennas). Ensure there are no kinks where routing cables and leave slack if they must flex.
- Wiring **shall** be supported at intervals not greater than 45 cm (18 in.). See SAE J378:201802 for more information. Wiring routed under carpets, trim, or moldings is considered supported.

E.10.4 Cable Labeling for Mobile Installations

All cables **shall** be legibly labeled as to function and destination at each end, as practicable. Fuse holders **shall** be labeled as to the fuse size and associated equipment. Some labeling examples are as follows:

- APX Radio 700 MHz Antenna
- APX Radio VHF Antenna
- APX Radio GPS Antenna
- APX Radio 20A

See Figure E-10 for an example.



Figure E-10. Example of Coax Cable Labeling

E.10.5 Speaker Installation

- The speaker **shall** be installed according to the radio manufacturer's instructions. See Figure E-11 for an example.
- The speaker **shall** be mounted out of the way so that it will not be kicked or knocked around by the vehicle occupants.
- The speaker **shall** be positioned to provide an unobstructed audio path to the user (see FCS1362:2022, section 4.4.4).
- The speaker **shall** be positioned to ensure any vehicle occupant is not likely to suffer discomfort from excessive audio levels (see FCS1362:2022, section 4.4.4).

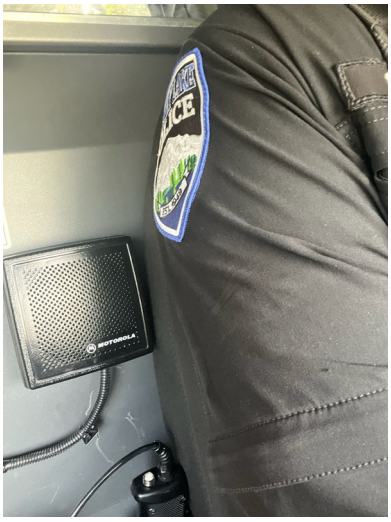


Figure E-11. Example of Speaker Installation in Police SUV

E.10.6 Microphone Installation

- The microphone **shall** be installed according to the radio manufacturer's instructions. See Figure E-2 and Figure E-12 for examples.
- The microphone hang-up clip **shall** be mounted within reach of the operator(s) and close enough to the control head to prevent cable strain.
- The microphone hang-up clip **shall** be mounted in a location that will prevent the microphone cable from interfering with normal vehicle operations and/or controls.



Figure E-12. Example of Microphone Installation

NOTE: Some radio microphone models require grounding of the microphone hang-up clip for Hang-up Box (HUB) operation to work correctly.

E.10.7 Equipment Installation in Vehicles with Airbags

Most modern vehicles are equipped with driver and passenger airbags, seat belt pretensioners, and other Supplementary Restraint Systems (SRS). These safety items are activated in the event of a collision. SRS components can be located in the steering wheel, under the dashboard fascia, sides of seats, front pillars, and side ceiling. The vehicle instruction manual and, if necessary, the vehicle manufacturer **shall** be consulted regarding the location of airbags and their deployment in the event of a collision. Care **shall** be taken during installation to avoid any possibility of inadvertently triggering the airbag or SRS equipment.

Airbags will affect the equipment installation location and associated cabling. The equipment and its cabling **shall not** impede the airbag deployment and operation.

If removing a seat containing side impact airbags, seatbelt pretensioners or other SRS, disconnect the vehicle battery as a safety precaution. Before unplugging seat wiring connectors, time must be allowed after the battery is disconnected to ensure any capacitors in the SRS circuitry have fully discharged. Check with the vehicle manufacturer's guidelines and/or dealer. All disturbed seat wiring **shall** be reconnected prior to restoring the vehicle battery or turning the ignition on. See FCS1362:2022, section 2.9.2.2, for more information.

WARNING: DO NOT mount any transceiver, microphone, speaker, or any other item in the deployment path of the airbag system.

WARNING: DO NOT use old-style test lights (test probes) on vehicles with supplemental restraint systems (airbags). Inadvertently testing the wrong wire with the test light can deploy the airbag system, possibly resulting in injury or death to the installer, and/or severe damage to the vehicle. Airbag-safe test lights are commercially available.

E.11 Power Wiring for Mobile Installations

NOTE: The recommendations and requirements contained within this section are based on a vehicle with a 12V negative ground power system. Other vehicle power system configurations may exist. In such cases, consultation with an Installation Engineer is recommended.

IMPORTANT: A 12 volt tap must not be taken from the batteries of a vehicle that has a supply greater than 12 volts. If a vehicle has a supply greater than 12 volts, then either the equipment **shall** be rated for the higher voltage, or a suitable regulator or converter **shall** be used that will provide the nominal supply voltage for which the equipment is designed. See FCS1362:2022, section 4.6.6 for more information.

- The power cable supplied by the radio manufacturer **shall** be used, where practicable.
- If the power cable must be extended, total voltage drop **shall** be considered. See “Power Conductors for Mobile Installations” on page E-20.
- Transceiver (+) power (red) connections should be made to one of the following:
  - To the battery directly, using appropriate hardware. See Figure E-13.
  - To an adequate power distribution center. Consult the vehicle manual and/or dealership to determine the power distribution center ampacity rating.
  - To the positive jump-start post, if present. See Figure E-14.
  - To the vehicle power disconnect switch, if applicable.
  - To the vehicle filtered battery distribution center (available on some emergency vehicles for the purpose of supplying power to the mission critical systems).
- The power conductor (+) **shall** be appropriately fused as close to the source as practicable. A weatherproof fuse holder is recommended.

- Transceiver (-) ground (black) should be connected to a convenient solid chassis ground point as close as practicable to the point where the battery-to-body connection is made (FCS1362:2022).
  - A factory-installed negative jump-start post is a good example. See Figure E-15.
  - **Do not** connect the ground (black) conductor directly to the battery's negative terminal.
- **Do not** fuse the ground (-) lead. If the ground-side fuse were to open, the entire supply current would be conducted by the coax shield. This could cause the coax to overheat with possible resulting damage.
- The radio power conductor (+) and ground (-) should be run together along their length as practicable to reduce induced noise (FCS1362:2022). The conductors can be twisted together for increased immunity to induced noise. See Figure E-16.
- Splices in the power cable **shall** be avoided, where practicable.
  - If required, splices **shall** be limited to one per power conductor, as practicable. If more than one splice is required, suitable solder splices (such as soldered compression butt splice) **shall** be used. See “Joining Conductors for Mobile Installations” on page E-26.
  - If required, splices **shall** be made at an easily accessible and conspicuous location.
  - Splices **shall not** be made in areas susceptible to physical damage and/or moisture intrusion.
- Cigarette lighter or “Power Point” receptacles **shall not** be used as power sources for mission critical equipment.
- Where low-power switched power sources are required (such as for radio ignition sense), do not tap into sources such as cigarette lighters and AM/FM radio. A vehicle-manufacturer-provided spare Ignition or Accessory source on the fuse block should be used instead. Install an in-line fuse holder with the proper size fuse for the equipment.

CAUTION: Do not fuse the transceiver ground (negative) conductor. If the ground-side fuse were to open, the entire supply current would be conducted by the coax shield or other alternative current return path. This could cause the coax to overheat with possible resulting damage.

CAUTION: Do not connect the ground (black) conductor directly to the battery's negative terminal.

IMPORTANT: If a high-power switched source is required, do not attempt to use the vehicle fuse block (see the vehicle documentation). A switching relay to control a direct connection to the vehicle battery (or equivalent) is required in these applications.

IMPORTANT: Except under engineering supervision, do not reuse existing radio power conductors or cables.

NOTE: Some vehicles (large buses, tractor-trailers, firefighting apparatus, and so on) may not have a source of clean DC power, and may require a DC power filter to filter out noise. Consultation with a technician and/or Installation Engineer may be required. See Figure E-17 for an example.

NOTE: In some heavy commercial vehicles, and in vehicles with tilting cabs where the cab may be isolated from the chassis by rubber mountings, a ground point is typically provided by the vehicle manufacturer within the cab to provide battery to cab grounding. Generally, this is located within the main fuse box. It is recommended that this point be used for installations in this instance. See FCS1362:2022 for more information.

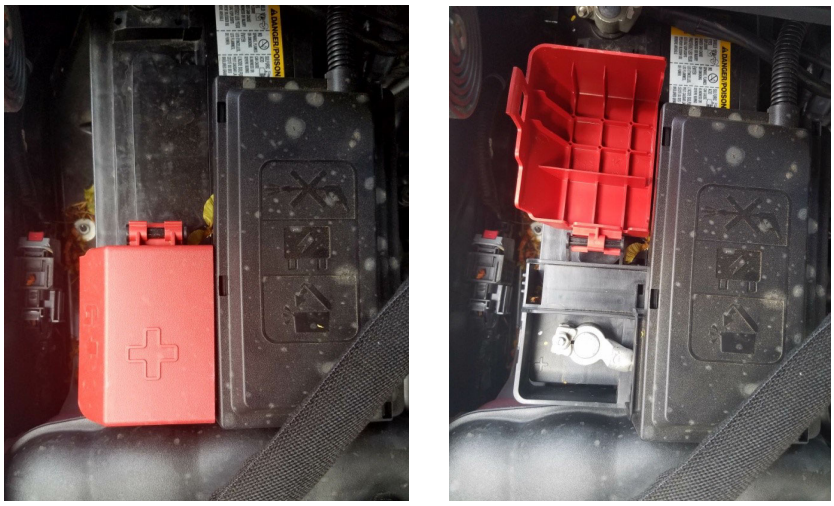


Figure E-13. Example of Vehicle Battery with External Terminal

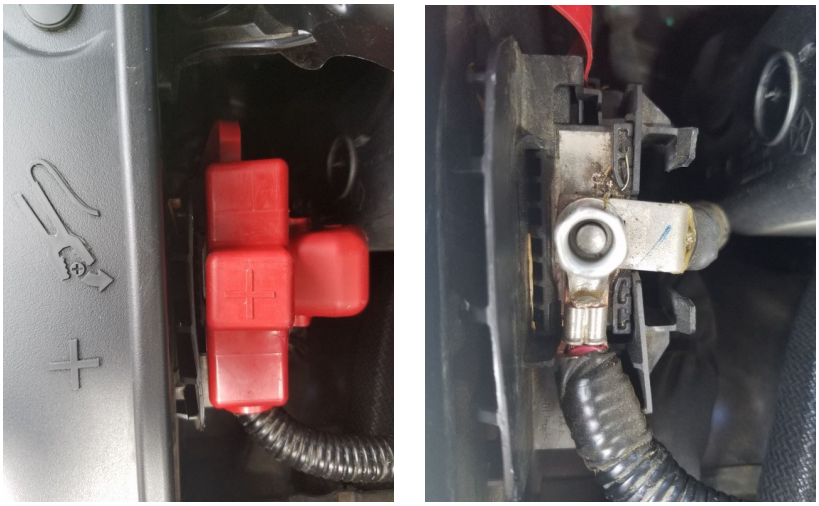


Figure E-14. Example of Vehicle Positive Jump Start Post

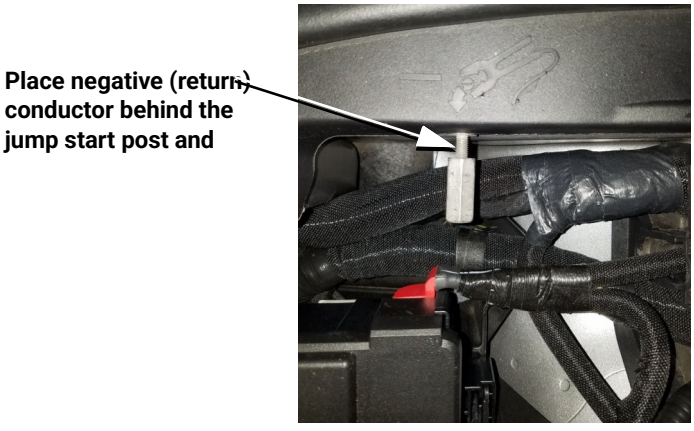


Figure E-15. Example of Vehicle Negative Jump Start Post



Figure E-16. Example of Power Conductors Twisted Together for Increased Noise Immunity



Figure E-17. Example of a Commercially Available DC Power Filter

IMPORTANT: Where a 24 volt or higher supply is used on an isolated return vehicle system, a suitable DC converter, providing DC isolation (no DC continuity between battery and output) **shall** be used. See FCS1362:2022, section 4.6.7.1, for more information.

E.11.1 Power Wiring Considerations for Electric-Powered And Hybrid Vehicles

WARNING: Hazardous high voltage is present from the large battery banks in electric-powered and hybrid vehicles (see FCS1362:2022, section 2.9.1 for more information). All vehicle-manufacturer-provided safety precautions SHALL be followed when working on electric-powered and hybrid vehicles.

Equipment installed in electric-powered and hybrid vehicles **shall** use the appropriate manufacturer-provided voltage and ground sources. Such sources may be busbars provided by the vehicle manufacturer. Check with the vehicle manufacturer or vehicle instruction manual for the location of the power and ground connection points for the communications and emergency equipment.

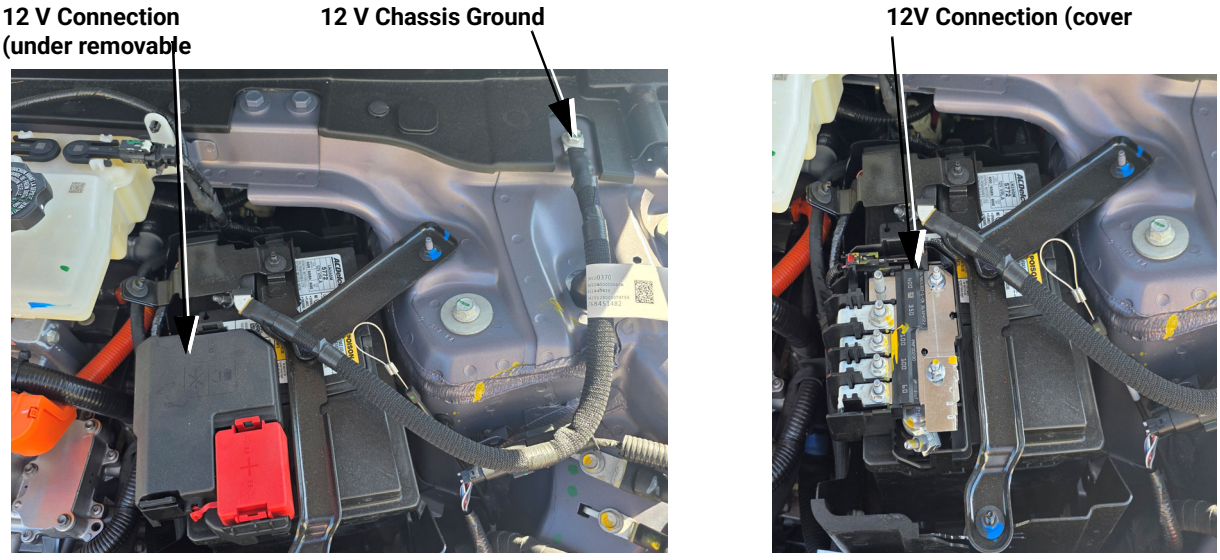


Figure E-18. Example of Plug-in Electric Vehicle Connections

E.11.2 Power Conductors for Mobile Installations

Power conductors used in mission critical mobile installations **shall** be appropriate for the application. The conductors **shall** be resistant to the following (as applicable): abrasion, battery acid, diesel fuel, gasoline, moisture, oil, sunlight, and so on (see SAE J1128).

Power conductors used in mission critical applications **shall** be rated as appropriate for the application:

- Conductors used in automotive applications **shall** be stranded automotive grade.
- Conductors used in marine applications **shall** be stranded marine grade.
  - Marine grade conductors are commonly tinned to provide additional corrosion resistance.
  - Conductors used in marine applications **shall** be UL 1426 (or equivalent) listed as required by jurisdictional regulations.

There are two main categories of automotive conductors:

- Polyvinyl chloride (PVC), which has three main types, as follows:
  - General Purpose Thermoplastic Insulated (GPT): Used for general circuit wiring. Rated to 80° C (176° F).
  - Thin Wall Thermoplastic Insulated (TWP): Lead-free thin wall wire. Rated to 105° C (221° F).
  - Heavy Duty Thermoplastic Insulated (HDT): Heavy wall wiring. Rated to 80° C (176° F).
- Cross-Linked (X), which has three main types, as follows:
  - General Purpose Cross Linked Polyolefin Insulated (GXL): Thin wall, the most common type, works with most standard automotive connectors. Rated to 125° C (257° F).
  - Special Purpose Cross Linked Polyolefin Insulated (SXL): Standard wall. Rated to 125° C (257° F).
  - Thin Wall Cross Linked Polyolefin Insulated (TXL): Extra thin wall, best for applications that require minimal size and weight. Rated to 125° C (257° F).

E.11.2.1 Selecting Conductor Size

The power cable supplied by the equipment manufacturer **shall** be used where practicable. If a power cable must be extended for a specific installation (such as in a large fire apparatus), the conductor used **shall** be the appropriate type and **shall** be appropriately sized for an acceptable voltage drop (see “Equipment Power Conductors Voltage Drop” on page E-20).

If the power conductor being extended must be increased in size in order to maintain an acceptable voltage drop (see “Equipment Power Conductors Voltage Drop” on page E-20), the splice **shall** be made as close to the equipment as practicable. The splice **shall** be made at an easily accessible and conspicuous location. The extended and/or larger conductor **shall** be fused the same as the original power cable, according to the equipment manufacturer’s requirements. The fuse holder **shall** be clearly labeled as to the fuse size and protected equipment (for example: APX radio, 20A).

E.11.2.2 Equipment Power Conductors Voltage Drop

Motorola Solutions recommends a maximum voltage drop of 5% from the battery (source) to the mission critical equipment (at full load). The total length of the positive and negative conductors **shall** be considered. If the specific equipment manufacturer requirements are less than 5% voltage drop, the manufacturer requirements **shall** be followed.

NOTE: A voltage drop of 5% in the power supply conductors from a 13.8 V source would result in a delivered voltage to the load (equipment) of 13.11 V at full load current. Voltage drop calculations other than 5% may require the assistance of an engineer. An online calculator is available at: http://www.calculator.net/voltage-drop-calculator.html.

Table E-1 provides the minimum copper conductor size for a given current and total power conductor length (positive and negative) that will provide 5% or less voltage drop to the load.

Table E-1. Minimum Copper Equipment Power Conductor Size (AWG) for Given Current and Length

	Current Flow in Amps												
	5A	**10A**	**15A**	**20A**	**25A**	**30A**	**40A**	**50A**	**60A**	**70A**	**80A**	**90A**	**100A**
10 ft	18	18	16	14	14	12	12	10	10	8	8	8	8
15 ft	18	16	14	12	12	10	10	8	8	8	6	6	6
20 ft	18	14	12	12	10	10	8	8	6	6	6	4	4
25 ft	16	14	12	10	10	8	8	6	6	6	4	4	4
30 ft	16	12	10	10	8	8	6	6	4	4	4	4	2
40 ft	14	12	10	8	8	6	6	4	4	2	2	2	2
50 ft	14	10	8	8	6	6	4	4	2	2	2	1	1
60 ft	12	10	8	6	6	4	4	2	2	2	1	1	1/0
70 ft	12	8	8	6	6	4	2	2	2	1	1/0	1/0	1/0
80 ft	12	8	6	6	4	4	2	2	1	1/0	1/0	2/0	2/0
90 ft	10	8	6	4	4	4	2	1	1	1/0	2/0	2/0	3/0
100 ft	10	8	6	4	4	2	2	1	1/0	1/0	2/0	3/0	3/0

NOTE: Recommended conductor sizes are in American Wire Gauge (AWG). Maximum voltage drop of 5% is based on a 13.8 V supply.
NOTE: If a listed conductor size is not commercially available, the next larger size conductor **shall** be used.

NOTE: Distance and/or current values exceeding those listed in the tables in this Appendix may require the assistance of an engineer.

NOTE: SAE conductors are 5% to 12% smaller than equivalent AWG, with current capacity typically 7% less than AWG conductors.

E.11.2.3 Power Distribution Unit

Where a Power Distribution Unit (PDU) or distribution busbar (see Figure E-19) is installed in an area of the vehicle, such as in the trunk or passenger compartment equipment console, the conductor supplying the PDU or busbar **shall** be sized for an acceptable voltage drop based on 125% of the expected maximum current draw. See “Power Distribution Unit Power Conductors” on page E-23 for PDU conductor voltage drop information.

NOTE: Consultation with an engineer may be required to determine the maximum current draw of the connected equipment. The calculated maximum current draw should be based on the actual current draw of the connected equipment, not their associated fuse sizes. An Installation Engineer may calculate the conductor size differently than what is shown in this section, based on 100% of non-continuous loads plus 125% of continuous loads. However, Motorola Solutions recommends not exceeding the recommended maximum voltage drop (see “Power Distribution Unit Power Conductors” on page E-23).



Figure E-19. Example of Power Distribution Unit

IMPORTANT: It is recommended to use a PDU for radio equipment and other sensitive electronics, and a separate PDU for other types of emergency equipment (for example: light-bars, flashers, gun locks, strobe lights, and so on).

When selecting the conductor size, perform the following actions:

1. Determine the maximum expected current draw from the PDU, based on the connected equipment. The PDU maximum current rating, and future equipment connections should be considered.
2. Multiply the current value in Step 1 by 1.25.
3. Determine the required total conductor length (positive and negative conductors).
4. Select the minimum conductor size according to “Power Distribution Unit Power Conductors” on page E-23, based on the current value calculated in Step 2, and the conductor length for the given installation in Step 3.
5. Determine the temperature rating of the proposed conductor.
6. Determine if the conductor will be installed, partially or completely, in the engine space.
7. Using “Power Conductor Ampacity and Fuse Rating” on page E-24 and Table E-3, determine if the conductor size selected in Step 4 meets the allowable current for the selected conductor (temperature rating) and installation location (inside or outside engine spaces).
8. If the conductor allowable current does not permit the current value from Step 2, increase the conductor size and/or conductor temperature rating as required.
9. Fuse the conductor according to the current value in Step 2.

Example 1:

1. PDU is rated for 80A.
2. 80A * 1.25 = 100A.
3. The total conductor length is 50 feet.
4. According to Table E-2, the minimum conductor size for the given current in Step 2 (100A), and the total conductor length in Step 3 (50 ft) is #2/0 AWG.
5. The proposed conductors have a temperature rating of 80° C (176° F).

6. A portion of the conductors will be installed in the engine space. Therefore, the “Inside Engine Spaces” column of Table E-3 will be used.
7. Table E-3 permits 222A for the proposed #2/0 AWG conductor.
8. In this example, no conductor size and/or temperature rating increase is required since the current in Step 2 (100A) does not exceed the allowable current permitted in Step 7 (222A).
9. The positive conductor (for negative ground vehicles) is fused at the Step 2 current value (100A) as close to the source as practicable.

Example 2:

1. PDU is rated for 80A.
2. 80A * 1.25 = 100A.
3. The total conductor length is 10 feet.
4. According to Table E-2, the minimum conductor size for the given current in Step 2 (100A), and the total conductor length in Step 3 (10 ft) is #6 AWG.
5. The proposed conductors have a temperature rating of 80° C (176° F).
6. A portion of the conductors will be installed in the engine space. Therefore, the “Inside Engine Spaces” column of Table E-3 will be used.
7. Table E-3 permits 78A for the proposed #6 AWG conductor.
8. In this example, the current from Step 2 (100A) exceeds the allowable current permitted in Step 7 (78A). Therefore, the conductor size and/or temperature rating must be increased using one of the following options (see Table E-3):
   - 105° C (or higher) rated #6 AWG
   - 80° C (or higher) rated #4 AWG
9. The positive conductor (for negative ground vehicles) is fused at the Step 2 current value (100A) as close to the source as practicable.

E.11.2.4 Power Distribution Unit Power Conductors

Motorola Solutions recommends a maximum voltage drop of 3% from the battery (source) to the Power Distribution Unit (PDU), at full load (see American Boat and Yacht Council standards for more information). The total length of the positive and negative conductors **shall** be considered.

When using a power distribution system, the use of a distributed ground bar is recommended. The conductor feeding the ground bar (-) should be sized the same as the conductor feeding the PDU (+). The conductor feeding the ground bar must be factored into the conductor size calculations (see examples in “Power Distribution Unit” on page E-21.

NOTE: A voltage drop of 3% in the PDU power supply conductors from a 13.8 V source would result in 13.39 V delivered to the PDU at full load current. Voltage drop calculations other than 3% may require the assistance of an engineer. An online calculator is available at http://www.calculator.net/voltage-drop-calculator.html.

Table E-2 provides the minimum copper conductor size for a given current and total power conductor length (positive and negative) that will provide 3% or less voltage drop to the PDU.

Table E-2. Minimum Copper Power Distribution Unit Conductor Size (AWG) for Given Current and Length

	Current Flow in Amps												
	5A	**10A**	**15A**	**20A**	**25A**	**30A**	**40A**	**50A**	**60A**	**70A**	**80A**	**90A**	**100A**
10 ft	18	16	14	13	12	11	10	9	8	7	7	6	6
15 ft	17	14	12	11	10	9	8	7	6	6	5	5	4
20 ft	16	13	11	10	9	8	7	6	5	4	4	3	3
25 ft	15	12	10	9	8	7	6	5	4	3	3	2	2
30 ft	14	11	9	8	7	6	5	4	3	3	2	2	1
40 ft	13	10	8	7	6	5	4	3	2	1	1	1/0	1/0
50 ft	12	9	7	6	5	4	3	2	1	1/0	1/0	2/0	2/0
60 ft	11	8	6	5	4	3	2	1	1/0	1/0	2/0	2/0	3/0
70 ft	10	7	6	4	3	3	1	1/0	1/0	2/0	3/0	3/0	4/0
80 ft	10	7	5	4	3	2	1	1/0	2/0	3/0	3/0	4/0	4/0
90 ft	9	6	5	3	2	2	1/0	2/0	2/0	3/0	4/0	4/0	300 kcmil
100 ft	9	6	4	3	2	1	1/0	2/0	3/0	4/0	4/0	300 kcmil	350 kcmil

NOTE: Recommended conductor sizes are in American Wire Gauge (AWG). Maximum voltage drop of 3% is based on a 13.8 V supply.
NOTE: If a listed conductor size is not commercially available, the next larger size conductor **shall** be used.

NOTE: Distance and/or current values exceeding those listed in the tables in this Appendix may require the assistance of an engineer.

NOTE: SAE conductors are 5% to 12% smaller than equivalent AWG, with current capacity typically 7% less than AWG conductors.

E.11.2.5 Power Conductor Ampacity and Fuse Rating

Conductor ampacity is commonly defined as the maximum amount of electric current a conductor can carry before sustaining immediate or progressive deterioration. Also described as the current-carrying capacity a conductor can continuously carry while remaining within its temperature rating. Conductor ampacity primarily depends on its insulation temperature rating.

The temperature rating of power conductors **shall** be considered and selected for the application. Motorola Solutions recommends a minimum conductor temperature rating of 80° C (176° F).

NOTE: Automotive-rated conductors with a minimum temperature rating of 80° C (176° F) are readily available.

NOTE: Conductors installed inside engine spaces have a lower ampacity due to the increased ambient temperature. Conductor insulation temperature must not exceed its rating. Ambient temperature and conductor temperature increase due to current flow (I^2R) are both conductor insulation temperature factors. Table E-3 considers ambient temperature and current flow.

Power conductors **shall** be fused according to the conductor ampacity (current carrying capacity) rating. Table E-3 provides the maximum allowable current for conductors under 50 V, based on the temperature rating of the conductor and the installation location (inside or outside engine spaces). Power conductors **shall** be fused no greater than that allowed in Table E-3.

Table E-3. Maximum Allowable Current for Conductors Under 50 Volts

Temperature Rating of Conductor Insulation										
Conductor Size		80°C (176° F)		90°C (194° F)		105°C (221° F)		125° C (257° F)		200°C (392° F)
AWG	Metric (mm^2)	Outside Engine Spaces	Inside Engine Spaces	Outside Engine Spaces	Inside Engine Spaces	Outside Engine Spaces	Inside Engine Spaces	Outside Engine Spaces	Inside Engine Spaces	Outside or Inside Engine Spaces
18	(0.8)	15	11.7	20	16.4	20	17.0	25	22.3	25
16	(1)	20	15.6	25	20.5	25	21.3	30	25.7	35
14	(2)	25	19.5	30	24.6	35	29.8	40	35.6	45
12	(3)	35	27.3	40	32.8	45	39.3	50	44.5	55
10	(5)	50	39.0	55	45.1	60	51.0	70	62.3	70
8	(8)	70	54.6	70	57.4	80	68.0	90	80.1	100
6	(13)	100	78.0	100	82.0	120	102	125	111	135
4	(19)	130	101	135	110	160	136	170	151	180
2	(32)	175	138	180	147	210	178	225	200	240
1	(40)	210	163	210	172	245	208	265	235	280
0	(50)	245	191	245	200	285	242	305	271	325
00	(62)	285	222	285	233	330	280	355	316	370
000	(81)	330	257	330	270	385	327	410	384	430
0000	(103)	385	300	385	315	445	378	475	422	510



Figure E-20. Example of Automotive Grade Mobile Radio Power Cable

E.12 Joining Conductors for Mobile Installations

Suitable methods of joining conductors include the following (see FCS1362:2022 and “Electrical Ring Terminals, Lugs, Splices, and Similar Devices” on page E-27 for more information):

E.12.1 Soldering

- Soldering typically requires more skill than crimping; therefore, it is subject to more mistakes.
- Soldered joints **shall** employ a mechanical aspect to give strength to the joint prior to soldering. Such as the following:
  - Non-insulated crimp butt connector
  - Wrapping one conductor around the other (see “Conductor Tapping and Soldering” on page E-30 and Figure E-29)
- Solder the conductors using industry accepted techniques. See Figure E-30 for an example of a completed solder connection.
- The soldered joint **shall** be sealed with one of the following:
  - Heat shrink tubing.
  - Self-amalgamating tape. See “Conductor Tapping and Soldering” on page E-30 and “Electrical Tape and Heat Shrink Tubing” on page E-31 for more information.
  - Insulation tape, which is then wrapped in a cloth tape. This will keep the insulation tape in place over time but still provide excellent insulation. See FCS1362:2022 for more information.
  - See “Electrical Tape and Heat Shrink Tubing” on page E-31 for more information.

IMPORTANT: Soldering, particularly with gas powered irons, may not be appropriate in certain environments. Caution **shall** be taken where a gas soldering iron has a hot air vent, which could easily cause damage to the insulation of other cables or the environment around the area of use. See FCS1362:2022 for more information.

E.12.2 Crimped (Butt) Connectors

- Crimped butt connectors are an acceptable method provided the correct size connector is chosen and the correct ratchet tool is used.
- Crimped butt connectors are only suitable for use inside a vehicle where the connector is not exposed to the elements. Crimped butt connectors **shall not** be used under vehicle carpet that is exposed to normal foot traffic.
- See “Electrical Ring Terminals, Lugs, Splices, and Similar Devices” on page E-27 for more information.

E.12.3 Heat Shrink Butt Connectors

- Heat shrink butt connectors come in two types, crimp and solder.
- They have a heat shrink outer casing, making them acceptable in areas where the connector may be exposed to the elements.
- Crimp versions **shall** be crimped before the outer casing is shrunk.
  - The correct crimp tool **shall** be used.
  - See “Electrical Ring Terminals, Lugs, Splices, and Similar Devices” on page E-27 for more information.
- Solder versions are self-contained with pre-fluxed solder within a transparent heat shrinkable tube.
  - Can be completed with just a heat gun.
  - Combine a soldered, strain relieved, encapsulated termination for weatherproofing and can be used on sensitive low-temperature wires such as PVC.
  - See Figure E-25 for an example.

E.12.4 Electrical Ring Terminals, Lugs, Splices, and Similar Devices

Electrical ring terminals, lugs, splices, and similar devices (electrical connection devices) used in mission critical applications **shall** be appropriate for the application (see Figure E-21).



Figure E-21. Examples of Electrical Connection Devices

The requirements and recommendations for electrical connection devices are as follows:

- Electrical connection devices **shall** be UL listed (or equivalent), Canadian Standards Association (CSA) certified, or have the CE (European Conformity) marking.
- Electrical connection devices **shall** be suitable for the type of conductor:
  - Solid
  - Stranded
- Electrical connection devices **shall** be suitable for the size of the conductor.
- Electrical connection devices **shall** be suitable for use in industrial, automotive, and other high-vibration electrical applications (see product documentation).
- Consumer-grade electrical connection devices **shall not** be used.
- Electrical conductors **shall** be prepared in such a way that no bare wire is exposed once the electrical connection device is attached.

- Electrical conductors **shall not** be damaged during preparation or stripping of insulation. Care **shall** be taken to ensure all conductor strands are intact and undamaged.
- Plastic auto electrical snap-lock splicing connectors that cut into the cable's insulation (the insulation displacement connector) should not be used as a connection method (FCS1362:2022, section 2.6.2). See Figure E-22 for examples.

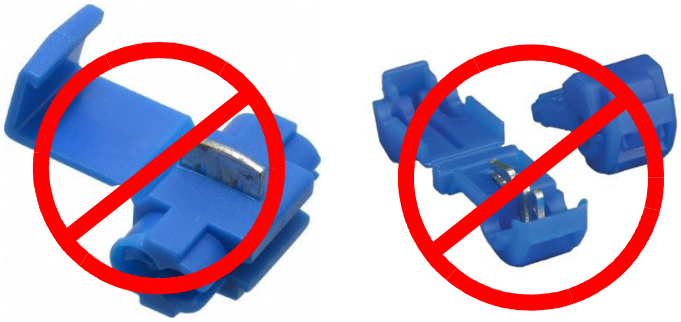


Figure E-22. Examples of Unacceptable Insulation Displacement Connectors

- Electrical connection devices used in marine applications **shall** be suitable for marine applications. See Figure E-23 for examples. Marine application devices typically have the following characteristics:
  - Constructed from tinned-copper for improved corrosion resistance.
  - Contain an adhesive-lined heat shrink insulator to seal connection from vibration and to provide improved strain relief.



Figure E-23. Examples of Marine-Grade Electrical Connection Devices

- Butt connectors exposed to the elements (for example: installed under the hood, or installed under the vehicle carpet and exposed to foot traffic) **shall** be heat shrink-type butt connectors (or marine grade). See Figure E-24 and Figure E-25 for examples.



Figure E-24. Example of Heat Shrink Crimped Butt Connector



Figure E-25. Example of Heat Shrink Solder Butt Connector

- Only manufacturer-approved crimping devices **shall** be used (see product documentation).
- Ring lugs should be used where practicable as opposed to spade lugs. Ring lugs have a larger contact area and are more secure.
- Electrical connection devices should have a brazed seam to protect the barrel from splitting during crimping. Proper crimping techniques **shall** be used to help prevent splitting of the barrel.
  - The connection device **shall** be inserted into the tool so the seam is within the round portion of the crimping tool (as applicable).
  - See Figure E-26 for an example.
  - See the specific crimper instructions.



Figure E-26. Example of Crimping Technique

- The crimping tool used **shall** be the approved tool by the electrical connection device manufacturer (see electrical connection device instructions).
  - A controlled cycle (ratcheting) crimping tool is recommended for consistent quality crimps. See Figure E-27 for an example of a controlled cycle crimping tool.



Figure E-27. Example of Controlled Cycle (Ratcheting) Crimper

E.13 Bonding Requirements for Mobile Installation

The following requirements apply where attaching a lug to a bonding surface, such as attaching an equipment ground (-) conductor to the vehicle chassis:

- Paint, enamel, lacquer, and other non-conductive coatings **shall** be removed from surface areas where connections are made to ensure good electrical continuity.
- Bonding surfaces **shall** be cleaned to remove dirt, corrosion, and oxidized material on the connection surface area.
- The use of a piloted bonding brush is recommended for cleaning the bonding surface. See Figure E-28 for an example of a piloted bonding brush.
- After bonding to a factory-painted surface, the area **shall** be thoroughly cleaned and coated with an approved corrosion inhibiting paint (or equivalent). See FCS1362:2022, section 2.11.3 for more information.

IMPORTANT: DO NOT install a washer of any kind between a lug and the bonding surface.

NOTE: Using a star washer does not alleviate the requirement to remove non-conductive coatings from attachment surfaces. Star washers should only be used as a lock washer.



Figure E-28. Example of Piloted Bonding Brush

E.14 Conductor Tapping and Soldering

Conductors must sometimes be tapped into a vehicle wiring system conductor. Such applications may be one or more of the following:

- Radio ignition sense conductors are required and an ignition switched power point is not readily available at the vehicle fuse box or other location.
- Vehicle horn conductor is required for radio accessory features, such as audible alert and/or siren features (“horn ring”).
- Vehicle lights conductor is required for radio accessory features, such as visual alert.

Since plastic auto electrical snap-lock splicing connectors (insulation displacement connectors) are not recommended (see “Electrical Ring Terminals, Lugs, Splices, and Similar Devices” on page E-27), soldering may be required (see FCS1362:2022).

Soldered joints **shall** employ a mechanical aspect to give strength to the joint prior to soldering; for example, by wrapping one conductor around the other (see Figure E-29).

Soldering **shall** be performed only by trained personnel. The following general process **shall** be followed (see FCS1362:2022):

1. Cut approximately 20 mm (0.8 in.) of insulation from the tapped conductor (red in Figure E-29).
2. Tin the tapped conductor.
3. Twist the tap conductor (yellow in Figure E-29) around the exposed tapped conductor approximately three times.



Figure E-29. Example of Wrapping Tap Conductor Around Tapped Conductor Prior to Soldering

4. Solder the conductors using industry-accepted techniques. See Figure E-30 for an example of a completed solder connection.
5. Clean the joint as needed and remove any sharp elements such as protruding wires.

6. Seal the joint with self-amalgamating tape, or insulation tape that is then wrapped in a cloth tape. Insulation tape is prone to losing its adhesive properties over time and through exposure to moisture and varying temperatures. See “Electrical Tape and Heat Shrink Tubing” on page E-31 and Figure E-32.



Figure E-30. Example of Completed Solder Connection

E.15 Electrical Tape and Heat Shrink Tubing

Electrical tape and similar products used **shall** be appropriate for the application. The general requirements and recommendations are as follows:

- Electrical tape **shall** be listed (for example, CSA or UL).
- Electrical tape **shall** be commercial-grade, professional-grade, or heavy duty-grade as defined by the manufacturer.
  - Consumer-grade or economy-grade tape **shall not** be used.
- Heat shrink tubing **shall** be listed (for example, CSA or UL). See Figure E-31 for examples.



Figure E-31. Examples of Heat Shrink Tubing

NOTE: Heat shrink tubing is readily available in many colors, sizes, and shrinking ratios.

- Heat shrink tubing is the preferred method of insulating as it provides excellent insulation and does not react adversely to moisture or typical seasonal temperature changes (FCS1362:2022).
  - Non-adhesive heat shrink tubing can be used inside a vehicle.
  - An adhesive-lined heat shrink tubing **shall** be used if the joint is exposed to the elements and/or in marine applications.
- The appropriate manufacturer-recommended heat source **shall** be used to shrink the tubing.
  - Typically a heat gun is used for this purpose.
  - An open flame is not recommended.
- Self-amalgamating (self-bonding or self-fusing) tape **shall** be designed for use as an electrical tape as defined by the manufacturer.
- Soldered joints on tapped conductors **shall** be insulated with self-amalgamating tape, or insulation tape that is then wrapped in a cloth tape. See “Conductor Tapping and Soldering” on page E-30 and Figure E-32.



Figure E-32. Example of Self-Amalgamating Tape

E.16 Antenna Installation and Testing

This section provides antenna installation requirements and guidelines. Instructions provided by the transceiver and antenna manufacturer **shall** be followed.

E.16.1 Coaxial Cable (Coax)

- The coax supplied by the radio manufacturer **shall** be used, where practicable.
- The coax used **shall** be commercial grade and designed for mission critical applications.
  - A minimum 95% shield is recommended.
  - Low loss as required by the frequency in use (consult with the system engineer).
- Stranded center conductor coax is recommended.
  - Solid center conductor coax should not be used in mobile installations. Solid center conductors are susceptible to breakage due to repeated flexing in mobile applications.
- The coax from the radio to the antenna **shall** be free of splices and/or extensions. The appropriate length of cable **shall** be used for the application.
- The appropriate connector **shall** be used for the type of coax used (see manufacturer's specifications).
- Marine grade coax **shall** be used in marine installations.
  - Marine grade coax is designed for UV and salt environments.
  - Marine grade coax center conductor and outer shield are tinned for corrosion resistance.
  - Marine grade coax typically has a white outer jacket.

IMPORTANT: Except under engineering supervision, DO NOT reuse existing coaxial cables.

E.16.2 Antenna Installation

NOTE: The information in this section is primarily taken from the *APX Mobiles Installation Manual*.

IMPORTANT: Ensure the installed antenna type and mounting location match the engineered system design. Changing the antenna type and/or mounting location without engineering approval can negatively affect the mobile radio's ability to transmit and/or receive on the intended system.

IMPORTANT: Antennas **shall** be tuned according to manufacturer instructions, as applicable.

Motorola Solutions recommends the following sequence for antenna system installation:

1. **External installation:** Check the requirements of the antenna supplier and install the vehicle antenna external to a metal body vehicle in accordance with those requirements.
2. **Roof top:** For optimum performance and compliance with RF Energy Safety standards, mount the antenna in the center area of the roof.
3. **Trunk lid:** On some vehicles with clearly defined, flat trunk lids, the antennas of some radio models (see restrictions below) can also be mounted on the center area of the trunk lid. For vehicles without clearly defined, flat trunk lids (such as hatchback autos, sports utility vehicles, and pickup trucks), mount the antenna in the center area of the roof.
4. Before installing an antenna on the trunk lid:
   - Be sure that the distance from the antenna location on the trunk lid will be at least 85 cm (33 in.) from the front surface of the rear seat-back to assure compliance with RF Energy Safety standards.
   - Ensure that the trunk lid is grounded by connecting grounding straps between the trunk lid and the vehicle chassis, as required.
5. Mounting restrictions for certain radio models.
   - For all VHF and UHF models, the ¼ wave antenna should be mounted only in the center area of the roof, not on the trunk lid, to assure compliance with RF Energy Safety standards.
6. Ensure that the antenna cable can be easily routed to the radio. Route the antenna cable as far away as possible from any vehicle electronic control units and associated wiring.
7. Check the antenna location for any electrical interference.
8. Ensure that any transmitting radio antennas on the vehicle are separated from each other by at least 0.9 m (3 ft.), as practicable. See Figure E-33.
9. The minimum distance between the antenna and the radio/accessories should be at least 91.44 cm (3 ft.).
10. The minimum distance between the antenna and the fuel filler cap **shall** be 30 cm (12 in.), as practicable to reduce the risk of the radiated electric field being a source of ignition (FCS1362:2022, section 4.2.3.2).

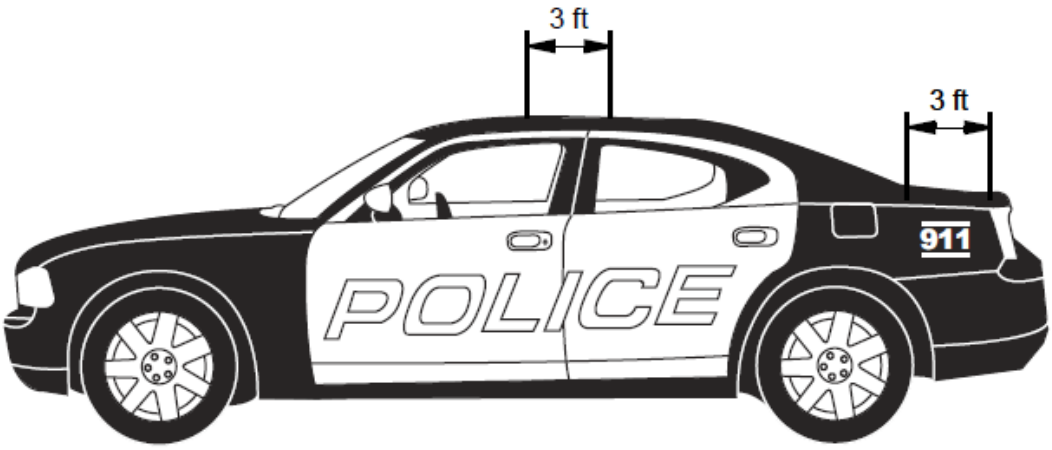


Figure E-33. Separation of Multiple Antennas

IMPORTANT: Except under engineering supervision, DO NOT reuse existing antennas and/or coaxial cables.

NOTE: Any two metal pieces rubbing against each other (such as seat springs, shift levers, trunk and hood lids, exhaust pipes, and so on) near the antenna can cause receiver interference.

NOTE: See FCS1362:2022, Appendix C for example antenna radiation patterns for common antenna installation locations.

E.16.3 Antenna Installations on Non-Metallic Surfaces

Many emergency vehicles, motorcycles, and marine vessels contain fiberglass or other non-metallic body parts (including the roof). Antennas mounted in these locations require special consideration to ensure proper antenna performance. Options for installations on non-metallic surfaces include (but are not limited to) the following:

- Antenna specifically designed for no ground plane installations.
- Foil ground plane tape designed specifically for mobile installations (see Figure E-34).
  - The foil tape is typically self-adhesive for ease of installation.
  - The foil tape is effective for uneven surfaces.
  - The foil tape is installed on the underside of the mounting surface (for example, a fiberglass roof).
  - The tape should be arranged so that at least four strips are equally spaced around a common intersecting point, as practicable. The intersecting point is the antenna mounting hole. See Figure E-35 for an example.
  - The coax mount grounding hardware **shall** make good electrical contact with the sections of foil tape.
  - The minimum length of the foil tape from the center intersection point to each end (radius of circle) should be equal to or greater than the ¼ wavelength of the desired frequency. See Table E-4 and the graph in Figure E-37 for example lengths at given frequencies.
- Metallic ground plate designed for mobile installations.
  - The ground plate is mounted in a similar fashion as described above for foil tape.
  - Metallic ground plate is ideal for smooth and even surfaces.
  - The radius of the plate should be sized the same as described for foil tape. See Table E-4 and the graph in Figure E-37.
  - See Figure E-36 for an example of a ground plate.
- Other engineered ground plane.



Figure E-34. Example of Foil Ground Plane Tape

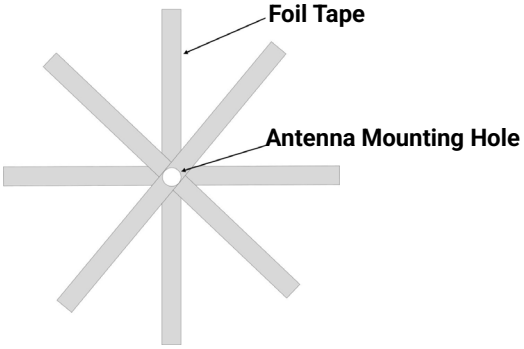


Figure E-35. Example of Minimum Recommended Foil Tape Installation Pattern



Figure E-36. Example of Metallic Ground Plane Plate

Table E-4. Frequency versus ¼ Wavelength

Frequency	Approximate ¼ Wavelength
27 MHz	2.8 m (109 in.)
50 MHz	1.5 m (59 in.)
100 MHz	0.75 m (29.5 in.)
150 MHz	0.5 m (19.7 in.)
170 MHz	0.44 m (17.4 in.)
430 MHz	0.174 m (6.9 in.)
450 MHz	0.167 m (6.6 in.)
700 MHz	0.107 m (4.2 in.)
800 MHz	0.094 m (3.7 in.)
900 MHz	0.083 m (3.3 in.)

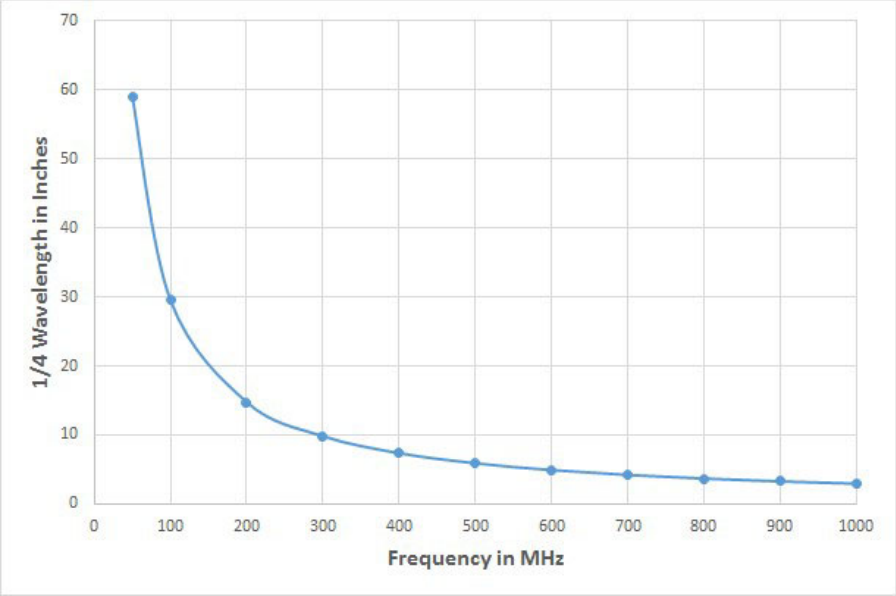


Figure E-37. Frequency versus ¼ Wavelength

NOTE: The wavelength of any given frequency can be calculated using the following formula: wavelength in meters = 300 / frequency in MHz. The wavelength is cut in half for every doubling of the frequency.

An example calculation for 156.8 MHz is as follows:

- Wavelength in meters = 300 / 156.8 MHz = 1.91 m (75.2 in.)
- ¼ wavelength = 1.91 m / 4 = 0.48 m (18.8 in.)

E.16.4 Mini-UHF Connection

NOTE: The information in this section is primarily taken from the *APX Mobiles Installation Manual*.

The mini-UHF connector is a common connector for Land Mobile Radio (LMR) and is covered in this subsection (see Figure E-38). The mini-UHF connector **shall** be installed according to manufacturer instructions, using manufacturer-approved crimping tool. A ratcheting crimp tool is recommended (see Figure E-39).



Figure E-38. Examples of Mini-UHF Connectors



Figure E-39. Example of Mini-UHF Ratcheting Crimp Tool (Motorola Solutions Part Number 6680388A26)

To ensure a secure connection of an antenna cable's mini-UHF plug to a radio's mini-UHF jack, their interlocking features must be properly engaged. If they are not properly engaged, the system will loosen. Using a tool (pliers or wrench) will not overcome a poor engagement, and is not recommended.

IMPORTANT: Applying excessive force with a tool can cause damage to the antenna jack or the connector (for example: stripping threads, deforming the collar or connector, or causing the connector to twist in the housing opening and break).

The mini-UHF connector tool (Motorola Solutions part number HLN6695) is designed to securely tighten the antenna plug-radio jack connection without damaging either the plug or the jack.

Motorola Solutions recommends the following sequence to ensure proper attachment of the system (see Figure E-40 and Motorola Solutions Inc. publication 6878215A01 *APX Mobiles Control Head Installation Manual*).

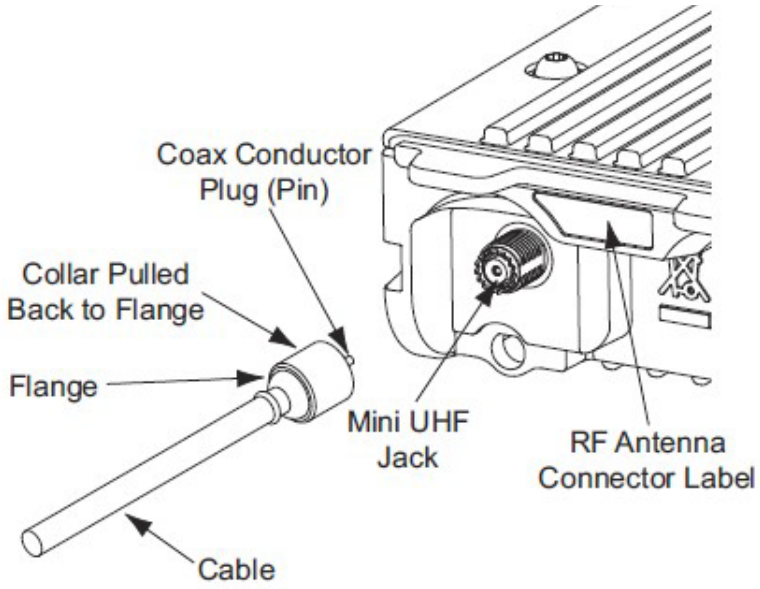


Figure E-40. Example of Mini-UHF Connection

1. Ensure that there is sufficient slack in the antenna cable.
2. Ensure that the collar of the antenna cable plug is loose and does not bind.
3. Ensure that the mini-UHF jack is tight in the radio housing.
4. Slide the collar back against the flange. Insert the antenna cable plug's pin fully into the radio jack, but do not engage the threads.
5. Ensure that the plug's and jack's interlocking features are fully seated. Check this by grasping the crimp on the cable jack, rotating the cable, and noting any movement. If the features are seated correctly, there should be **no** movement.
6. Finger-tighten the antenna cable plug's collar onto the radio's jack.
7. Give a final tug, by hand, to the collar, and tighten by hand as firmly as possible.
8. Slip the mini-UHF connector tool over the coaxial cable, using the gap between the tool's legs (see Figure E-41). Then, slide the tool up onto the plug's knurled collar. Squeeze the two straight legs of the tool firmly together between your thumb and index finger and turn clockwise (as shown) to tighten the collar (¼ turn or less). When you feel the tool slipping on the collar, the connection has been sufficiently tightened. The tool can also be used to loosen a tight collar.

IMPORTANT: DO NOT use pliers or any other device to grip the tightening tool. It has been designed to enable you to achieve the proper torque on the collar without excessive tightening. Excessive tightening of the collar can damage the connector and the radio.

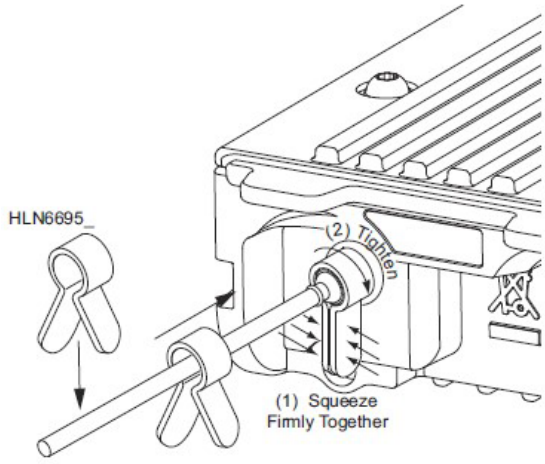


Figure E-41. Mini-UHF Connector Torque Tool

E.16.5 Antenna VSWR Testing

As part of the mobile radio installation, antennas **shall** be tested for Voltage Standing Wave Ratio (VSWR) or Return Loss (RL) (see FCS1362:2022 for more information). VSWR or RL testing may be completed using a through-line directional wattmeter (for example, Bird Technologies® APM-16) or a cable and antenna analyzer.

The antenna VSWR or RL **shall** meet the manufacturer's specifications (see the antenna specification sheet). Typical mobile antenna VSWR specifications are 1.5:1 (RL = 14 dB) or 2.0:1 (RL = 9.54 dB).

IMPORTANT: VSWR testing of digital format radios (for example: DMR, MOTOTRBO, P25 or TETRA) requires the use of an average reading power meter. An analog wattmeter will not provide accurate results unless the radio can be put in an analog test mode.

IMPORTANT: Antennas **shall** be tuned according to manufacturer instructions, as applicable.

NOTE: The preferred method of testing an antenna is to use a cable and antenna analyzer (frequency domain reflectometer or vector network analyzer). The cable and antenna analyzer allows a technician to easily see how the antenna is operating across the entire customer frequency spectrum.

NOTE: A VSWR of 1.5:1 or an RL of 14 dB is equivalent to 4% reflected power. A VSWR of 2.0:1 or an RL of 9.54 dB is equivalent to 11% reflected power.

When testing the antenna VSWR or RL, the following **shall** be followed:

- All vehicle doors, trunk, and hood **shall** be closed.
- All antennas, lightbars, and other metallic objects **shall** be installed on the vehicle. Metallic objects (including antennas other than the antenna under test) can impact the VSWR/RL measurement.
- Adapters **shall** be avoided as practicable. The wattmeter **shall** have the appropriate connectors installed.
- If using a wattmeter, the vehicle battery **shall** be fully charged or the vehicle **shall** be running during the test. Ensure adequate ventilation or test outdoors.
- The wattmeter or cable and antenna analyzer **shall** be in known good working condition and **shall** be within factory calibration tolerances.

- If VSWR testing is made using a directional wattmeter, the measured forward power output **shall** match the power recorded in "Transceiver Preventive Maintenance and Inspection" on page E-6. If the power does not match within ± 5%, a technician **shall** be engaged to troubleshoot the problem.

IMPORTANT: When testing the antenna VSWR using a wattmeter, it is important to check multiple frequencies across the customer frequency spectrum. This is to help ensure antenna match on all customer frequencies.

NOTE: Analyzers are suitable for analog and digital systems, whereas the traditional analog power meter is only suitable for analog systems (see FCS1362:2022).

E.16.5.1 Wattmeter and Test Accuracy Considerations

Wattmeter tests have forward and reflected power measurement accuracy limitations that must be considered. Wattmeters may specify their accuracy using different methods, and often specify a measurement accuracy based on one of the following:

- A percentage of the reading (for example, ± 5% of the measured value)
- A percentage of the full scale (for example, ± 5% of the full scale)
- A dB value of the reading (for example, ± 0.4 dB of the measured value)
- A combination of one or more of the above (for example, ± 4% of the measured value and ± 1% of full scale).

Examples

A wattmeter with an accuracy specification of ± 5% of the measured value:

- Measuring a 100-watt radio would have an accuracy range of 95 - 105 watts (± 5% of 100).
- Measuring a 50-watt radio would have an accuracy range of 47.5 - 52.5 watts (± 5% of 50).
- Measuring a 35-watt radio would have an accuracy range of approximately 33 - 37 watts (± 5% of 35).
- Measuring a 15-watt radio would have an accuracy range of approximately 14 - 16 watts (± 5% of 15).

A wattmeter with an accuracy specification of ± 5% of the full scale:

- Measuring a 100-watt radio using a 100-watt element would have an accuracy range of 95 – 105 watts (± 5% of full scale). In this example, 5% of the full range is 5 watts.
- Measuring a 50-watt radio using a 100-watt element would have an accuracy range of 45 – 55 watts (± 5% of full scale). In this example, 5% of the full range is 5 watts.
- Measuring a 50-watt radio using a 50-watt element would have an accuracy range of 47.5 – 52.5 watts (± 5% of full scale). In this example, 5% of the full range is 2.5 watts.
- Measuring a 35-watt radio using a 50-watt element would have an accuracy range of 32.5 – 37.5 watts (± 5% of full scale). In this example, 5% of the full range is 2.5 watts.
- Measuring a 15-watt radio using a 25-watt element would have an accuracy range of 13.75 – 15.25 watts (± 5% of full scale). In this example, 5% of the full range is 1.25 watts.

A wattmeter with an accuracy specification of ± 0.4 dB of the measured value:

- Measuring a 100-watt radio would have an accuracy range of approximately 91 – 110 watts (± 0.4 dB of the measured value).
- Measuring a 50-watt radio would have an accuracy range of approximately 46 – 55 watts (± 0.4 dB of the measured value).
- Measuring a 35-watt radio would have an accuracy range of approximately 32 – 38.5 watts (± 0.4 dB of the measured value).
- Measuring a 15-watt radio would have an accuracy range of approximately 13.5 – 16.5 watts (± 0.4 dB of the measured value).

A wattmeter with an accuracy specification of ± 4% of the measured value and ± 1% of the full scale:

- Measuring a 100-watt radio using a 100-watt element would have an accuracy range of 95 – 105 watts (± 5 watts). In this example, 4% of the measured value is 4 watts, and 1% of the full scale is 1 watt (4 + 1 = 5 watts).
- Measuring a 50-watt radio using a 100-watt element would have an accuracy range of 47 – 53 watts (± 3 watts). In this example, 4% of the measured value is 2 watts, and 1% of the full scale is 1 watt (2 + 1 = 3 watts).
- Measuring a 50-watt radio using a 50-watt element would have an accuracy range of 47.5 - 52.5 watts (± 2.5 watts). In this example, 4% of the measured value is 2 watts, and 1% of the full scale is 0.5 watts (2 + 0.5 = 2.5 watts).
- Measuring a 35-watt radio using a 50-watt element would have an accuracy range of approximately 33.1 – 36.4 watts (± 1.9 watts). In this example, 4% of the measured value is 1.4 watts, and 1% of the full scale is 0.5 watts (1.4 + 0.5 = 1.9 watts).
- Measuring a 15-watt radio using a 25-watt element would have an accuracy range of approximately 14 – 16 watts (±1 watt). In this example, 4% of the measured value is approximately 0.6 watts, and 1% of the full scale is 0.25 watts (0.6 + 0.25 = 0.85 watts or ≈ 1 watt).

E.16.5.1.1 Wattmeter Element and Frequency Selection

For a wattmeter to provide an accurate power reading, the correct frequency range must be selected. Depending on the wattmeter model, the frequency range is set by software, or a frequency-specific element is installed.

When measuring reflected power, use the lowest power-rated element (or power selection) that will provide a measurement that is in the middle range of the meter movement (approximately 50 – 80% of full scale). Due to accuracy limitations, higher power elements (or power settings) cannot provide the required accuracy at lower power levels.

IMPORTANT: To prevent wattmeter damage when measuring reflected power, start with a high-power element (or power selection) to ensure excessive high reflected power does not damage the meter movement. Then, reduce the element power rating (or power setting) as needed to achieve a meter movement of approximately 50–80% of full scale.

E.16.5.1.2 Test Cable Requirements

The test cable used between the radio and wattmeter **shall** be of high quality, in known good condition, and the loss for the given frequencies must be known. Cable loss can be measured using a vector network analyzer.

IMPORTANT: The loss of the test cable must be accounted for in the measurement. For example, if the test cable has a known loss of 0.5 dB and the transmitter power output is 100 watts, the value measured at the wattmeter would be 0.5 dB less than the actual, or 89 watts. Several dB calculator apps are available that can be used to determine the expected power based on the cable loss, such as the Rohde & Schwarz dB Calculator app.

E.17 Effective Receiver Sensitivity Testing

Effective receiver sensitivity is a measure of how well a receiver performs under actual operating conditions. Effective receiver sensitivity may be degraded by nearby noise sources. Examples are, but not limited to, emergency lights, high-intensity LED lights, mobile data computers, strobe lights, transmitters, vehicle charging systems, vehicle ignition systems, Wi-Fi hotspots, wireless broadband cards, and so on.

Mission-critical land mobile radio installations **shall** be tested for effective receiver sensitivity. In large projects and/or fleet installations, testing of a small sample of each vehicle/installation type is required. Examples of vehicle/installation types include:

- Police Department Patrol 2026 Ford Explorer
- Police Department Patrol 2025 Ford Explorer
- Police Department Patrol Chevrolet Tahoe
- Police Department Traffic Dodge Charger
- Fire Department Ladder Truck
- Fire Department Engine
- Fire Department Medic Unit

Testing should include as many frequencies across the customer frequency band as practicable. For trunking radios, testing should be included on the available test channels (see the radio maintenance manual).

IMPORTANT: Testing may not be possible on active channels. Normal channel activity could appear as degradation during the test.

Effective receiver sensitivity testing requires the use of a capacitive coupler, commonly known as an Iso-T. Testing for receiver degradation and effective sensitivity is detailed in the following steps and summarized in Table E-5:

1. Ensure the vehicle battery is fully charged. Turn vehicle off and turn off all other vehicle systems, except the radio under test.
2. Measure and record the basic sensitivity (in dBm) of the receiver as described in “Transceiver Preventive Maintenance and Inspection” on page E-6. See Figure E-42.
3. Configure the test setup as shown in Figure E-43. The communications analyzer (signal generator) is connected to the capacitively coupled (isolated) port.
4. Adjust the signal generator for 12 dB SINAD or 5% Bit Error Rate (BER). Record the value (in dBm).
5. Configure the test setup as shown in Figure E-44. The 50 ohm termination is replaced with the vehicle antenna.
6. Adjust the signal generator as required for 12 dB SINAD or 5% BER (the same method used in Step 4). Monitor the 12 dB SINAD or 5% BER for at least 60 seconds to help ensure that no intermittent interference exists. Record the value (in dBm).
7. Calculate the amount of receiver degradation (in dB) by subtracting the value recorded in Step 4 from the value recorded in Step 6. This value should be a positive number or zero.
8. Calculate the effective receiver sensitivity (in dBm) by adding the amount of receiver degradation (in dB) from Step 6 to the basic receive sensitivity value recorded in Step 2. Record the results.
9. Start the vehicle and all vehicle systems (for example: lightbars, LED running lights, data terminals, video recording system, sirens, RADAR devices, and so on).
10. Repeat steps 5 through 8 and record the results as required.

11. Report the findings to the system engineer and/or system manager.

Table E-5. Example of Receiver Degradation Calculation

Step Number	Example Value	Notes
2	-120 dBm	Typical value.
4	-90 dBm	50 ohm load is connected. The Iso-T “isolated” port and 6 dB attenuator have an isolation of 30 dB.
6	-89 dBm	The vehicle antenna is connected in place of the 50 ohm load.
7	-89 dBm - -90 dBm = 1 dB Mathematically rewritten as: -89 dBm + 90 dBm = 1 dB	The amount of receiver degradation is calculated as follows: Step 4 value subtracted from Step 6 value. In this example, 1 dB of receiver degradation is measured from the external environment (not vehicle systems).
8	-120 dBm + 1 dB = -119 dBm	The effective receiver sensitivity is calculated as follows: Step 2 value + Step 7 value. Effective Sensitivity = Basic sensitivity + receiver degradation. -120 dBm + 1 dB = -119 dBm
6	-87 dBm	The vehicle antenna is connected in place of the 50 ohm load. The vehicle is running and all vehicle systems are on.
7	-87 dBm - -90 dBm = 3 dB Mathematically rewritten as: -87 dBm + 90 dBm = 3 dB	The amount of receiver degradation is calculated as follows: Step 4 value subtracted from Step 6 value. In this example, 3 dB of receiver degradation is measured from the external environment and vehicle systems.
8	-120 dBm + 3 dB = -117 dBm	The effective receiver sensitivity is calculated as follows: Step 2 value + Step 7 value. Effective Sensitivity = Basic sensitivity + receiver degradation. -120 dBm + 3 dB = -117 dBm

IMPORTANT: Any degradation in receiver sensitivity **shall** be reported to the system engineer and/or system manager.

NOTE: Measurement of receiver degradation and/or effective receiver sensitivity **shall** be performed by a qualified technician.

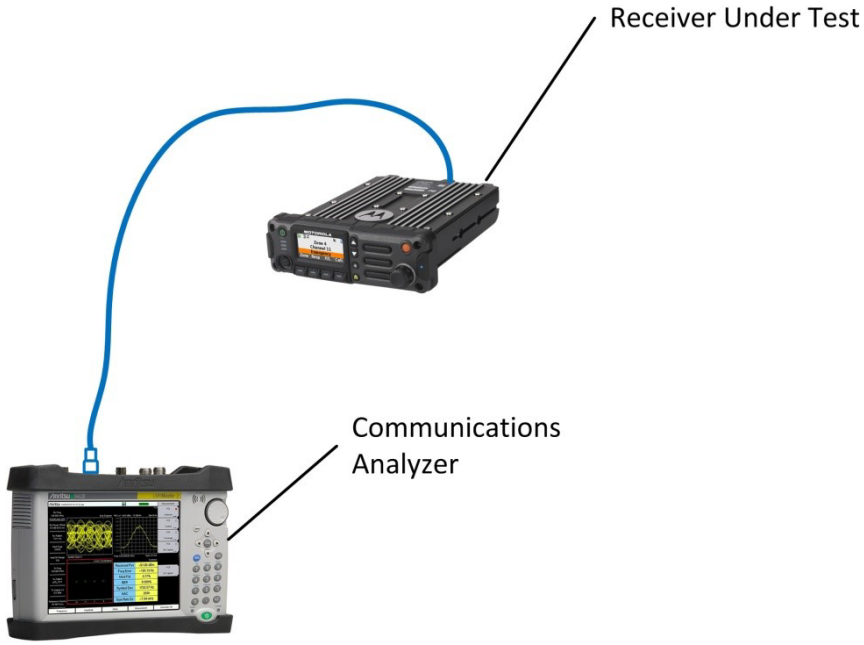


Figure E-42. Configuration for Measurement of Basic Receiver Sensitivity

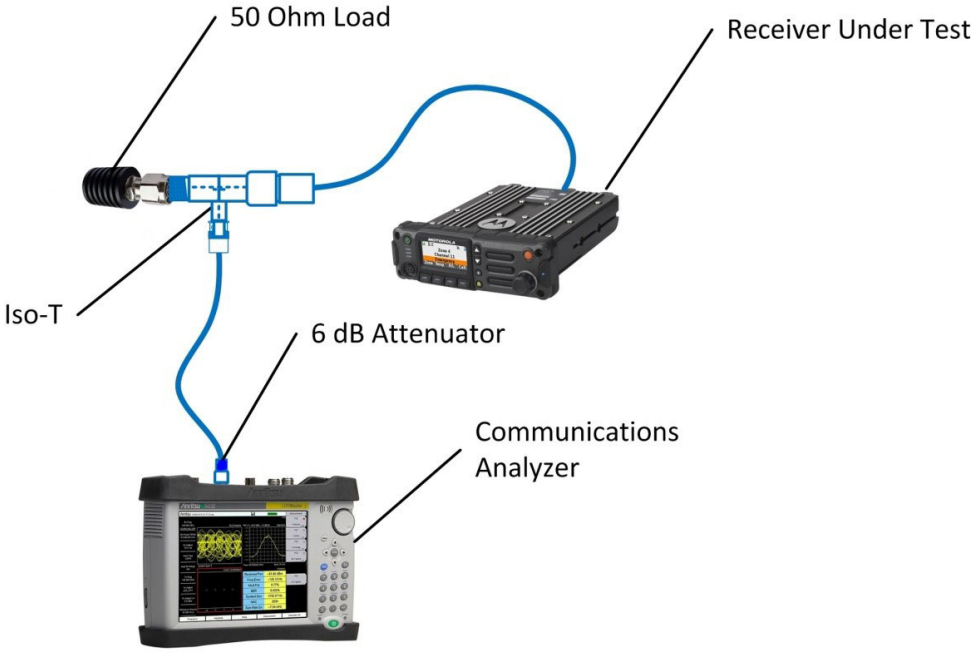


Figure E-43. Configuration for Measurement of Effective Receiver Sensitivity with 50 Ohm Load

NOTE: The 6 dB attenuator shown in Figure E-43 and Figure E-44 helps provide impedance matching between the isolated port of the Iso-T and the communications analyzer. Impedance matching improves accuracy and repeatable results.

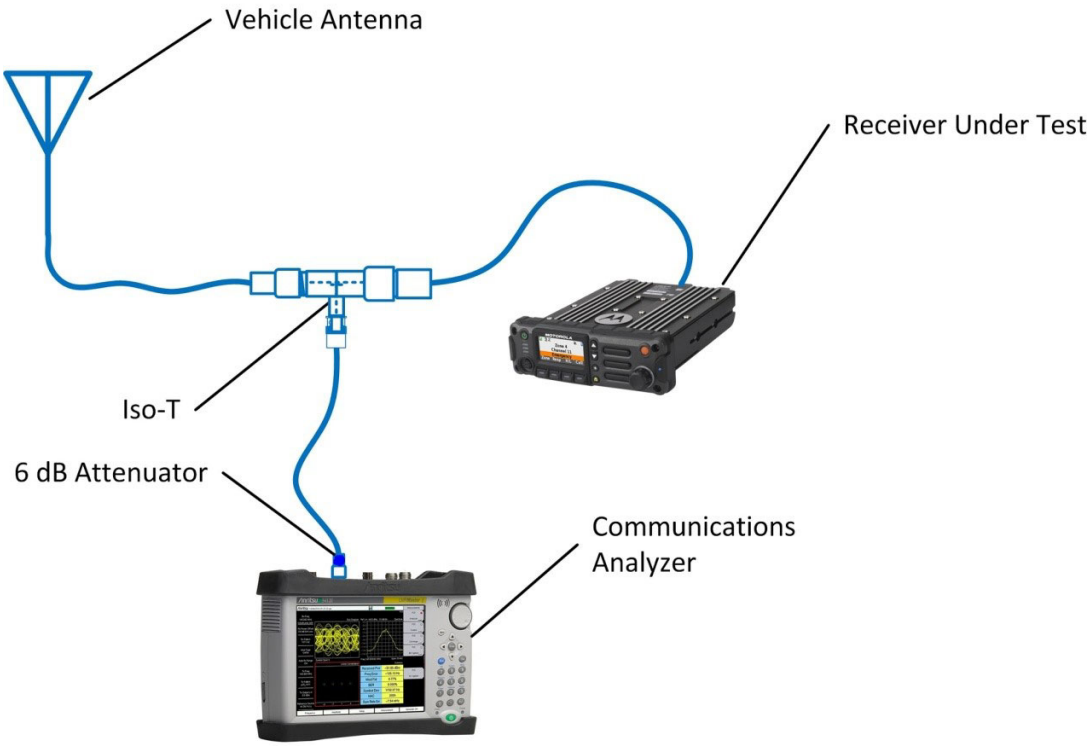


Figure E-44. Configuration for Measurement of Effective Receiver Sensitivity with Vehicle Antenna

Table E-6 provides a general summary of receiver degradation impact. Actual system coverage impact may vary on a per system basis. The measured receiver degradation **shall** be reported to the system engineer and/or system manager.

Table E-6. Summary of Impact of Receiver Degradation

Receiver Degradation	Impact of Findings
0 dB to 3 dB	This amount of degradation is generally considered normal.
3 dB to 5 dB	This amount of degradation is generally considered significant and may impact system coverage. Consult with the system engineer. Troubleshooting for the degradation source is required.
5 dB to 10 dB	This amount of degradation is generally considered high and will degrade system coverage. Consult with the system engineer. This level of degradation must be resolved or reduced to an acceptable level.
Greater than 10 dB	This amount of degradation is generally considered severe and will significantly degrade system coverage. Consult with the system engineer. This level of degradation must be resolved or reduced to an acceptable level.

E.18 Radio Transmit Noise Testing

Perform the TX noise test using a convenient customer channel (such as a lesser used TAC channel) as follows:

NOTE: For digital systems (for example: DMR, MOTOTRBO, P25, or TETRA), this test may require the radio to be put in an analog test mode.

1. Connect the radio directly to the high-power input port of the communications analyzer (see Figure E-45).
2. Start the vehicle engine and turn on vehicle systems (for example: data terminals, LED running lights, lightbars, RADAR devices, sirens, strobe lights, video recording system, and so on).

WARNING: Ensure adequate ventilation when running the vehicle.

3. Monitor the radio's transmit (Tx) channel with the communications analyzer.
4. With the engine running, key the radio and listen to the communications analyzer speaker for noise (alternator, engine, lightbar motors, strobes, and so on).
5. With the vehicle in park, rev the engine to approximately 1500 RPM (see FCS1362:2022) and listen for noise on the communications analyzer. If noise is present, troubleshoot the root cause and correct as needed.

IMPORTANT: The testing described in this section should also be completed with the vehicle siren running to help ensure the siren audio is not excessively coupled to the radio microphone. This test requires significant acoustical isolation from the receiver. As such, it may be more practical for a remotely located technician to monitor an over-the-air transmission using a customer subscriber unit. Obtain necessary customer permissions as needed when testing on an active channel.

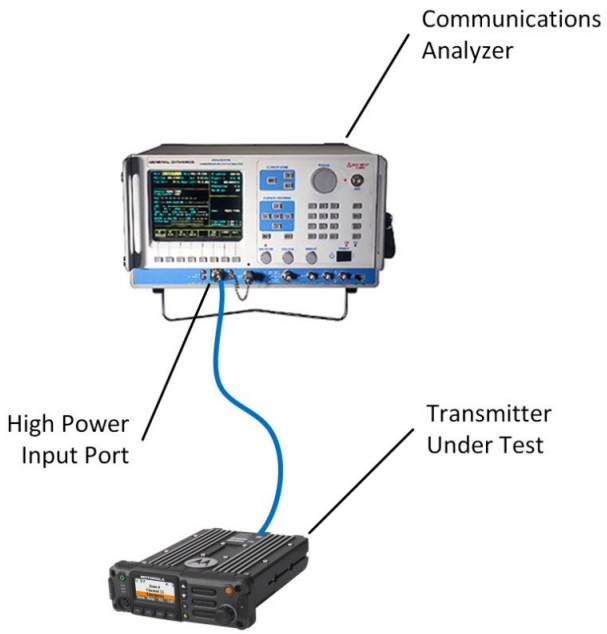


Figure E-45. Example of Configuration for Transmitter Noise Test

E.19 Installation of Miscellaneous Equipment

Emergency vehicles often contain equipment and electronics beyond the two-way radio. Such equipment may be one or more of the following:

- Computers
- Lightbars
- RADAR systems
- Relays
- Sirens
- Strobe lights
- Video recording systems

The installation of other miscellaneous equipment should follow the general guidelines and requirements provided in this Appendix. The specific installation instructions from each equipment manufacturer **shall** be followed.

E.19.1 Power and Ground Sources

- See “Power Wiring for Mobile Installations” on page E-16.
- For vehicles with a Power Distribution Unit (PDU), it is recommended to use a PDU for radio equipment and other sensitive electronics, and a separate PDU for other types of emergency equipment such as lightbars, flashers, gun locks, strobe lights, and so on.
- For vehicles with a PDU ground, it is recommended to use one ground for radio equipment and other sensitive electronics, and a separate ground for other types of emergency equipment (for example: lightbars, flashers, gun locks, strobe lights, and so on).

E.19.2 Relays

For vehicles that use electromechanical relays to control external devices (for example: lights, motors, switch boxes, and so on), these relay circuits should be isolated as practicable from the mobile radio equipment (and other electronics). Diode suppression should also be used across the relay coil to minimize the noise produced by the collapsing magnetic field (see Figure E-46).

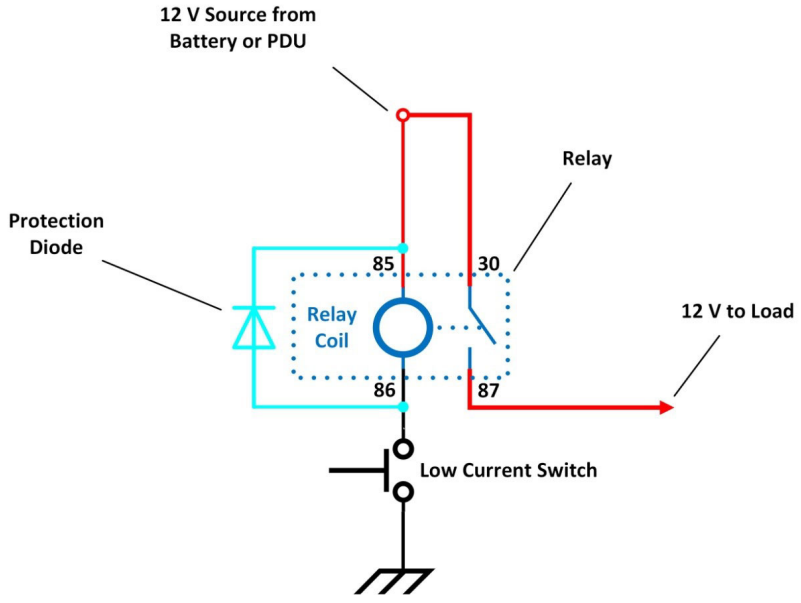


Figure E-46. Example of Relay Diode Wiring

NOTE: The numbers 30, 85, 86, and 87 in Figure E-46 represent the typical automotive relay terminal numbering standard.

E.19.3 Sirens

In addition to the specific instructions provided by the siren manufacturer, the following **shall** be observed:

- The siren speaker **shall** be positioned with the sound-projecting opening pointing forward, parallel to the ground, and not obstructed by structural components of the vehicle such as the radiator (NIJ Guide 500-00 and SAE J1849). See Figure E-47 for examples.
  - Mounting the siren under the hood and behind the radiator will result in a reduction of sound pressure levels at locations away from the vehicle and is not recommended (NIJ Guide 500-00 and SAE J1849).
- The siren speaker should be mounted as far from the vehicle occupants as practicable, preferably in the front grille area (NIJ Guide 500-00 and SAE J1849). See Figure E-47 for examples.
- Installation of two speakers, such as in high-power output applications, requires the speakers to be wired in phase (see Figure E-47). When connecting two speakers in parallel, wire similar speaker terminals together to ensure maximum loudness and prevent “dead spots.” For example, if the terminals are marked “1” and “2”, connect the terminals marked “1” together and connect those wires to one speaker lead. Connect the terminals marked “2” together and connect those wires to the other speaker lead (see Figure E-48).



Figure E-47. Examples of Siren Installations

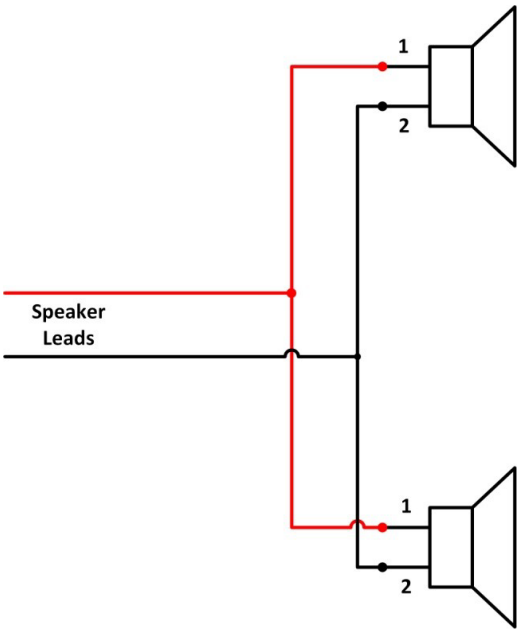


Figure E-48. Example of Two Siren Speakers Wired in Phase for High Power Output Applications

E.19.4 Strobe Lights

In addition to the specific instructions provided by the strobe light manufacturer, the following **shall** be observed:

- Strobe lights **shall** be installed according to manufacturer instructions.
- Strobe light cables **shall** maintain as much separation as practicable from vehicle and radio cabling/wiring.
- Strobe light cable shields **shall** be grounded according to manufacturer instructions.
- Strobe lights **shall** use a separate Power Distribution Unit (PDU) from sensitive electronic equipment (such as computers and radios).
- Strobe lights **shall** use a separate PDU ground (-) distribution point from sensitive electronic equipment (such as computers and radios).

NOTE: Light Emitting Diode (LED) technology lights are increasingly replacing strobe lights.

E.20 Motorcycle Installations

Motorcycle installations can be much more complicated than typical vehicle installations; therefore, only installers trained and experienced with motorcycle applications **shall** perform such installations.

In addition to the specific instructions provided by each equipment manufacturer, the following **shall** be observed:

- Equipment installed on motorcycles **shall** be rated for such installations and **shall** be appropriately weather-resistant as required.
- Equipment **shall** be installed according to manufacturer instructions.
- Equipment **shall** be installed in weather-resistant enclosures as applicable (see manufacturer instructions).
- Forward components (for example: control head, microphone, and speaker) **shall not** interfere with visual or physical access to controls and instruments.
- Forward components **shall not** interfere with the handling of the motorcycle.
- All components **shall** be securely mounted to withstand the constant vibration experienced on a motorcycle.
- Hardware used in motorcycle installations **shall** be stainless steel (or equivalent) to help prevent corrosion.
- Cabling **shall** be protected using a split loom (or equivalent) as necessary. See “Protection of Conductors and Cabling for Mobile Installations” on page E-12.
- Cabling **shall** be run so that it does not interfere with motorcycle operation. See “Routing of Conductors and Cabling for Mobile Installations” on page E-12.
- Cabling **shall** be routed away from motorcycle components that become hot during operation of the motorcycle. See “Routing of Conductors and Cabling for Mobile Installations” on page E-12.
- Cabling **shall** be secured using nylon cable ties (or equivalent) at frequent intervals as required to prevent damage caused by motorcycle vibration.
- Equipment positive (+, red) conductors **shall** connect directly to the battery or other adequate motorcycle manufacturer-provided power points. See the motorcycle manual and/or contact the dealer for information.
- Equipment requiring an ignition sense voltage **shall** terminate to an adequate fuse box ignition point. See the motorcycle manual and/or dealer for location recommendations and current draw limitations. If the current draw limitations on the motorcycle are inadequate, an ignition relay may be required.
- Equipment negative (-, black) conductors **shall** be connected to an adequate chassis ground point on the motorcycle. See the motorcycle manual and/or contact the dealer for more information. **Do not** connect the black conductor directly to the negative battery post.

NOTE: See “Antenna Installations on Non-Metallic Surfaces” on page E-34 for information regarding antenna installations with limited and/or no ground plane.

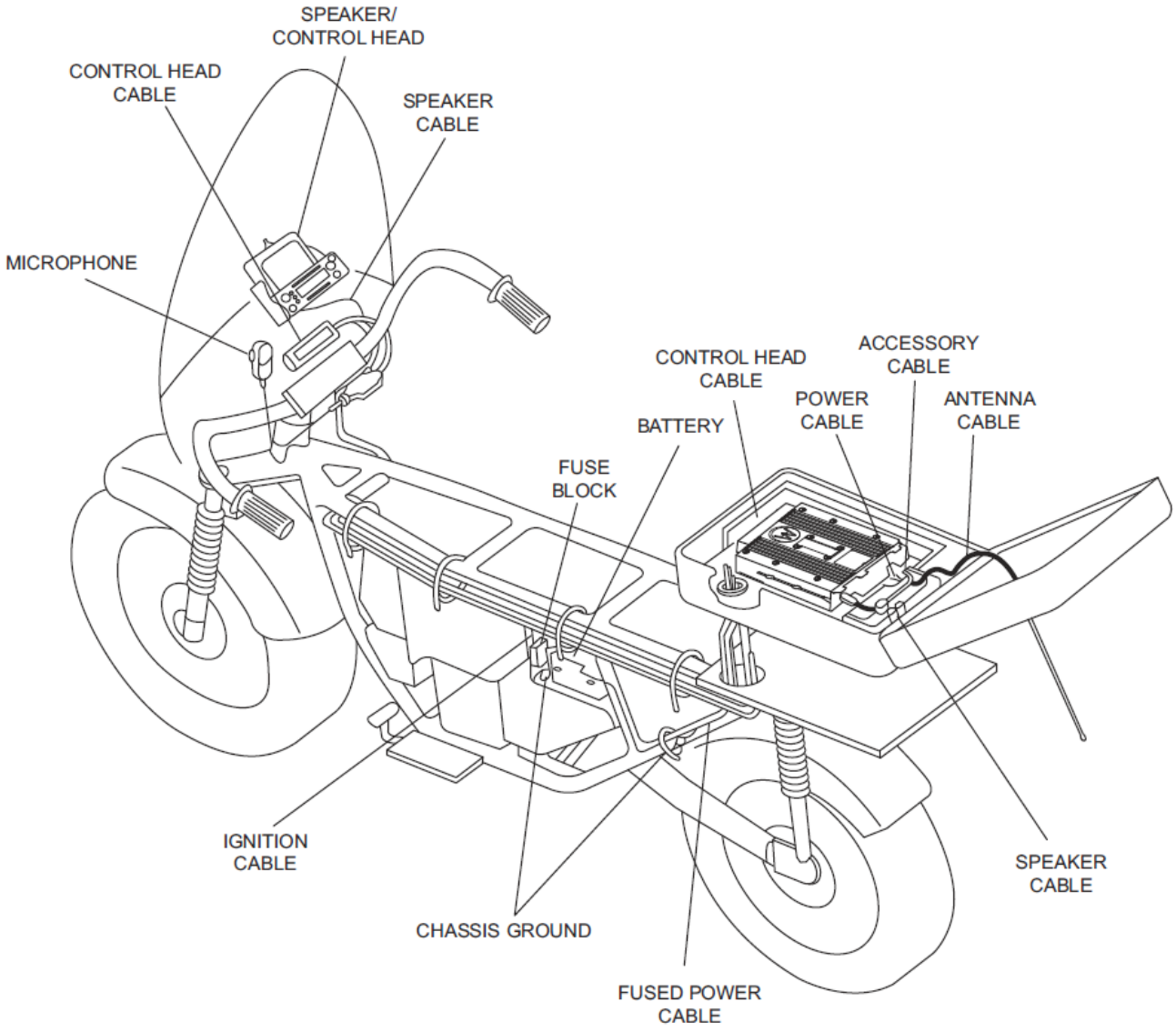


Figure E-49. Example of Motorcycle Radio Installation

E.21 Marine Installations

The information in this section applies to land mobile radios installed in marine applications, such as Police or Fire Department boats. Marine radios used for marine applications **shall** follow applicable installation requirements of the authority having jurisdiction. See “Mobile Installer Training and Certification” on page E-4 for certification requirements and recommendations.

While under operation, a marine vessel can be subject to extreme vibration. Careful attention **shall** be given to proper mounting techniques and securing of equipment and associated cabling/wiring.

Installation of mission critical two-way radio equipment and associated devices, such as lightbars and sirens, **shall not** impede the functionality of other marine vessel equipment (for example, other radios and RADAR) or any functions pertaining to the operation of the vessel.

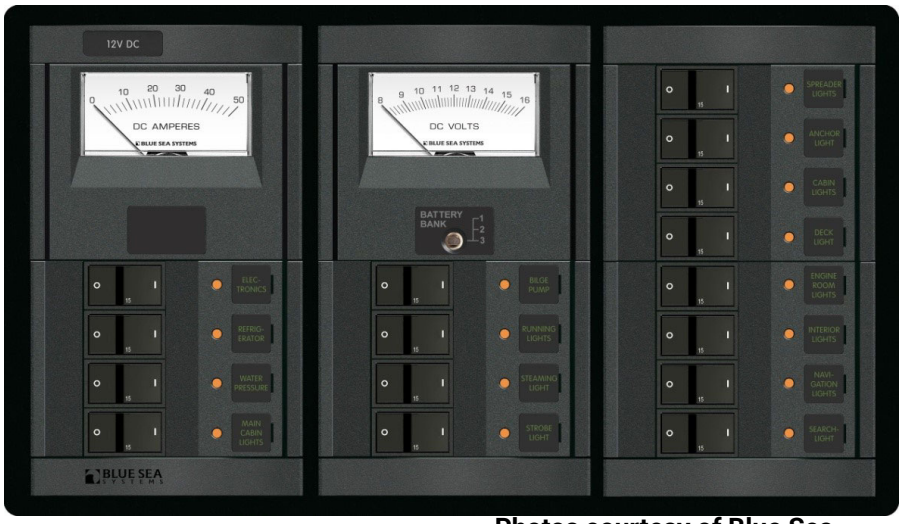
In addition to the specific equipment manufacturer instructions, the following **shall** be observed:

- Antennas and other equipment **shall** be installed away from the RADAR antenna as much as practicable, as required by the RADAR manufacturer.

NOTE: See “Antenna Installations on Non-Metallic Surfaces” on page E-34 for information regarding antenna installations with limited and/or no ground plane.

- Equipment power connections (positive) **shall** be made to an adequate marine vessel-provided 12V power distribution point (+).
  - Equipment **shall** be fused according to manufacturer requirements.
  - See Figure E-50 for an example.
- Equipment power return (negative) **shall** be made to an adequate marine vessel-provided power return bus (-).
- Power conductors **shall** be marine grade (see “Power Conductors for Mobile Installations” on page E-20).
- Mounting hardware **shall** be corrosion resistant (such as stainless steel). See “Securing Hardware for Mobile Installation” on page E-11.
- Electrical connection devices used in marine applications **shall** be suitable for marine applications. Marine application devices typically have the following characteristics:
  - Constructed from tinned-copper for improved corrosion resistance.
  - Contain an adhesive-lined heat shrink insulator to seal connection from vibration and to provide improved strain relief.
  - See “Electrical Ring Terminals, Lugs, Splices, and Similar Devices” on page E-27 for more information.
- Mechanical electrical connections should use a conductive antioxidant compound.
  - The antioxidant compound **shall** be designed for electrical connections.
  - The antioxidant compound **shall** be approved for marine applications (see manufacturer instructions).
- Marine grade coax **shall** be used.
  - Marine grade coax is designed for UV and salt environments.
  - Marine grade coax center conductor and outer shield are tinned for corrosion resistance.
  - Marine grade coax typically has a white outer jacket.
- The use of marine grade antennas is recommended. Standard vehicle antennas are highly prone to corrosion from salt air.

NOTE: Refer to standards from the National Marine Electronics Association and the American Boat & Yacht Council for more details.



Photos courtesy of Blue Sea

Figure E-50. Example of Marine 12V DC Power Distribution Panel

E.22 Aircraft Installations

The following paragraph applies to aircraft installations in the United States. Installations outside of the United States **shall** follow the requirements of the local jurisdiction.

Installations in aircraft carry additional requirements and responsibilities which are beyond the scope of this Appendix. However, persons performing these installations should hold an Airframe and Powerplant (A&P) Certification, and work **shall** be inspected by an Airframe and Powerplant Certificate Holder with Inspection Authorization (A&P-IA) or a certified repair station. Equipment installed in aircraft **shall** have an approved STC (Supplemental Type Certificate) or FAA Field Approval for the aircraft in which the equipment is to be installed.

E.23 Example of Installation Checklist

NOTE: A customer-specific checklist may need to be created for unique installation requirements.

Installation Checklist			
Date			
Customer			
Project			
Vehicle Make		License/Vehicle Number	
Vehicle Model		Mileage	
Radio Model		Radio ID #	

Installation Checklist (continued)			
Radio SN		Radio Asset #	
Radio Firmware			

Vehicle Condition
* Note any existing physical damage on “Existing Vehicle Damage Form” at the end of this document.

	Pre	Post
Low - Beams		
Hi-Beams		
Brake Lights		
Left Signal		
Right Signal		
Hazard Lights		
Fog Lights		
Reverse Lights		
Running Lights		
Air Conditioning		
Seat Belt Operation		
SRS (Air Bag)		
Engine Compartment Light		
Check Engine Light		
Interior Trim		

	Pre	Post
Door Locks		
Power Windows		
Wipers Front		
Wipers Rear		
Power Mirrors		
Power Seats		
AM / Radio		
Clock		
Interior Light		
Trunk Light		
Instrument Lights		
Roof Lining		
12 VDC Power Ports		
Horn		
Fluid Leaks		

Vehicle Condition Items Not Listed on Previous Page

	Pre	Post

Accessories

Installation Checklist (continued)					
	Pre	Post		**Pre**	**Post**
Light bar			Spotlight		
Headlight Flasher			Gun Release		
Corner Strobes			P/A		
Siren			Air Horn		
Siren Park Kill			Horn/Ring		
Take Downs			Map Light		
Alley Lights			Pump Panel Lights		
Ignition Bypass			Radio Power-up - No Key		
Existing Radios					
RADAR			Radio Off With Key		
Accessories Items Not Listed Above				**Pre**	**Post**

Installation Information	
Equipment	**Equipment Location**
Transceiver	
Control Head	
Microphone	
Speaker	
Antenna	
Other Equipment	**Equipment Location**

Installation Checklist (continued)					
Power Cable Gauge		AWG			
Antenna Model			Antenna Frequency		MHz

Radio Testing			
Wattmeter Model		Wattmeter SN	

TX Forward Power		Watts	TX Reflected Power		Watts
Voltage Drop During Transmit		VDC			

VSWR = (1 + sq. root (P(r)/P(f))) / (1 – sq. root (P(r)/P(f)))			VSWR (< 1.5:1)

Communications Service Monitor Model		SN	

Radio Receiver Basic Sensitivity		dBm
Radio Receiver Effective Sensitivity		dBm

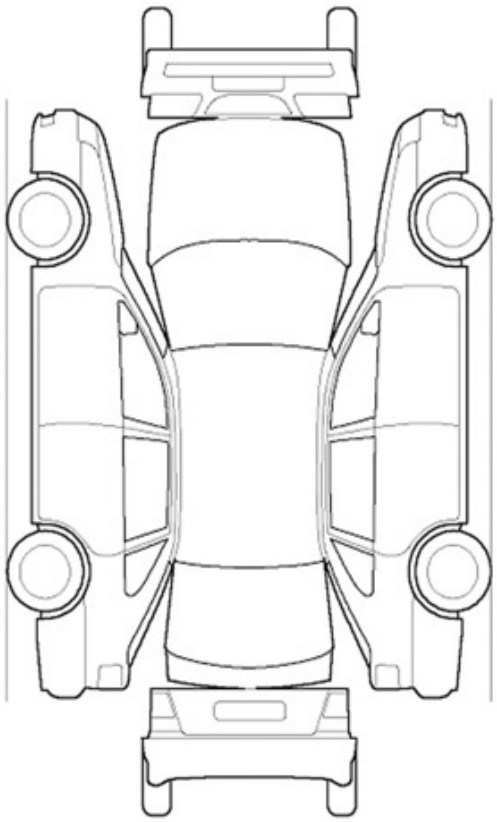
Radio Check					
	Pass	Fail		Pass	Fail
Channel Name:					
Outbound Voice Heard Clearly			Inbound Voice Heard Clearly		
Channel Name:					
Outbound Voice Heard Clearly			Inbound Voice Heard Clearly		
Channel Name:					
Outbound Voice Heard Clearly			Inbound Voice Heard Clearly		

Equipment installed correctly according to installation requirements:	Yes	No
Customer Name		

Installation Checklist (continued)						
Customer Signature						
Installer Name						
Installer Signature						
Notes						

Existing Vehicle Damage

Location(s) of Damage Observed:



Notes: