9. ELECTRICAL AND RF SAFETY – AJ6JG

Chapter 9 Part 1 of 1

ARRL General Class
Sections 9.1, 9.2, 9.3

Electrical Safety

Preventing Electric Shock

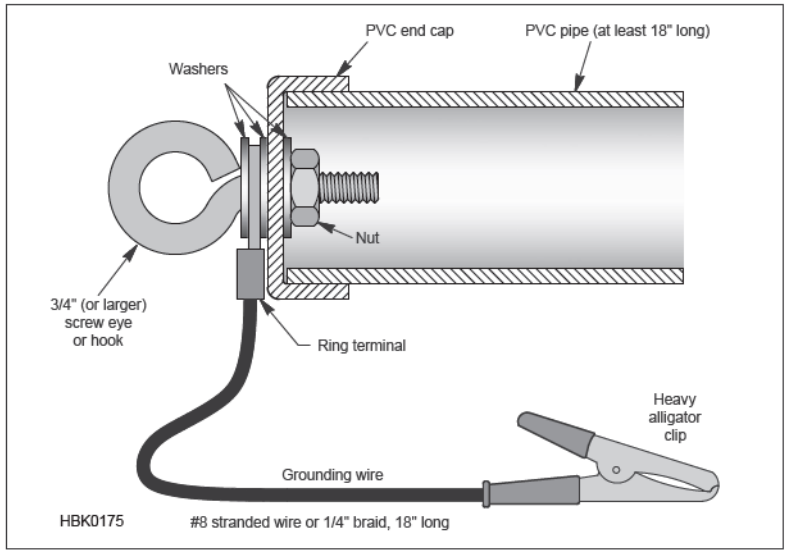
Have a master OFF/ON switch for station and workbench

- Clearly labeled and somewhat away from the equipment

Don’t put yourself in a position to be shocked

When working inside equipment, remove, insulate, or secure loose wires and cables

Use grounding stick to remove charge from capacitors



Effects of Electric Current Through the Body of an Average Person

Current	*Effect (1 sec contact)*
Below 1 mA	Generally not perceptible.
1 mA	Faint tingle
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries.
6 – 25 milliamperes (women)	Painful shock, loss of muscular control*
9 – 30 milliamperes (men)	The freezing current or "let-go" range.* Individual cannot let go, but can be thrown away from the circuit if the extensor muscles are stimulated.
50 – 150 milliamperes	Extreme pain, respiratory arrest, severe muscular contractions. Death is possible.
1,000 – 4,300 milliamperes	Rhythmic pumping action of the heart ceases. Muscular contraction and nerve damage occur; death likely.
10,000 milliamperes	Cardiac arrest, severe burns; death probable

*If the extensor muscles are excited by the shock, the person may be thrown away from the power source.

Source: W.B. Kouwenhoven, "Human Safety and Electric Shock," Electrical Safety Practices, Monograph, 112, Instrument Society of America, p. 93. November 1968.

Soldering Safety

Primarily lead-based; tin added to lower melting point

- Lead is a known toxin
- Solder in a well-ventilated area
- Rosin flux smoke likely not good for you in high doses
- When finished, wash hands to remove solder or flux residue

As of 2006, environmental regulations were passed for solder to eventually be lead-free (leaded solder still available)

- Lead-free solder melts at significantly higher temperature than traditional “60/40” solder (60% tin / 40% lead) … greater risk of damaging heat-sensitive components

Wiring Practices

National Electrical Code Handbook contains details for handling AC wiring in home and station

Use local building codes to ensure home is properly wired to meet special local conditions

Standard wire color conventions

- Hot: Red or Black insulation, connect to brass terminal or screw
- Neutral: White insulation, connect to silver terminal or screw
- Ground: Green insulation or bare wire, connect to green or bare terminal or screw

WARNING: Don't run antenna feed lines over power lines or service drops from a transformer to the house.

Standard Wiring Conventions

Fuses shall be on the HOT conductor.
Do not fuse neutral or ground.

240VAC circuits have TWO hot conductors

Table 9.2
Current Carrying Capacity of Some Common Wire Sizes

Copper Wire Size (AWG)	*Allowable Ampacity (A)*	*Max Fuse or Circuit Breaker (A)*
6	55	50
8	40	40
10	30	30
12	25 (20)*	20
14	20 (15)*	15

*The National Electrical Code limits the fuse or circuit breaker size (and as such, the maximum allowable circuit load) to 15 A for AWG #14 copper wire and to 20 A for AWG #12 copper wire conductors.

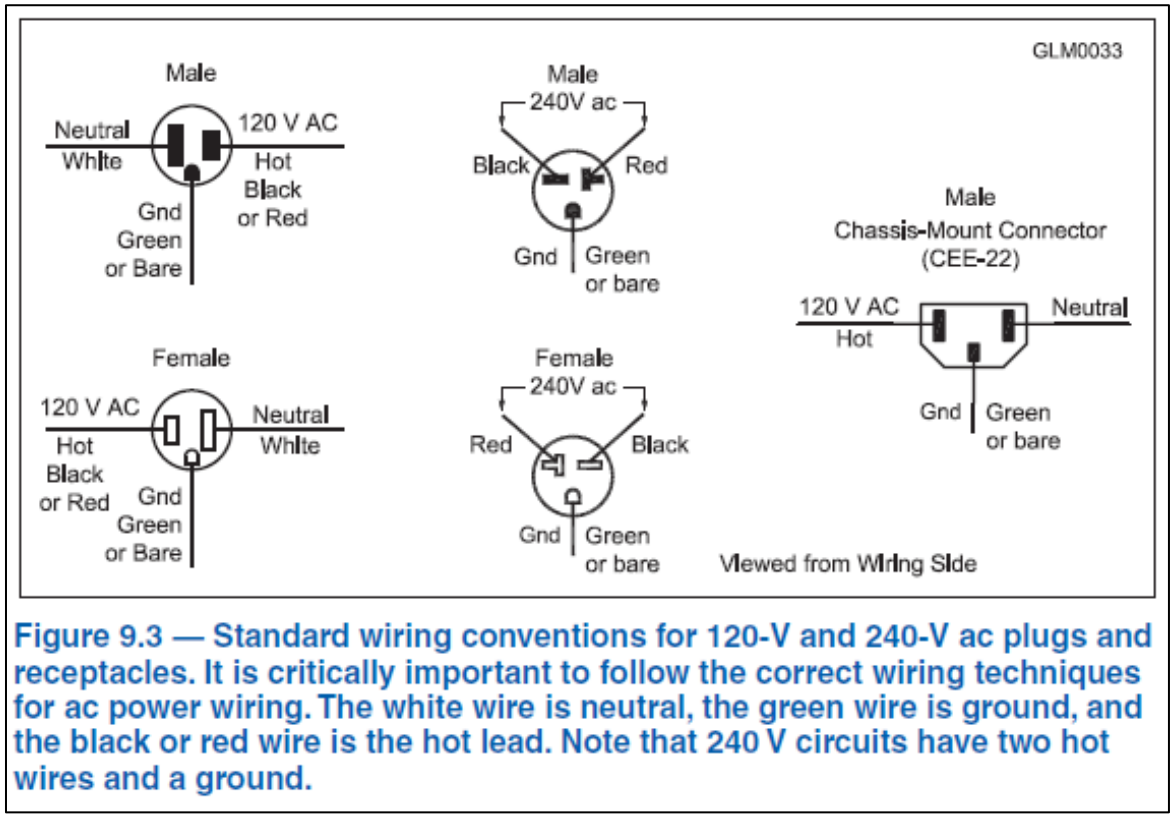


Figure 9.3 — Standard wiring conventions for 120-V and 240-V ac plugs and receptacles. It is critically important to follow the correct wiring techniques for ac power wiring. The white wire is neutral, the green wire is ground, and the black or red wire is the hot lead. Note that 240 V circuits have two hot wires and a ground.

Ground fault circuit interrupter (GFCI) circuit breakers

Used in ac power circuits to prevent shock hazards

Trips if imbalance is sensed in currents carried by hot and neutral conductors

Sensitive to just a few milliamperes (mA) of imbalance between hot and neutral, well below threshold for electrical injury

Safety Interlock

Switch that prevents dangerous voltages or intense RF from being present when a cabinet or enclosure is opened

Several types …

- Physically disconnects high voltage (HV) or RF when activated
- Shorts or grounds HV circuit when activated, possibly blowing a circuit breaker or fuse in a power supply

Generator Safety

Fueling and ventilation problems cause more injuries associated with generators than from any other cause

Install generators outdoors

- Carbon monoxide (CO) in exhaust can quickly build up to toxic levels

When using generators regularly, install CO detector alarms in living and working areas

Generator output connected directly to a home's wiring system must have the ability to disconnect power service from utility lines

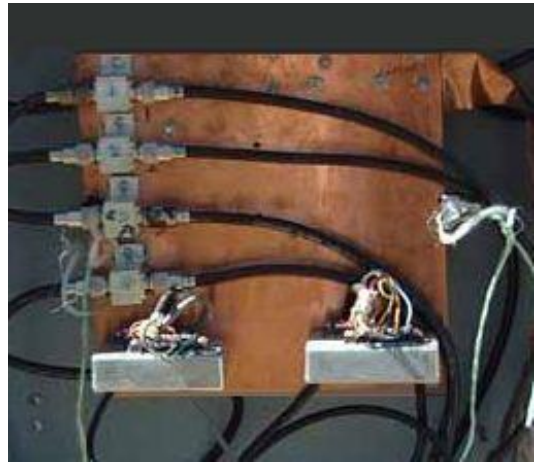
Generators should always be shut off when refueling to avoid igniting fumes or splashed liquid from the spark plug

A fire extinguisher should be kept near the generator and separated from the fuel

Lightning

Goals of lightning protection:

- Provide fire prevention for your home
- Reduce or prevent electrical damage to your equipment



Use metal entry panel where signal & control cables enter the house

- Panel should be grounded nearby with a heavy, short metal strap
- Ground rod must be bonded to the ac service entry ground rod outside the building with a heavy conductor
- Lightning arrestors should be installed at the entry panel (where feed line enters)

Grounding wires and straps should be as short and direct as possible

Do not use solder to make ground connections (solder joints could melt if hit with a lightning-sized current -- use mechanical clamps, brazing, or welding)

All towers, masts, and antennas should be grounded

RF Exposure

At high power levels, for some frequencies, the amount of energy that the body absorbs can be a problem

Maximum permissible exposure (MPE): Maximum intensity of RF radiation to which a human being may be exposed

Factors to consider when estimating MPE: transmitted power level or density, frequency, average exposure time, and duty cycle of the transmission (power density & frequency are primary ones)

Stations with a time-averaged transmission of **more than one milliwatt** are subject to the FCC's RF exposure rules; if your station exceeds the exemption criteria, you will need to evaluate it according to the FCC OET Bulletin 65

Power Density

Heating from exposure to RF signals is caused by the body tissue absorbing RF energy

Measured in mW/cm^2 (milliwatts per square centimeter)

- RF field strengths can also be measured in V/m and A/m, (mW/cm^2 is the most useful for amateur requirements)

Power density is highest near antennas and in the directions in which antennas have the most gain

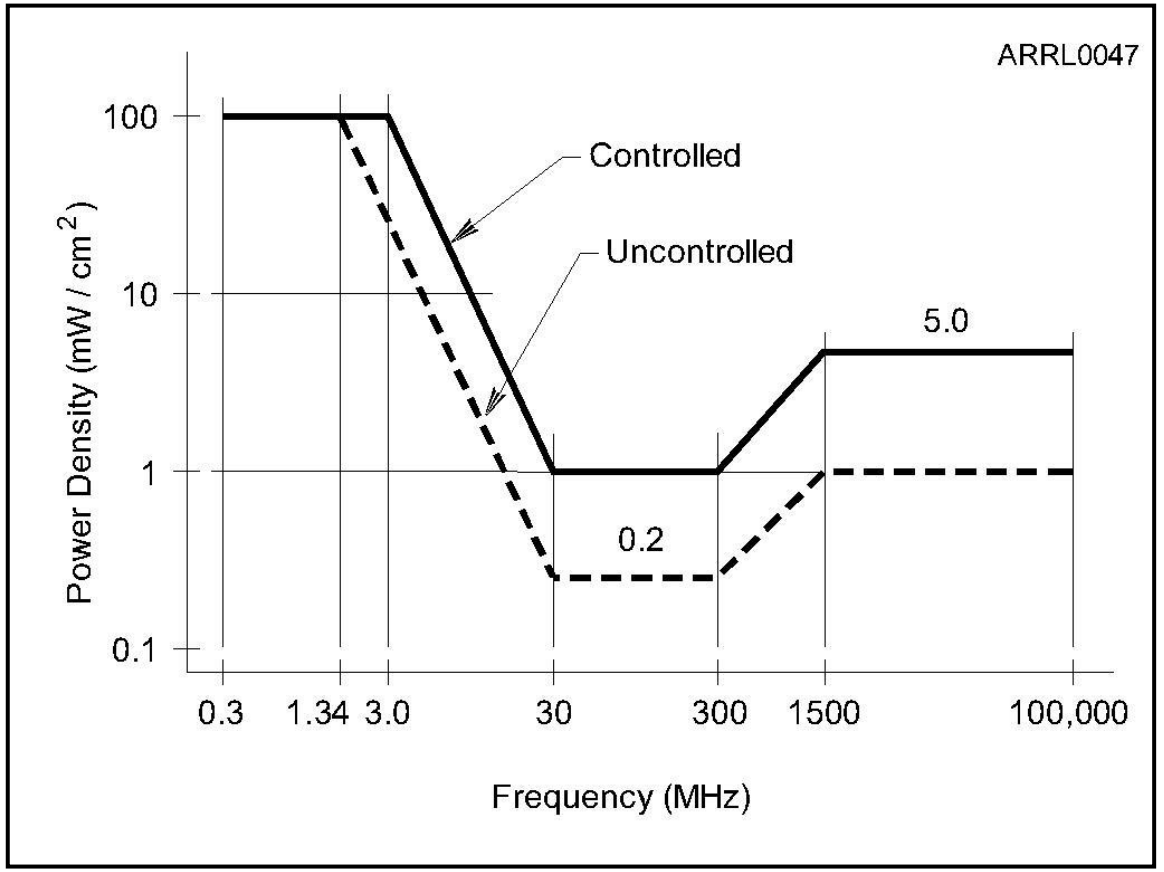
Decreasing transmitter power and increasing distance from an antenna lowers power density (lowers RF energy), and vice versa

Maximum Permissible Exposure

SAR (specific absorption rate): Rate at which energy is absorbed from the power to which the body is exposed

(MPE) limits vary with frequency because the body responds differently to energy at different frequencies. The controlled and uncontrolled limits refer to the environment in which people are exposed to the RF energy.

https://www.arrl.org/rf-exposure-calculator



Operating Duty Factor of Modes Commonly Used by Amateurs

For most amateurs operating, listening and transmitting time are about the same, so operating duty cycle is rarely higher than 50%.

Mode	*Duty Cycle*	*Notes*
Conversational SSB	20%	1
Conversational SSB	40%	2
SSB AFSK data	100%	
SSB SSTV	100%	
Voice AM, 50% modulation	50%	3
Voice AM, 100% modulation	25%	
Voice AM, no modulation	100%	
Voice FM	100%	
Digital FM	100%	
ATV, video portion, image	60%	
ATV, video portion, black screen	80%	
Conversational CW	40%	
Carrier	100%	4

Notes
1) Includes voice characteristics and syllabic duty factor. No speech processing.
2) Includes voice characteristics and syllabic duty factor. Heavy speech processing.
3) Full-carrier, double-sideband modulation, referenced to PEP. Typical for voice speech. Can range from 25% to 100% depending on modulation.
4) A full carrier is commonly used for tune-up purposes.

Minimum Exemption Distances (λ/2π)

Band (MHz)	*Distance*	*Band (MHz)*	*Distance*
1.8	87.0 ft	24.9	6.3 ft
3.6	43.5 ft	28.2	5.6 ft
3.9	40.2 ft	50.1	3.1 ft
7.1	22.1 ft	146	1.1 ft
10.1	15.5 ft	223	8.4 in
14.1	11.1 ft	440	4.3 in
18.1	8.7 ft	902	2.1 in
21.2	7.4 ft	1296	1.5 in

Exposure Safety Measures / Good Practices

Locate or move antennas away from where people can be exposed to excessive RF fields … locate antenna away from property lines and place fence around base of ground-mounted antennas

Don’t point gain antennas where people are likely to be; use beam antennas to direct RF energy away from people

When using stealth, attic, or other indoor antennas, make sure MPE limits are not exceeded in living quarters

On VHF and UHF, place mobile antennas on roof or trunk of car to maximize shielding of passengers

Use dummy load or dummy antenna when testing a transmitter

Reduce the power and duty cycle of your transmissions

Outdoor Safety

Installing antennas

Place all antennas and feed lines well clear of power lines! No part of antenna system should be closer than 10 feet from power lines

When working on roofs, trees, or towers, climbers and helpers should wear appropriate protective gear at all times … run through a safety checklist every time

Turn off and unplug all AC equipment, locking circuits out and tagging them if possible

Transmitters should be off and disconnected from feed line to avoid shock or excessive RF exposure

Belts and harnesses must be within their service life and adequately rated for weight

Check the weather report!

Take your time

QUESTIONS?

ONLINE EXAM REVIEW AND PRACTICE QUESTIONS:

http://www.arrl.org/examreview

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