
# Amateur Radio Technician Exam Preparation Course

ARRL
The National Association for Amateur Radio®

# Safety is your responsibility

## Module 9

## Safety

This presentation is designed to help you pass the licensing exam. It is also intended to introduce you to some of the hazards present in the amateur radio hobby to show you some of the ways to avoid them.

It does not include all possible dangers.

When participating in the hobby, if you encounter a process that you are unfamiliar with, you should get help and training.

You are responsible for your own safety, not the ARRL, this club, or these presenters.

# Electrical Injuries

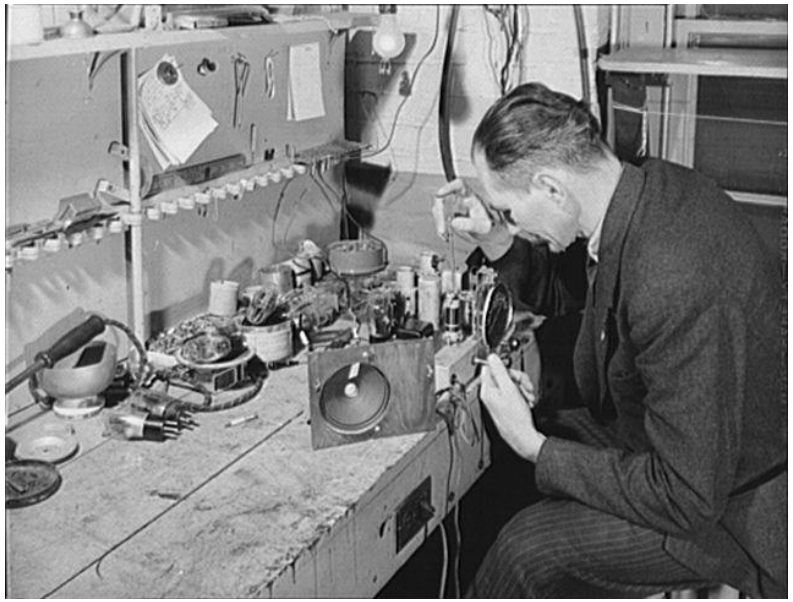
- Electrical current through the body can disrupt the electrical function of cells
  - Can cause involuntary muscle contractions
  - Large currents can burn the skin and heat tissue

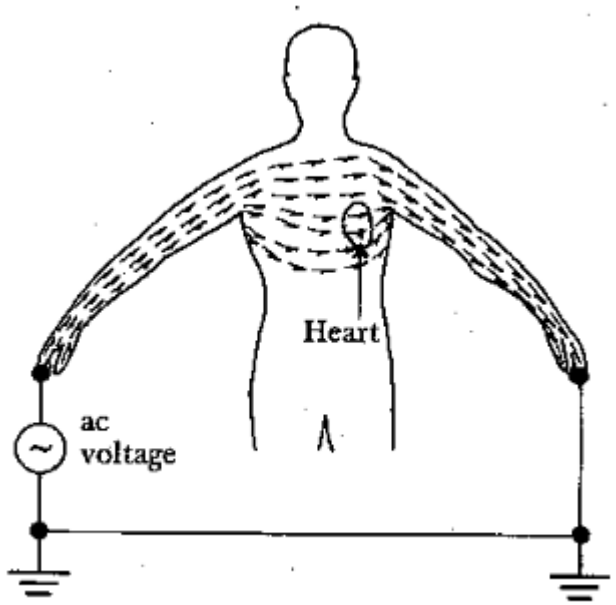
**Table 9.1**
**Effects of Electric Current in the Human Body**

| *Current* | *Reaction* |
|---|---|
| Below 1 milliampere | Generally not perceptible |
| 1 milliampere | Faint tingle |
| 5 milliamperes | Slight shock felt; not painful but disturbing. Average individual can let go. Strong involuntary reactions can lead to other injuries. |
| 6-25 milliamperes (women)<br>9-30 milliamperes (men) | Painful shock, loss of muscular control*; the freezing current or "can't let-go" range. |
| 50-150 milliamperes | Extreme pain, respiratory arrest, severe muscular contractions. Death is possible. |
| 1000-4300 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 |

# Electrical Injuries

- Ohms law applies here, too
- Many Factors affect the value of R in I=V/R





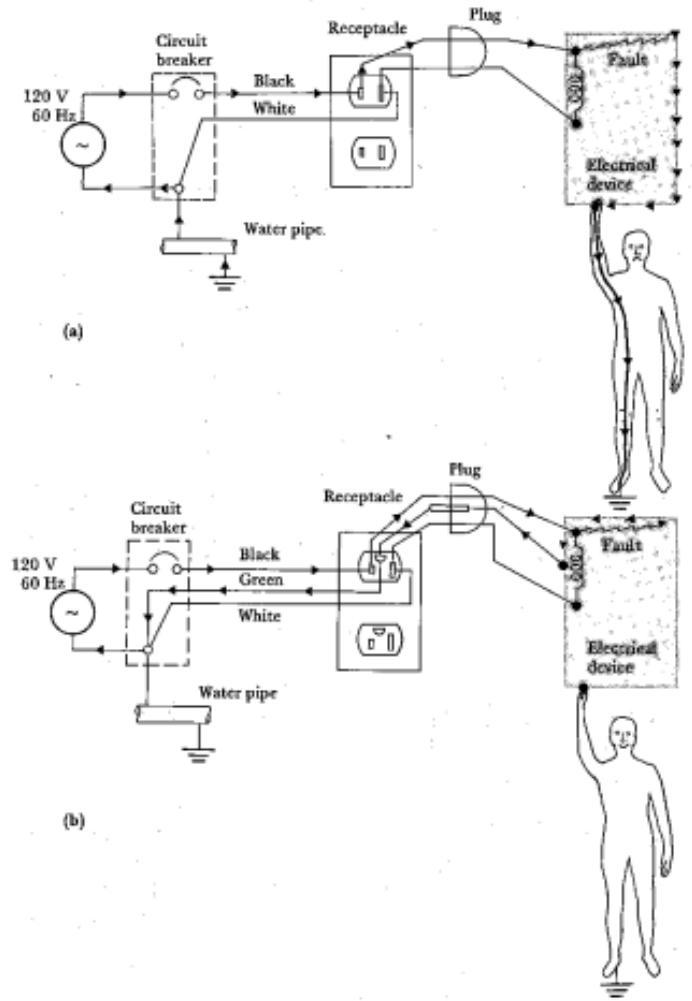

Images: Wikimedia Commons & F.J. Weibell “Electrical Safety in the Hospital” 1974

# Avoiding Electrical Hazards

- Safety tips for working with power **ON**
  - Keep one hand in your pocket
  - Wear insulating shoes
  - Never bypass a safety interlock during testing
  - Make sure capacitors are discharged
  - Keep metal objects clear of storage battery terminals
  - Avoid working on equipment with the battery connected
  - Remove unnecessary jewelry from your hands
  - Avoid working alone

# AC Safety Grounding

- The *safety ground* is a connection to the power system's ground reference connection in your main electrical service box
- The ground connection causes a fuse or circuit breaker to remove power from the equipment



# AC Safety Grounding (cont.)

- Some Grounding guidelines …
  - Use three-wire power cords and plugs
  - Make sure all equipment has a connection to the ground
  - Use ground fault circuit interrupter (GFCI) circuit breakers/outlets
  - Verify AC wiring is done properly
  - Never replace a fuse or circuit breaker with one of a larger size
  - Don’t overload single outlets

# AC Safety Grounding (cont.)

- When wiring circuits, be sure to follow the US standard …
  - Hot — black wire (occasionally red)
  - Neutral — white wire
  - Safety or equipment ground — green
- Use cable and wire sufficiently rated for the expected current load
- Use the proper size fuses and circuit breakers
- Be sure fuses or circuit breakers are installed in series with the hot conductor or conductors

**Table 9.2**

**Current-Carrying Capability of Some Common Wire Sizes**

| *Copper Wire Size (AWG)* | *Allowable Current (A)* | *Max Fuse or Circuit Breaker (A)* |
|---|---|---|
| 6 | 55 | 50 |
| 8 | 40 | 40 |
| 10 | 30 | 30 |
| 12 | 25 (20)[1] | 20 |
| 14 | 20 (15)[1] | 15 |

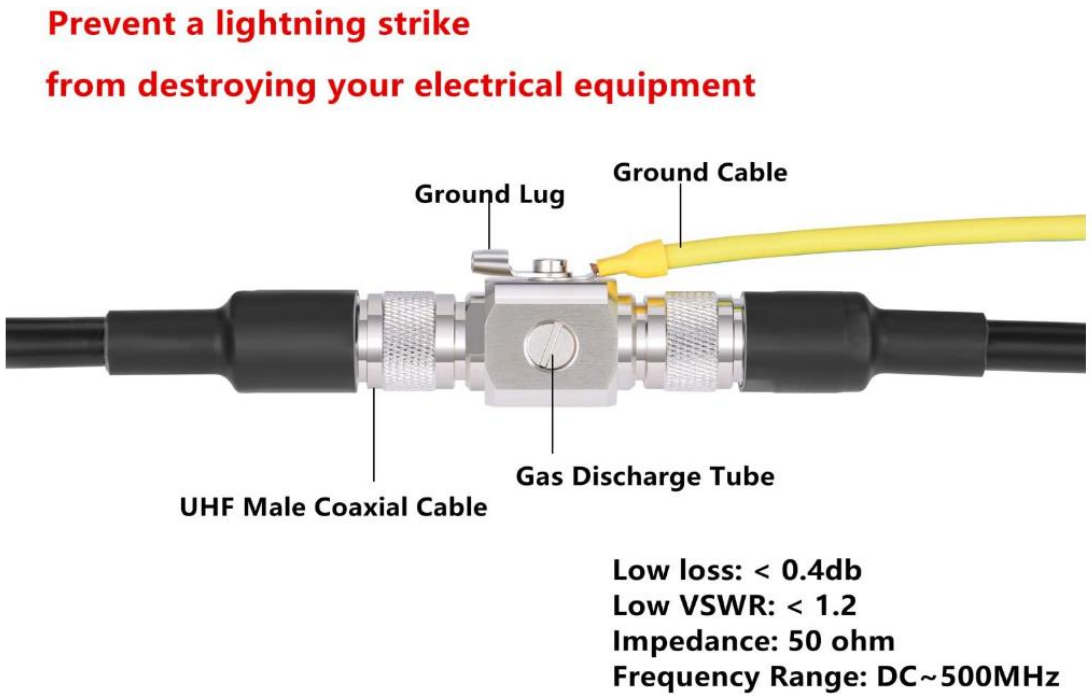
[1]The National Electrical Code limits the fuse or circuit breaker size (and as such, the maximum allowable circuit load current) to 15 A for #14 AWG copper wire and to 20 A for #12 AWG copper wire conductors.

# Lightning Protection

- Lightning protection is intended to provide fire protection for your home
- Starting at your antennas, all towers, masts, and antenna mounts should be grounded according to local building and electrical codes
- Connections are made at the tower base though a large-diameter wire to a ground rod
- Ground connections should be as short and direct as possible — avoid sharp bends
- Use lightning arrestors grounded to a common plate that is in turn connected to a nearby external ground
- All ground rods and earth connections must be bonded together with heavy wire

# Lightning Protection

- Example of a Lightning Arrestor from Amazon.



# Managing RF in Your Station

- Your station wiring, feed lines, power connections, and other cables all pick up RF from your transmitted signal
- It is not practical to “ground” RF current in the same way as for AC power and lightning protection
- Best approach is to *bond* all of the equipment together
  - Keeps all of your equipment at the same voltage so that RF current does not flow between the different pieces
- RF current on cables and enclosures can cause audio distortion, erratic operation of computer equipment, and even RF “burns”
- “RF feedback” via a microphone cable can cause distorted transmitted audio

# Bonding Tips

- Bond all metal equipment enclosures to a common RF ground bus
- Use short, wide conductors such as copper flashing or strap or heavy solid wire
  - Solid strap is best because it presents the lowest impedance to RF
- Keep all connections, straps and wires as short and direct as possible
- Connect the ground bus to your AC safety ground and any earth connections
- See Figure 9.2 in text

# RF Interference (RFI) and Filters

- Interference between appliances and ham radio is called *radio frequency interference* (RFI)
- Filters are used to …
  - Prevent unwanted signals from being radiated
  - Keep unwanted signals from being received

- AC power line filters keep RF signals from passing into or out of equipment via the hot and neutral conductors of the AC power connection
  - They reject all signals with frequencies greater than a few kHz
- Ferrite chokes are also used to reduce RF current on the outside of shielded audio, microphone, and computer cables.

# Filters (cont.)

## Ferrite — The RFI Buster

One of the most useful materials in dealing with RFI is the *ferrite core*. Ferrite is a ceramic magnetic material — you may have used ferrite magnets. The type of ferrite used for RFI suppression is specially designed to absorb RF energy over a broad frequency range, such as HF or VHF. Ferrite is available in many different *mixes* of slightly different composition that absorbs best in a particular range.

One popular form of ferrite is the snap-core shown in the figure. The actual ferrite is a rectangular block with a large hole in it, sawn in half. A plastic case with a snap holds the two pieces together. This allows cords or cables to be wound on the core even if they already have connectors attached, such as power cords or video cables.

Ferrite is available as round *cores* (toroids), rods and beads shown in **Figure 9.4**. Wires or cables are then wound on or passed through the ferrite forms. Beads are made large enough that they can be slipped over coaxial cables and secured with tape or a locking wire-tie. A wire or cable wound on such a ferrite core forms an RF choke.

**Figure 9.4 — Ferrite is a ceramic magnetic material used to make choke filters for RFI suppression. It is available in many different forms: rings (toroids), rods, and beads. Cables can be passed through or wound on these cores to prevent RF signals from flowing along their outside surfaces.**

# Interference from Amateur Transmissions

- The most common causes of RFI from your transmissions are *fundamental overload*, *harmonics*, and *spurious emissions*
- Very strong signals may overwhelm a receiver's ability to reject them
  - This is called *fundamental overload*
- Consumer equipment is often unable to reject strong signals outside the bands it is intended to receive
- A *high-pass filter* can be connected at antenna input of FM & TV receivers to reject strong lower-frequency signals from amateur HF signals
- *Broadcast-reject filters* attenuate signals from nearby AM, FM, or TV broadcast stations

# Harmonics, Spurious Emissions & Leakage

- Every transmitter's RF output signal contains weak *harmonics* of the desired output signal and other *spurious emissions* that can cause interference to nearby equipment
- A *low-pass* or *band-pass filter* can be installed at the transmitter's connection to the antenna feed line to prevent harmonics
- *Leakage* is another source of interference
- The most common cause of leakage is faulty coaxial connectors on the cable feed line
  - Be sure the connectors are installed correctly and attached tightly

# Good Practices in Your Station

- Regardless of the source, you can reduce or eliminate much interference by making sure your own station follows good amateur practices for grounding and filtering
  - Make sure your station is in good working order with appropriate grounding, filtering, and good quality connections
  - Use shielded wire and shielded cables to prevent coupling with unwanted signals and undesired radiation … be sure to connect the shield properly
  - Eliminate interference to your own home appliances and televisions first

# RFI and Neighbors

- Start by making sure it's really your transmissions that are causing the problem
- Offer to help determine the nature of interference

- If you're the recipient of the RFI …
  - Make sure your station meets the standards of good amateur practices
  - Offer to help determine the source of interference
  - You may have to politely explain to the neighbor that FCC rules prohibit them from using a device that causes harmful interference
  - Be diplomatic in dealing with your neighbors

# RF Exposure

- With its relatively low frequency, RF energy is *non-ionizing radiation*
- RF radiation is not the same as ionizing radiation from radioactivity because the energy in signals at radio frequencies is far too low to cause an electron to leave an atom (can't cause genetic damage)
- Per FCC rules the station licensee is responsible for ensuring that no one is exposed to RF energy above the FCC exposure limits
- Heating as a result of exposure to RF fields is caused by the body absorbing RF energy
- Absorption varies with frequency because the body absorbs more RF energy at some frequencies than others
- RF burns can be eliminated by proper bonding techniques or by preventing access to an antenna

# Exposure Limits

**Controlled Exposure (6-Minute Average)**

| *Frequency Range (MHz)* | *Power Density ($mW/cm^2$)* |
|---|---|
| 0.3-3.0 | (100)* |
| 3.0-30 | ($900/f^2$)* |
| 30-300 | 1.0 |
| 300-1500 | f/300 |
| 1500-100,000 | 5 |

**Uncontrolled Exposure (30-Minute Average)**

| *Frequency Range (MHz)* | *Magnetic Field Power Density ($mW/cm^2$)* |
|---|---|
| 0.3-1.34 | (100)* |
| 1.34-30 | ($180/f^2$)* |
| 30-300 | 0.2 |
| 300-1500 | f/1500 |
| 1500-100,000 | 1.0 |

f = frequency in MHz
* = Plane-wave equivalent power density

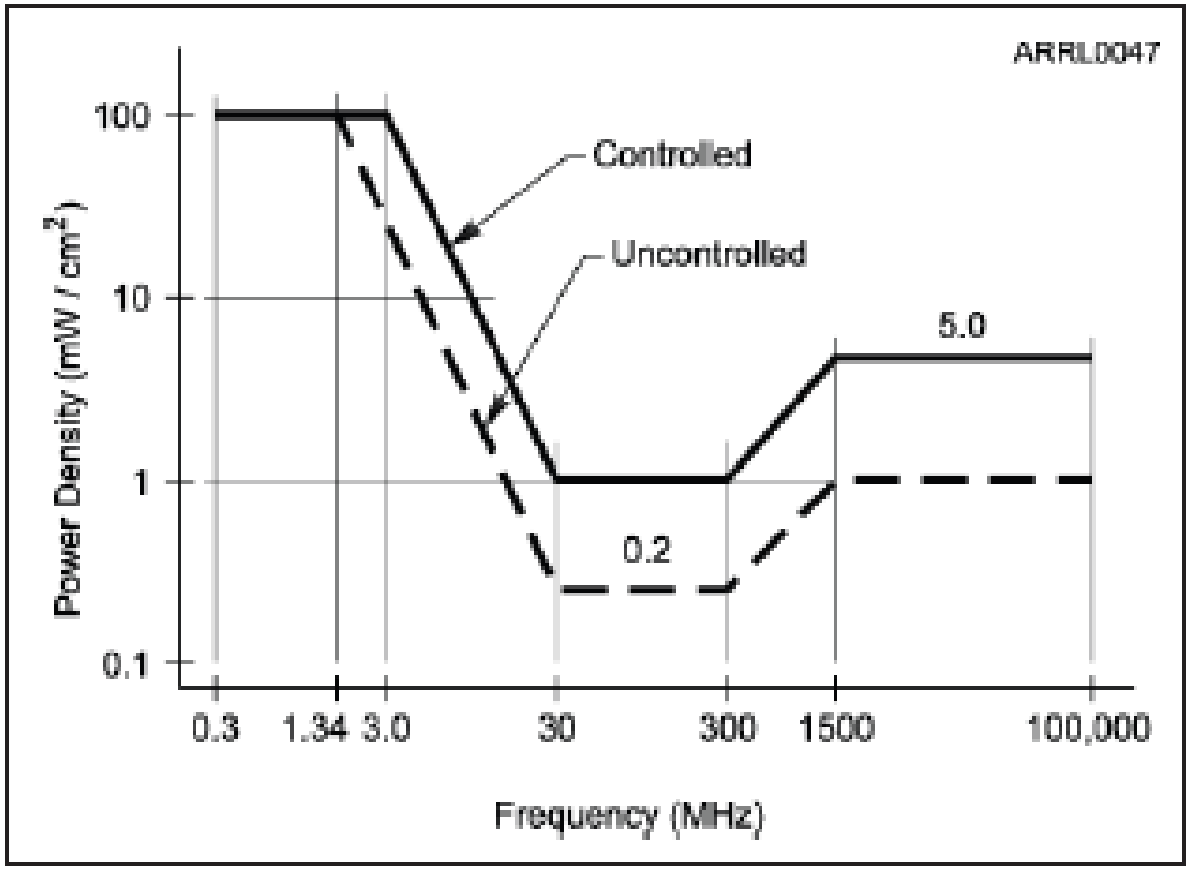



Figure 9.5 — Maximum Permissible Exposure (MPE) limits vary with frequency because the body responds differently to energy at different frequencies. The controlled and uncontrolled limits refer to the environment in which people are exposed to the RF energy.

# Exposure Limits (refer to previous slide)

- People in *controlled environments* are aware of their exposure and can take the necessary steps to minimize it
- People in *uncontrolled environments* are not aware of their exposure, (areas open to the general public or your neighbor's property)
- Frequencies at which the body has the highest absorption rate are from 30 to 1500 MHz (see graph)

# Averaging and Duty Cycle

- MPE limits are based on averages, not peak exposure, allowing exposure to be averaged over fixed time intervals
- Transmitters only generate RF for a fraction of the time they operate (only when transmitting … they receive or sit idle the remaining time)
  - This lowers the *duty cycle* of the emissions … the ratio of the transmitted signal's on-the-air time to the total operating time
- Duty cycle must be considered when evaluating exposure
- *Because the signal is only present for about ½ the time (50% duty cycle), the signal power can be twice as high and still have the same average power as transmitting continuously with a duty cycle of 100%*

# Evaluating Exposure

- All fixed stations must perform an exposure evaluation … three ways of making this evaluation …
  - Use the techniques outlined in the FCC's OET (Office of Engineering Technology) Bulletin 65
  - Measure the power density of your transmissions
  - Make computer models of your station
- You only need to re-evaluate if you change equipment in your station that affects average output power
- The following web page lists resources that make the job a lot easier (http://www.arrl.org/fcc-rf-exposure-regulations-the-station-evaluation)
  - You'll need information on the RF signal's frequency and power level, distance
  - from the antenna and the antenna's radiation pattern

# Exposure Safety Measures

- Locate antennas away from where people can get close to them
- Raise the antenna
- Avoid pointing beam antennas where people are likely to be
- Use a lower gain antenna to reduce radiated power density or reduce transmitter power
- Limit the average power of your transmissions
- Place mobile antennas on the roof or trunk of the car (maximizes shielding)
- Use a remote microphone to hold a handheld transceiver away from your head

# Mechanical Safety … Antennas & Supports

- Make sure your plans satisfy any local zoning codes or covenants or restrictions in your deed or lease
- Place all antennas and feed lines well clear of power lines
- A good guideline is to separate the antenna from the nearest power line by 150% of total height of tower or mast plus antenna
  - A minimum of 10 feet of clearance during a fall is required
- Never attach an antenna or guy wire to a utility pole
- Grounding rules for antennas and supports must be followed according to your local electrical code
- Towers should be grounded with separate 8-foot long ground rods for each tower leg, bonded to the tower and each other
- Place a safety wire through any turnbuckles used to tension guy lines (prevents loosening due to vibration and twisting)

# Tower Work and Climbing Safety

- Climbers and ground crew should wear appropriate protective gear any time work is under way on the tower
- Be sure to get sufficient training on safe tower climbing techniques before beginning, use appropriate tie-off to the tower at all times, and always wear an approved climbing harness
- Never climb a crank-up tower supported only by the cable that supports the sections
- Double-check all climbing belts and lanyards before climbing
- Make sure all ropes and load-bearing hardware are in good condition before placing them in service
- Use a gin pole so that you do not have to hoist things directly
- Double-check the latest weather report
- Avoid climbing alone

# Gin Pole