Lesson 7: Electrical Safety

Preparation for Amateur Radio Technician Class Exam

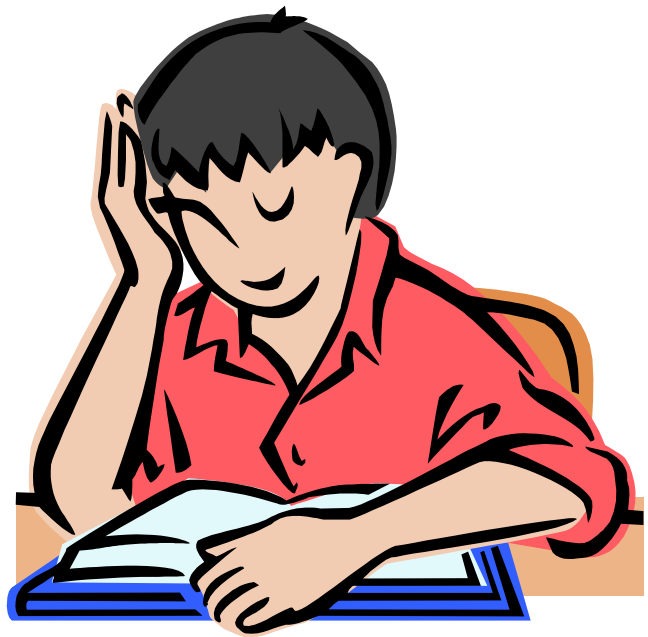
Topics

- Review
- FCC MPE Limits
- Measuring Field Strength
  - Reactive Near-Field
  - Radiating Near-Field
  - Radiating Far-Field
- Calculating Field Strengths
- Look up Field Strengths in Tables
- Exam Questions for this section

Reading

- Chapter 10 – 10.16-10.24

A Quick Review!

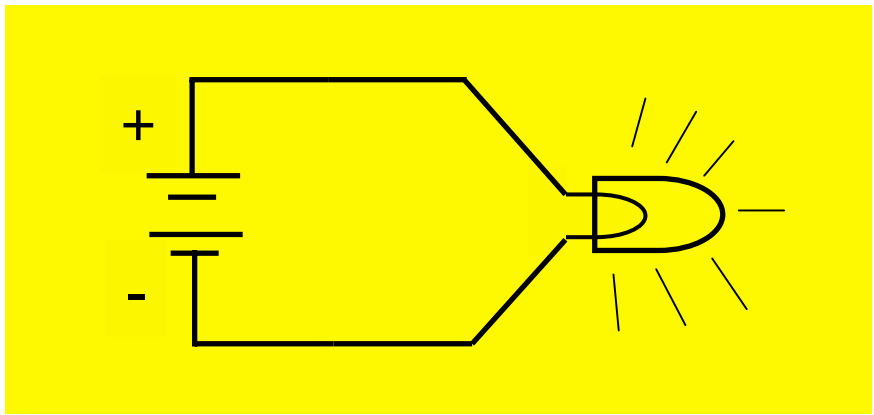


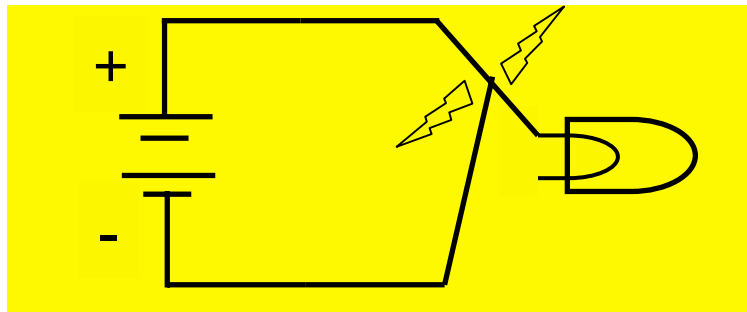
Electrical Safety

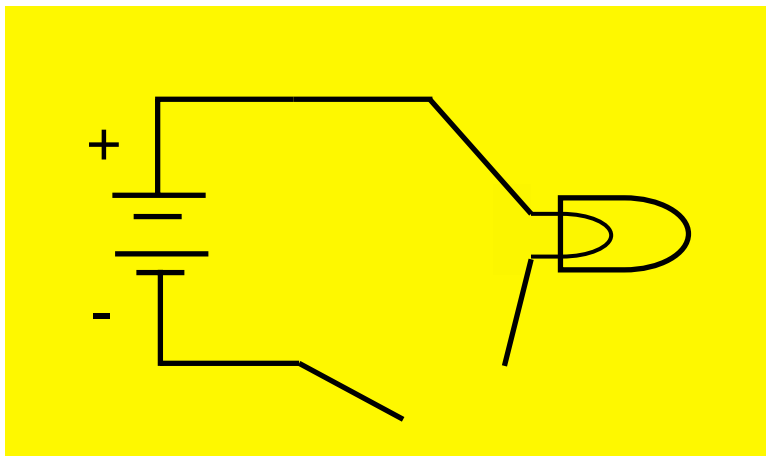
- Treat electricity with respect – it can be dangerous!
  - As little as 100 milliamps or 1/10 amp can be fatal!
  - At this level, heart rhythm can be disrupted
- The minimum voltage considered dangerous to humans is 30 volts

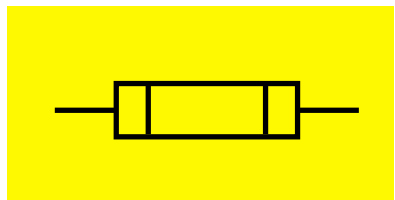
It’s volts that jolts, but mills that kills!

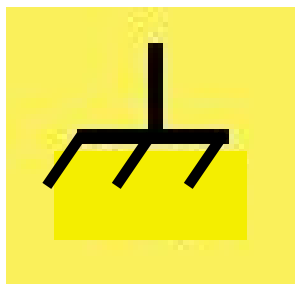
Circuit Review











Electrical Safety

- When working with 120V three wire power cords the three wires have different roles:
  - Black or red is the “hot” wire
  - White is the “neutral” wire
  - Green is the “ground” wire
- This color scheme is typical, but you can’t depend on it

RF Energy

- Electromagnetic Radiation (EMR)
  - RF energy
  - Power-frequency electromagnetic fields (50-60 Hz)
- FCC has set Maximum Permissible Exposure (MPE) limits
- RF energy causes heating of body tissues
  - You can get a nasty burn from an improperly grounded radio chassis or energized antenna
  - In extreme cases, RF heating of the eyes can cause cataracts and blindness

RF Energy

- The effect of RF on your body depends on several things:
  - Frequency of the energy (some frequencies are more readily absorbed than others)
    - RF radiation is from 3 kHz to 300 GHz
      - All frequencies between 300 kHz and 100 GHz are controlled by MPE
      - FCC is most concerned with frequencies in the 30 MHz to 300 MHz range
  - Power density of the RF field (measured in Milliwatts per square centimeter).
    - This is not regulated by the FCC, only the total RF exposure.
  - Polarization of the wave
  - Body size (wavelengths that affect children are shorter than wavelengths that affect adults)

FCC MPE Limits

- The FCC requires that your station operate below the Maximum Permissible Exposure (MPE) Limits for RF radiation
  - You *should* evaluate your station periodically
- Some stations *must* be evaluated for compliance
  - The FCC does not require you to keep records of your station evaluations, nor do they indicate how you must do the evaluation

FCC MPE Limits

- You do not have to evaluate your station for RF output in the following categories:
  - Stations operating below the PEP outputs in Section 97.13 (c) of the FCC Rules. This is measured at the input to the antenna
    - For example, any station operating at or below 50 watts peak envelope power (PEP) does not have to be evaluated
  - Some repeater stations
  - Portable transceivers, such as hand-held radios and vehicle-mounted mobile radios, with a push-to-talk (PTT) button

FCC MPE Limits

- The FCC MPE limits are defined in FCC Part 1 and Office of Engineering and Technology (OET) Bulletin 65
- The FCC MPE limits are given in terms of electric and magnetic field strengths and power density of the signal transmitted from your station
  - Some of the limits are constant numbers, others must be calculated

FCC MPE Limits - Examples

- Referring to Figure T0-1 on page 11.4:
- The MPE limit on the Technician (with code credit) HF bands for a controlled RF radiation exposure environment is:
  - 1842/frequency for electrical field strength in V/m
  - 4.89/frequency for magnetic field strength in A/m
  - 900/frequency^2 in mw per square cm
    - Frequency in MHz

FCC MPE Limits - Examples

- Referring to Figure T0-1 on page 11.4:
- The MPE limit for uncontrolled environments on the 2-meter (146 MHz) band is:
  - 27.5 V/m for electrical field strength
  - 0.073 A/m for magnetic field strength
  - 0.2 mW/cm^2 for power density, averaged over 30 minutes

FCC MPE Limits

- To evaluate your station, you need to determine the electric and magnetic field strengths of your transmissions
- There are several ways you can evaluate your stations for RF radiation:
  - Use a field-strength meter to take measurements directly
  - Use a computer program to calculate the field strengths
  - Look up the information in published tables

Measuring Field Strength

- Using a calibrated field-strength meter with a calibrated field-strength sensor, you can measure the electric and magnetic field strengths around your antenna while transmitting a signal
  - Equipment accurate enough for these measurements is expensive
  - It is difficult to get accurate readings due to environmental factors and the skill of the person doing the measuring

Measuring Field Strengths

- The field strengths are different in various regions around the antenna:
  - Reactive near-field region
  - Radiating near-field region
  - Radiating far-field region

Reactive Near-field

- Closest to the antenna is the reactive near-field
  - The magnetic field predominates in this region
  - The antenna acts as though it were a large lumped-constant inductor or capacitor, storing energy in the near-field
  - This field decreases in strength as you move away from the antenna

Radiating Near-field

- A little way out from the antenna is the radiating near-field
  - Metal objects or conductors in the near-field interact with the theoretical electric and magnetic fields to add or subtract intensity, making it difficult to measure field strength
  - You can have a region near the antenna that is within FCC MPE limits, but have “hot spots” inside the region, such as telephone wiring or aluminum siding
  - The field strength varies with the distance from the antenna, but how it does so depends on the type of antenna

Radiating Far-Field

- The radiating far-field forms the traveling electro-magnetic waves
  - The boundary between the near-field and the far-field depends on wavelength of the frequency and size of the antenna
  - Electric and magnetic fields are perpendicular to each other
  - For accurate measurements, you need to be several wavelengths away from the antenna
  - Power density is proportional to the inverse square of the distance from the antenna

Calculating Field Strengths

- There are a variety of computer programs that will calculate the field strengths for you. They take into account:
  - The type of antenna
  - The gain and directivity of the antenna
  - All conductors within a few wavelengths of the antenna
  - Ground conductivity and interactions

Calculating Field Strengths

- You can calculate the field strength by hand using the amateur supplement of Bulletin 65 from the FCC Office of Engineering and Technology (OET)

Look up Field Strengths in Tables

- You look up field strength in tables in the amateur supplement of Bulletin 65 from the FCC Office of Engineering and Technology (OET)
  - The tables are based on the type of antenna you have, the input power in watts, and the height above of the ground where you are exposed to RF from the antenna

Look up Field Strengths in Tables

- For example, using Figure T0-2 on page 11.4:
- You are using a half-wavelength dipole antenna on 7 MHz at 100 watts PEP. What is the minimum safe distance for a controlled RF radiation environment from the station?
  - 1.4 foot

Look up Field Strengths in Tables

- For example, using Figure T0-2 on page 11.4:
- You are using a 3-element "triband" Yagi antenna on 28 MHz at 100 watts PEP. What is the minimum safe distance for an uncontrolled RF radiation environment from the station?
  - 24.5 feet

Look up Field Strengths in Tables

- For example, using Figure T0-2 on page 11.4:
- You are using a 146 MHz quarter-wave whip antenna at 10 watts PEP. What is the minimum safe distance for a controlled RF radiation environment from the station?
  - 1.7 feet

Look up Field Strengths in Tables

- For example, using Figure T0-2 on page 11.4:
- You are using a 17-element Yagi on a five-wavelength boom on 144 MHz at 100 watts PEP. What is the minimum safe distance for a controlled RF radiation environment from the station?
  - 32.4 feet

Look up Field Strengths in Tables

- For example, using Figure T0-2 on page 11.4:
- You are using a 446 MHz 5/8-wave ground plane vertical antenna at 10 watts PEP. What is the minimum safe distance for an uncontrolled RF radiation environment from the station?
  - 4.3 feet

Exam Questions

- The following slides contain questions from the exam pool that are covered in this section of the notes

T0D04

- T0D04 In the far field, as the distance from the source increases, how does power density vary?
  - A. The power density is proportional to the square of the distance
  - B. The power density is proportional to the square root of the distance
  - C. The power density is proportional to the inverse square of the distance
  - D. The power density is proportional to the inverse cube of the distance

T0D05

- T0D05 In the near field, how does the field strength vary with distance from the source?
  - A. It always increases with the cube of the distance
  - B. It always decreases with the cube of the distance
  - C. It varies as a sine wave with distance
  - D. It depends on the type of antenna being used

T0D07

- T0D07 What factors determine the location of the boundary between the near and far fields of an antenna?
  - A. Wavelength and the physical size of the antenna
  - B. Antenna height and element length
  - C. Boom length and element diameter
  - D. Transmitter power and antenna gain

T0D08

- T0D08 Referring to Figure T0-1, which of the following equations should you use to calculate the maximum permissible exposure (MPE) on the Technician (with code credit) HF bands for a controlled RF radiation exposure environment?
  - A. Maximum permissible power density in mw per square cm equals 900 divided by the square of the operating frequency, in MHz
  - B. Maximum permissible power density in mw per square cm equals 180 divided by the square of the operating frequency, in MHz
  - C. Maximum permissible power density in mw per square cm equals 900 divided by the operating frequency, in MHz
  - D. Maximum permissible power density in mw per square cm equals 180 divided by the operating frequency, in MHz

T0D09

- T0D09 Referring to Figure T0-1, what is the formula for calculating the maximum permissible exposure (MPE) limit for uncontrolled environments on the 2-meter (146 MHz) band?
  - A. There is no formula, MPE is a fixed power density of 1.0 milliwatt per square centimeter averaged over any 6 minutes
  - B. There is no formula, MPE is a fixed power density of 0.2 milliwatt per square centimeter averaged over any 30 minutes
  - C. The MPE in milliwatts per square centimeter equals the frequency in megahertz divided by 300 averaged over any 6 minutes
  - D. The MPE in milliwatts per square centimeter equals the frequency in megahertz divided by 1500 averaged over any 30 minutes

T0E01

- T0E01 If you do not have the equipment to measure the RF power densities present at your station, what might you do to ensure compliance with the FCC RF radiation exposure limits?
  - A. Use one or more of the methods included in the amateur supplement to FCC OET Bulletin 65
  - B. Call an FCC-Certified Test Technician to perform the measurements for you
  - C. Reduce power from 200 watts PEP to 100 watts PEP
  - D. Operate only low-duty-cycle modes such as FM

T0E02

- T0E02 Where will you find the applicable FCC RF radiation maximum permissible exposure (MPE) limits defined?
  - A. FCC Part 97 Amateur Service Rules and Regulations
  - B. FCC Part 15 Radiation Exposure Rules and Regulations
  - C. FCC Part 1 and Office of Engineering and Technology (OET) Bulletin 65
  - D. Environmental Protection Agency Regulation 65

T0F01

- T0F01 Is it necessary for you to perform mathematical calculations of the RF radiation exposure if your VHF station delivers more than 50 watts peak envelope power (PEP) to the antenna?
  - A. Yes, calculations are always required to ensure greatest accuracy
  - B. Calculations are required if your station is located in a densely populated neighborhood
  - C. No, calculations may not give accurate results, so measurements are always required
  - D. No, there are alternate means to determine if your station meets the RF radiation exposure limits

T0F02

- T0F02 What is one method that amateur radio licensees may use to conduct a routine station evaluation to determine whether the station is within the Maximum Permissible Exposure guidelines?
  - A. Direct measurement of the RF fields
  - B. Indirect measurement of the energy density at the limit of the controlled area
  - C. Estimation of field strength by S-meter readings in the controlled area
  - D. Estimation of field strength by taking measurements using a directional coupler in the transmission line

T0F03

- T0F03 What document establishes mandatory procedures for evaluating compliance with RF exposure limits?
  - A. There are no mandatory procedures
  - B. OST/OET Bulletin 65
  - C. Part 97 of the FCC rules
  - D. ANSI/IEEE C95.1--1992

T0F04

- T0F04 Which category of transceiver is NOT excluded from the requirement to perform a routine station evaluation?
  - A. Hand-held transceivers
  - B. VHF base station transmitters that deliver more than 50 watts peak envelope power (PEP) to an antenna
  - C. Vehicle-mounted push-to-talk mobile radios
  - D. Portable transceivers with high duty cycles

T0F06

- T0F06 How may an amateur determine that his or her station complies with FCC RF- exposure regulations?
  - A. By calculation, based on FCC OET Bulletin No. 65
  - B. By calculation, based on computer modeling
  - C. By measurement, measuring the field strength using calibrated equipment
  - D. Any of these choices

T0F07

- T0F07 Below what power level at the input to the antenna are amateur radio operators categorically excluded from routine evaluation to predict if the RF exposure from their VHF station could be excessive?
  - A. 25 watts peak envelope power (PEP)
  - B. 50 watts peak envelope power (PEP)
  - C. 100 watts peak envelope power (PEP)
  - D. 500 watts peak envelope power (PEP)

T0F08

- T0F08 Above what power level is a routine RF radiation evaluation required for a VHF station?
  - A. 25 watts peak envelope power (PEP) measured at the antenna input
  - B. 50 watts peak envelope power (PEP) measured at the antenna input
  - C. 100 watts input power to the final amplifier stage
  - D. 250 watts output power from the final amplifier stage

T0F09

- T0F09 What must you do with the records of a routine RF radiation exposure evaluation?
  - A. They must be sent to the nearest FCC field office
  - B. They must be sent to the Environmental Protection Agency
  - C. They must be attached to each Form 605 when it is sent to the FCC for processing
  - D. Though not required, records may prove useful if the FCC asks for documentation to substantiate that an evaluation has been performed

T0F10

- T0F10 Which of the following instruments might you use to measure the RF radiation exposure levels in the vicinity of your station?
  - A. A calibrated field strength meter with a calibrated field strength sensor
  - B. A calibrated in-line wattmeter with a calibrated length of feed line
  - C. A calibrated RF impedance bridge
  - D. An amateur receiver with an S meter calibrated to National Bureau of Standards and Technology station WWV

T0F11

- T0F11 What effect does the antenna gain have on a routine RF exposure evaluation?
  - A. Antenna gain is part of the formulas used to perform calculations
  - B. The maximum permissible exposure (MPE) limits are directly proportional to antenna gain
  - C. The maximum permissible exposure (MPE) limits are the same in all locations surrounding an antenna.
  - D. All of these choices are correct

T0F14

- T0F14 Which of the following factors must be taken into account when using a computer program to model RF fields at your station?
  - A. Height above sea level at your station
  - B. Ionization level in the F2 region of the ionosphere
  - C. Ground interactions
  - D. The latitude and longitude of your station location

T0F15

- T0F15 In which of the following areas is it most difficult to accurately evaluate the effects of RF radiation exposure?
  - A. In the far field
  - B. In the cybersphere
  - C. In the near field
  - D. In the low-power field

T0D10

- T0D10 What is the minimum safe distance for a controlled RF radiation environment from a station using a half-wavelength dipole antenna on 7 MHz at 100 watts PEP, as specified in Figure T0-2?
  - A. 1.4 foot
  - B. 2 feet
  - C. 3.1 feet
  - D. 6.5 feet

T0D11

- T0D11 What is the minimum safe distance for an uncontrolled RF radiation environment from a station using a 3-element "triband" Yagi antenna on 28 MHz at 100 watts PEP, as specified in Figure T0-2?
  - A. 7 feet
  - B. 11 feet
  - C. 24.5 feet
  - D. 34 feet

T0D12

- T0D12 What is the minimum safe distance for a controlled RF radiation environment from a station using a 146 MHz quarter-wave whip antenna at 10 watts, as specified in Figure T0-2?
  - A. 1.7 feet
  - B. 2.5 feet
  - C. 1.2 feet
  - D. 2 feet

T0D13

- T0D13 What is the minimum safe distance for a controlled RF radiation environment from a station using a 17-element Yagi on a five-wavelength boom on 144 MHz at 100 watts, as specified in Figure T0-2?
  - A. 72.4 feet
  - B. 78.5 feet
  - C. 101 feet
  - D. 32.4 feet

T0D14

- T0D14 What is the minimum safe distance for an uncontrolled RF radiation environment from a station using a 446 MHz 5/8-wave ground plane vertical antenna at 10 watts, as specified in Figure T0-2?
  - A. 1 foot
  - B. 4.3 feet
  - C. 9.6 feet
  - D. 6 feet

T0E10

- T0E10 Why should you not stand within reach of any transmitting antenna when it is being fed with 1500 watts of RF energy?
  - A. It could result in the loss of the ability to move muscles
  - B. Your body would reflect the RF energy back to its source
  - C. It could cause cooling of body tissue
  - D. You could accidentally touch the antenna and be injured