

## Safety

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### RF Safety

- Be cautious with VHF & UHF transmitting antennas
  - ↳ 23 cm amateur band is similar to energy within a microwave oven
  
- Locate all antennas where they cannot be accidentally touched
  - ↳ Confine RF energy to the antenna
  - ↳ Avoid RF Burns
    - ✓ Light bulbs are rated in watts - So is RF energy emissions
  
- Keep antennas away from power lines
  
- Do not operate equipment with the shields or covers removed
  - ↳ RF Safety
  - ↳ Electrical shock
  
- Do not look into open end of a microwave feed horn and expose your eyes to high levels of radiation
  
- Stay 24 inches away from power supplies and electrical fans
  - ↳ Lower frequencies penetrate deeper into the body than higher frequencies

## Safety

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### RF Safety - Continued

- No person should ever be near a transmitting antenna
  - ↳ Especially true for mobile or ground-mounted vertical antennas
  - ↳ Avoid using 25 watts or more in a mobile installation
  - ↳ Mobile roof mount antennas provide the best shielding
  - ↳ Avoid using indoor/attic mounted antennas
  - ↳ Never point a high gain antenna at nearby inhabited areas
  - ↳ Never work on an antenna with the power applied
  
- Station measurements must take all radiation elements into consideration
  - ↳ Repeater installation
    - ✓ Signal must be considered as part of total RF radiation of the site
  
- Keep hand-held Handi-Talkie (HT) antenna away from head and eyes
  - ↳ VHF & UHF has the most effect on soft tissue
  - ↳ Hand-held (HT) is considered to be a 'portable' device
  - ↳ Use separate microphone to allow the radio to be located away from your head
  - ↳ Turn radio upside down when transmitting
    - ✓ Keep away from your head and other persons

# Safety

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## PART 97--AMATEUR RADIO SERVICE

### General Provisions

#### Sec. 97.13 Restrictions on station location.

- (c) Before causing or allowing an amateur station to transmit from any place where the operation of the station could cause human exposure to RF electromagnetic field levels in excess of those allowed under Sec. 1.1310 of this chapter, the licensee is required to take certain actions .
  - (1) The licensee must perform the routine RF environmental evaluation prescribed by Sec. 1.1307(b) of this chapter, if the power of the licensee's station exceeds the limits given in the following table:
    - 
    - 
    - See Now You're Taking, page 10.18 for table*
    - 
    -
  - (2) If the routine environmental evaluation indicates that the RF electromagnetic fields could exceed the limits contained in Sec. 1.1310 of this chapter in accessible areas, the licensee must take action to prevent human exposure to such RF electromagnetic fields. Further information on evaluating compliance with these limits can be found in the FCC's OET Bulletin Number 65, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields" .

## Safety

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### Thermal Effects of RF Energy

- Exposure to high levels of RF radiation causes heat damage to body tissues
  - ↳ Factors
    - ✓ Frequency
    - ✓ Power Density
    - ✓ Polarization
    - ✓ Near Field & Far Field
  
- RF energy is absorbed more efficiently at frequencies near the body's natural resonant frequency
  - ↳ 35 MHz if grounded
  - ↳ 70 MHz if insulated from ground

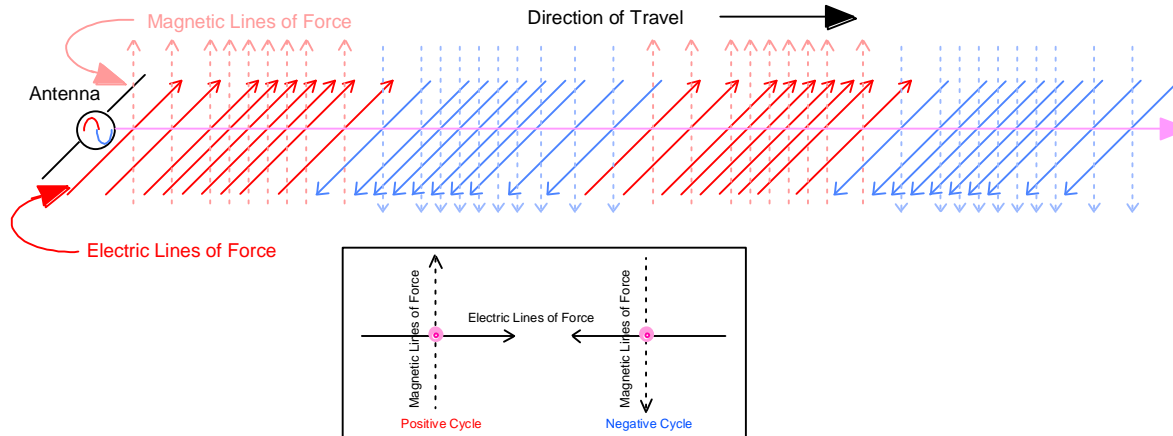
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## Terms

- q RF Radiation: Exposure to electric and magnetic fields between 3 kHz and 300 GHz
  - u FCC RF Radiation Exposure Guidelines: 300 kHz - 300 GHz
- q Controlled Environment: Aware of RF Radiation
- q Uncontrolled Environment: Unaware of RF Radiation
- q EMR: Electro-Magnetic Radiation - Contains both electric field and magnetic field at 90°



## Safety

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### Terms - Continued

#### q MPE : Maximum Permissible Exposure

- u Frequency dependent on whole body *Specific Absorption Rates* (SAR)
- u Regulations are based on *Specific Absorption Rate* (SAR) and NOT field strength
- u Power Density in  $\text{mW}/\text{cm}^2$  ( $P = E \times I / \text{area}$ )
  - v Supplied for all bands
- u Established by ANSI/IEEE
- u FCC establishes *Maximum Exposure Limits* (MPE)
- u Defined in FCC Part 1 Rules and Office of Engineering Technology Bulletin 65
- u Based on time averages
  - v *6 minutes for controlled environment*
  - v *30 minutes for uncontrolled environment*

#### q SAR: Specific Absorption Rate - absorption of RF energy

- u The rate at which RF energy is absorbed into the human body
  - v Frequency dependant
- u Most critical between 30 MHz and 300 MHz
- u *MPE* is based on whole body *SAR* values

## Safety

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### RF Radiation Field

#### q Factors Effecting RF Field Radiation

- u Frequency and Power Level
- u Antenna Height and Distance
- u Radiation Pattern

#### q RF Field Radiation

- u Causes body tissue to heat - Potential RF Burns
  - v Direct result of non-ionizing radiation
- u Licensee responsible for all emissions from his/her station

#### q Station Evaluations

- u All amateurs required to perform a station evaluation
- u Certified on amateur license application (FCC Form 605)
  - v Read and understand FCC Rules about RF Radiation Exposure
- u Records are not required
- u Perform one or more methods included in FCC OET Bulletin 65
  - v Do not have to perform mathematical calculations
- u Use the FREE RF Safety program '**RFSFX.EXE**' to perform your station evaluation
  - v <http://www.ham.net/libraries/miscellaneous>

# Safety

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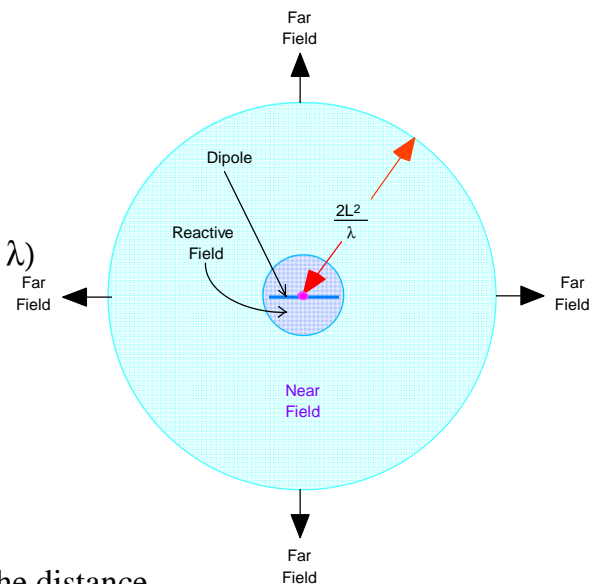
## Factors

### q Reducing RF Radiation

- u Reduce Power and Duty Cycle
  - ✓ Duty Cycle: Ratio of operating on time to total time
  - ✓ Limit Transmitter Operation
- u Increase Antenna Height and Distance

### q RF Field Radiation

- u Near Field/Far Field
- u Based on wavelength and antenna size
- u **Reactive Near Field:** (inductance/capacitance) ( $\approx \frac{1}{2} \lambda$ )
  - ✓ Electrostatic fields
  - ✓ Magnetic fields
  - ✓ Effected by objects located within the field
- u **Radiating Near Field:**
  - ✓ Effected by near by objects
  - ✓ May have hot spots
- u **Radiating Far Field:**
  - ✓ Power density decreases by the inverse square of the distance
  - ✓ Electric and magnetic fields are perpendicular and in phase



## Safety

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### Q Radiated Near Field – Far Field Boundary Calculation

- U  $D \approx \frac{2L^2}{\lambda}$ 
  - ✓ L = Length from antenna
  - ✓  $\lambda$  = wavelength
- U Approximately several wavelengths

### Q Power Density Formula

- U Use for Far Field calculations
- U Assumes an isotropic antenna and no other natural effects (Earth, metal, buildings, etc.)
- U  $P_d = \frac{P_t}{4\pi d^2}$ 
  - ✓  $P_d$  = power density in watts per meters<sup>2</sup> (watts/m<sup>2</sup>)
  - ✓  $P_t$  = power out of the transmitter
  - ✓  $\pi \approx 3.14159$
  - ✓ d = distance from the antenna in meters
- U  $4\pi d^2$  = area of a sphere
- U Power distributes across the area of a sphere and decreases inverse to the square of the distance

## Safety

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### Example 1

Referring to the table on page 22, which of the following equations should be used to calculate the maximum permissible exposure (MPE) limit on the Technician HF bands for a controlled RF radiation exposure environment?

**NOTE:** *HF frequency range is 0.3 – 30 MHz*

1. Turn to handout page 21
2. Look for the table that provides the “*Controlled*” exposure formulas
3. Look for the column in the units specified in the answers – *power density*
4. Look for the row that addresses the frequency of interest - *0.3 - 30*
5. Look for the formula where the row and column intersect

$$\text{Power Density MPE} = 900/f^2$$

**NOTE:** If you were operating on the 75 meter band at 3.7 MHz, insert the frequency into the formula and perform the calculation

$$\text{MPE} = (900/3.7^2) = 65.7 \text{ mw/cm}^2$$

## Safety

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### Example 2

Referring to table on page 22, what is the formula for calculating maximum permissible exposure (MPE) limit for uncontrolled environments on the 2 meter (146 MHz) band?

**NOTE:** *2-Meter frequency range is 30 – 300 MHz*

1. Turn to handout page 23
2. Look for the table that provides the “*Uncontrolled*” exposure formulas
3. The Maximum Permissible Exposure (MPE) expressed in Power Density ( $\text{mW}/\text{cm}^2$ )
4. Look up the value across the row for the frequency range (30-300) and under the column for Power Density MPE = 0.2
5. The MPE is stated as a constant (0.2); therefore, there isn't a formula.

## Safety

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### Example 3

What is the minimum safe distance for an **controlled** RF radiation environment from a station using a **146 MHz quarter-wave whip** antenna at **100 watts** as specified in Table on page 23?

1. Turn to handout page 23
2. Read the Section description to find the antenna (**146 MHz quarter-wave whip**)
3. Find the power level row of interest (**10 watts**)
4. Find the column for the type of environment stated in the problem (**controlled**)
6. Read the distance from the table: **1.7 ft**

# Safety

## RF Exposure Limits

### ? Example 1

(A) Limits for Occupational/ <b>Controlled</b> Exposure				
Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field (A/m)	Power Density (mW/cm <sup>2</sup> )	Averaging Time (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	(900/f <sup>2</sup> )*	6
30-300	61.4	0.163	1.0	6
300-1500	-----	-----	f/300	6
1500-100,000	-----	-----	5	6
f = frequency in MHz		* = Plane-wave equivalent power density		
(B) Limits for General Population/ <b>Uncontrolled</b> Exposure				
Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field (A/m)	Power Density (mW/cm <sup>2</sup> )	Averaging Time (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	(180/f <sup>2</sup> )*	30
30-300	27.5	0.073	0.2	30
300-1500	-----	-----	f/1500	30
1500-100,000	-----	-----	1.0	30
f = frequency in MHz		* = Plane-wave equivalent power density		

### ? Example 2

# Safety

## Estimated distances for RF power density

Antenna: horizontal 1/2 wave dipole  
 Frequency: 7.0 MHz  
 Antenna Gain: 2.0 dBi  
 EPA Ground Reflection Factor: 2.56  
 Controlled Limit: 18.37 mW/cm<sup>2</sup>  
 Uncontrolled Limit: 3.67 mW/cm<sup>2</sup>

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
100	1.4 ft	3.1 ft
500	3.1 ft	6.9 ft
1000	4.3 ft	9.7 ft
1500	5.3 ft	11.9 ft

## Estimated distances for RF power density

Antenna: 17-element tri-band Yagi, 5-• boom  
 Frequency: 144.0 MHz  
 Antenna Gain: =16.8 dBi  
 EPA Ground Reflection Factor: 2.56  
 Controlled Limit: 1.0 mW/cm<sup>2</sup>  
 Uncontrolled Limit: 0.2 mW/cm<sup>2</sup>

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
10	10.2 ft	22.9 ft
100	32.4 ft	72.4 ft
500	72.4 ft	162.0 ft
1500	125.5 ft	280.6 ft

## Estimated distances for RF power density

Antenna: UHF ? -• ground plane mobile whip  
 Frequency: 146.0 MHz  
 Antenna Gain: =4.0 dBi  
 EPA Ground Reflection Factor: 2.56  
 Controlled Limit: 1.49 mW/cm<sup>2</sup>  
 Uncontrolled Limit: 0.3 mW/cm<sup>2</sup>

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
10	1.9 ft	4.3 ft
50	4.3 ft	9.6 ft
150	7.5 ft	16.7 ft

## Estimated distances for RF power density

Antenna: 3-element tri-band Yagi @ 14, 21, 28 MHz  
 Frequency: 28.0 MHz  
 Antenna Gain: =8.0 dBi  
 EPA Ground Reflection Factor: 2.56  
 Controlled Limit: 1.15 mW/cm<sup>2</sup>  
 Uncontrolled Limit: 0.23 mW/cm<sup>2</sup>

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
100	11.0 ft	24.5 ft
500	24.5 ft	54.9 ft
1000	34.7 ft	77.6 ft
1500	42.5 ft	95.1 ft

## Estimated distances for RF power density

Antenna: VHF ¼-• ground plane mobile whip  
 Frequency: 146.0 MHz  
 Antenna Gain: =1.0 dBi  
 EPA Ground Reflection Factor: 2.56  
 Controlled Limit: 1.0 mW/cm<sup>2</sup>  
 Uncontrolled Limit: 0.2 mW/cm<sup>2</sup>

Transmitter power (watts)	Distance to controlled limit	Distance to uncontrolled limit
10	1.7 ft	3.7 ft
50	3.7 ft	8.3 ft
150	6.4 ft	14.4 ft

? Example 3