RF Exposure Evaluation

Rogue Valley Amateur Radio Club

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History

- FCC Adopted RF Exposure Criteria for various services.
  - Published OET 65 in November 1997.
- Amateurs had many blanket exceptions – not necessary to perform routine evaluation.
- FCC changed requires – all amateurs are required to evaluate their station operations for RF Exposure.
  - There are now relevant questions on the amateur license exam.
- The exposure regulations themselves have not changed.

FCC OET 65b – November 1997

This table was cancelled by rule two years ago.

Evaluation now required in all circumstances.

Table 1. Power Thresholds for Routine Evaluation of Amateur Radio Stations

Wavelength Band	Evaluation Required if Power* (watts) Exceeds:
MF	
160 m	500
HF	
80 m	500
75 m	500
40 m	500
30 m	425
20 m	225
17 m	125
15 m	100
12 m	75
10 m	50
VHF (all bands)	50
UHF	
70 cm	70
33 cm	150
23 cm	200
13 cm	250
SHF (all bands)	250
EHF (all bands)	250
Repeater stations (all bands)	non-building-mounted antennas: height above ground level to lowest point of antenna < 10 m and power > 500 W ERP building-mounted antennas: power > 500 W ERP

* Transmitter power = PEP input to antenna. For repeater stations ***only,*** power exclusion based on ERP (effective radiated power).

Effect Depends on Frequency

Non-ionizing: effect due to heating only

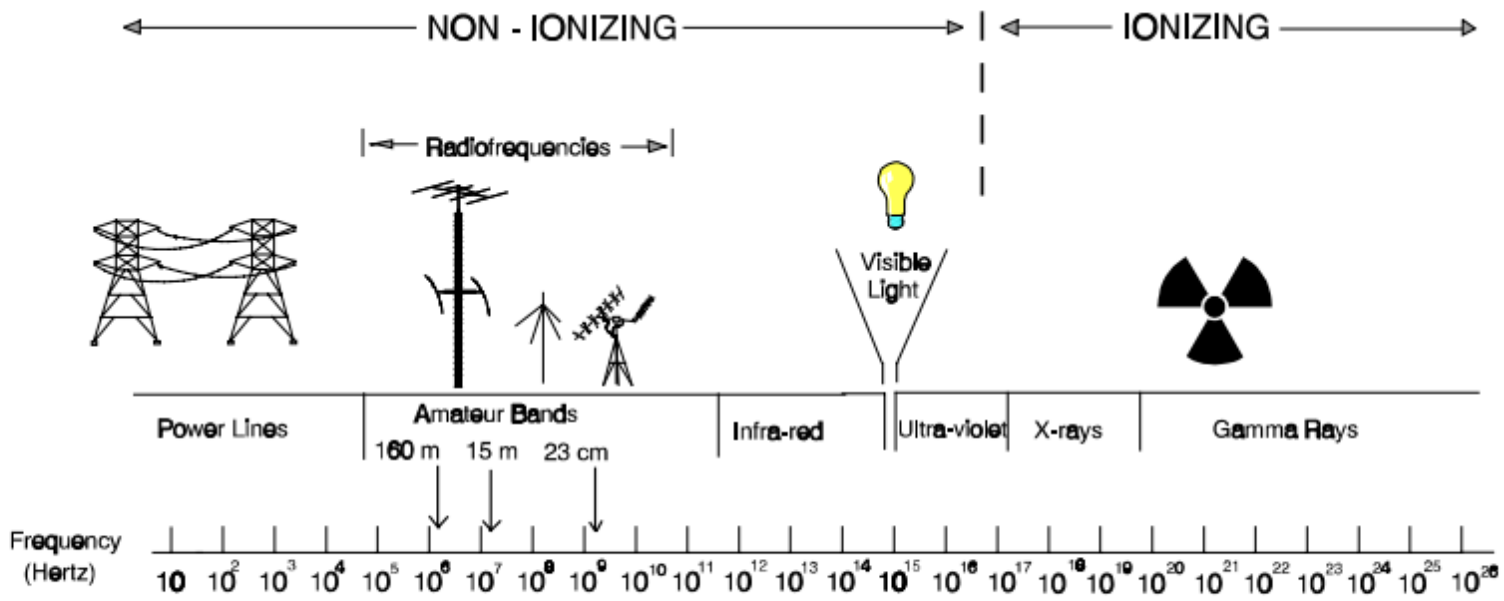

Figure 1. The Electromagnetic Spectrum

Field Strength vs Power Density

- Far field: E {volts / meter} / H {amps / meter} = 377
  - Sometimes called the “impedance” of free-space.
  - It’s not really an impedance, it’s the ratio of the electric field to the magnetic field. Units of ‘per-meter’ cancel out leaving volts/amps {ohms}.
- Power density = E * H = volts * amps / meter^2
- Power density, E, and H equivalents are derived from the value of 377 ohms.
- Absorption (heating) is frequency-dependent. FCC limits are most stringent from 30 – 300 MHz.

Maximum Permissible Exposure limits: mW / cm^2

(1 mW / cm^2 = 10W / $m^{2)}$

FCC OET 65b – November 1997

This is still the rule as of 2021.

Table 1. ***FCC Limits for Maximum Permissible Exposure (MPE)***

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	($900/f^2$)*	6
30-300	61.4	0.163	1.0	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	($180/f^2$)*	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

Based on time-averaged Power in the exposure region.

- Things that affect this:
  - Antenna gain, feedline loss, mode (duty-factor), duty-cycle, ground (reflection) gain.
- Controlled Exposure:
  - Example: Exposure to you or your family on your property.
  - Averaged over 6 minutes.
- Uncontrolled Exposure:
  - Example: Exposure to your neighbor.
  - Averaged over 30 minutes.

- *Note the averaging time for Uncontrolled exposure is much longer.*

Mode Duty Cycle

Table 2. Duty Factor of Modes Commonly Used by Amateurs

Mode	Duty Factor	Notes
Conversational SSB	20%	Note 1
Conversational SSB	50%	Note 2
Voice FM	100%	
FSK or RTTY	100%	
AFSK SSB	100%	
Conversational CW	40%	
Carrier	100%	Note 3

Note 1: Includes voice characteristics and syllabic duty factor. No speech processing.
Note 2: Includes voice characteristics and syllabic duty factor. Heavy speech processor employed.
Note 3: A full carrier is commonly used for tune-up purposes

Transmit Duty Cycle

- Ratio of on-time to (on + off) time:
- Example: transmit one minute, receive one minute: = 1 / (1+1) = 50%
- Example: Transmit 1 minute, receive 5 minutes: 1 / (1+5) = 18%

Putting it all together.

- Key variables:
  1. Power at the antenna
  2. Mode of operation (mode duty cycle)
  3. T/R Duty cycle (transmit duty cycle)
  4. Antenna gain
     a) FCC ‘clarified’ this is dBd (gain compared to a dipole). Don’t know if the ARRL webpage is updated to accommodate this.
  5. Frequency
  6. Ground reflection
  7. Controlled vs. Uncontrolled Exposure.
- A lot to keep track of.
- ARRL Has an on-line web-based tool to do the calculations for you. And it’s easy to use.
  - https://www.arrl.org/rf-exposure-calculator

The ARRL Webpage Form

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

Parameters

- Power at Antenna: (Need help with this?) _____ (watts)
- Mode duty cycle:
  Conversational SSB, no speech processing (mode duty cycle=20%)
- Transmit duty cycle: (time transmitting)
  You transmit for 5 minutes then receive for 10 minutes (and repeat).
- Antenna Gain (dBi): (Need help with this?) _____
- Operating Frequency (MHz): _____

☑ Include Effects of Ground Reflections

If you would like to receive future announcements of any FCC news related to RF-exposure or the requirements for amateurs to evaluate their stations, you may **optionally** provide an email address.

Email Address:	_____ (optional)
Comments:	_____ (optional)

Calculate

Example 75 meters (e.g.: Print Result)

RF Exposure Calculator

Parameters

- Power at Antenna: 100 (watts)
- Mode duty cycle:
  Conversational SSB, no speech processing (mode duty cycle=20%)
- Transmit duty cycle: (time transmitting)
  You transmit for 3 minutes then receive for 3 minutes (and repeat).
- Antenna Gain (dBi): 0
- Operating Frequency (MHz): 3.9

☑ Include Effects of Ground Reflections

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 59.1716
Minimum Safe Distance (feet): 0.1925
Minimum Safe Distance (meters): 0.0587

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 11.8343
Minimum Safe Distance (feet): 0.4305
Minimum Safe Distance (meters): 0.1312

Example: 2 meter FM

RF Exposure Calculator

Parameters

- Power at Antenna: 50 (watts)
- Mode duty cycle:
  FM (duty cycle=100%)
- Transmit duty cycle: (time transmitting)
  You transmit for 3 minutes then receive for 3 minutes (and repeat).
- Antenna Gain (dBi): 0
- Operating Frequency (MHz): 144

☑ Include Effects of Ground Reflections

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 1.0000
Minimum Safe Distance (feet): 2.3414
Minimum Safe Distance (meters): 0.7136

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 0.2000
Minimum Safe Distance (feet): 5.2355
Minimum Safe Distance (meters): 1.5958

Note exposure limit on 2M:
200 microwatts / cm^2

The calculator can be conservative.

- Using NEC4 to compute exposure limits usually results in:
  - More accurate results.
  - Closer distances allowed.
- However not justified unless the on-line calculations are worrisome.

- FCC normally does not require you to produce documentation.
  - You are required to do the evaluation (with certain caveats).
  - They can ask you to produce documentation if a question arises.

4NEC2 MPE Field Day Example

Conservative: 150w * 50% mode duty cycle (SSB heavily compressed) * 66% transmit duty cycle (lot of CQ'ing): 50W average power.

Green: OK. Yellow: exceed uncontrolled exposure Red: exceed controlled exposure