RF Exposure Guidelines for Amateur Radio Operators

Basic information every operator must know!

May 2023

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What we’ll cover:

- Definitions of RF Radiation, RF Exposure, and Harmful Effects
- Current FCC rules for amateurs
- Maximum Permissible Exposure (MPE)
- Controlled environments
- Uncontrolled environments
- Using the ARRL calculator
- New regulations

RF Exposure in General

What is Radio Frequency Radiation (RFR)?

Every radio device emits Radio Frequency Radiation and therefore can create an RF Exposure

- Electromagnetic radiation consists of waves of electric and magnetic energy moving together (i.e., radiating) through space at the speed of light.

Search for this:

FCC Radio Frequency Safety

What is RF Exposure?

Every radio transmitter creates some RF exposure

- The energy levels associated with RF and microwave radiation are not great enough to cause the ionization of atoms and molecules, and RF energy is, therefore, is a type of non-ionizing radiation.
- Other types of non-ionizing radiation include visible and infrared light.
- Biological effects that result from heating of tissue by RF energy are often referred to as thermal effects.
- Specific Absorption Rate (SAR) is now a big deal in the cell phone industry
- Basically, it is how much heat can your body absorb. Limit is now 1.6 watts/kilogram

What are the harmful effects of RFR?

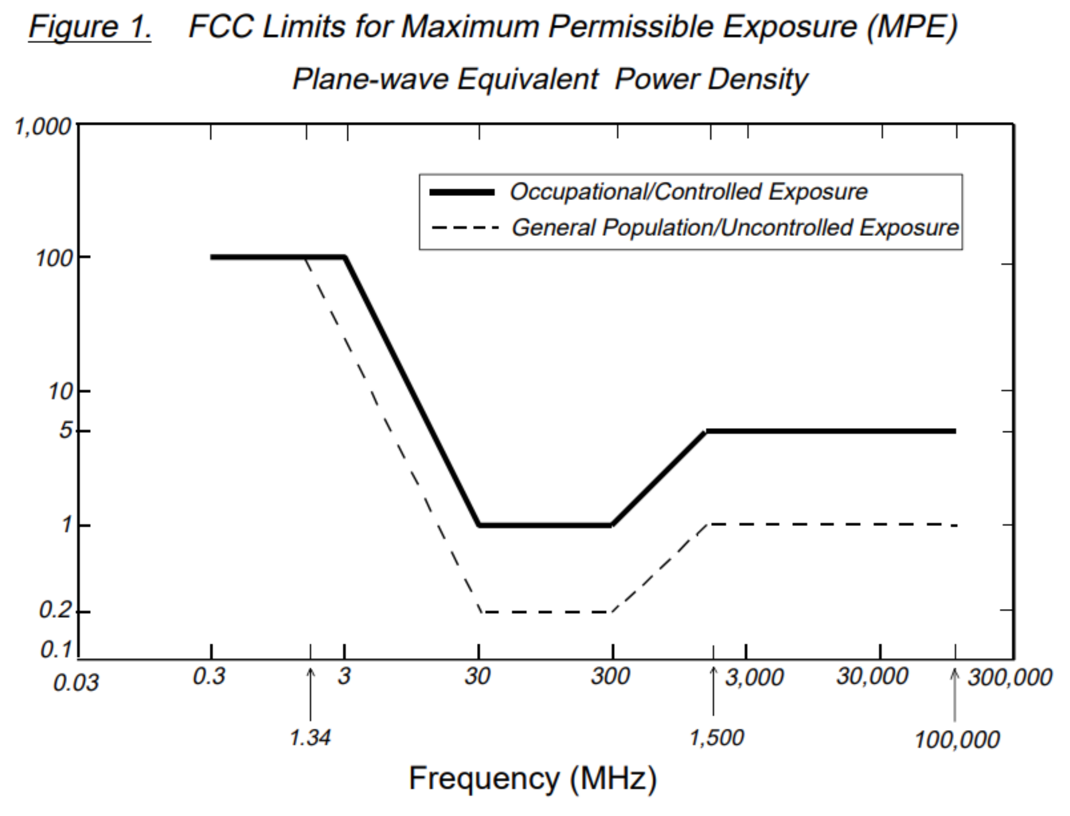
Heating of tissue is the most harmful effect

- Exposure to very high RF intensities can result in heating of biological tissue and an increase in body temperature.
- Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated.
- Question—What frequency do microwave ovens “transmit” at?

Maximum Permissible Exposure (MPE)

Exposure guidelines have been around for years.

- Guidelines are different for different transmitting frequencies.
- The most restrictive limits on whole-body exposure are in the frequency range of 30-300 MHz where the human body absorbs RF energy most efficiently when the whole body is exposed.



Current FCC Rules for Amateur Radio

Hams must meet exposure limits:

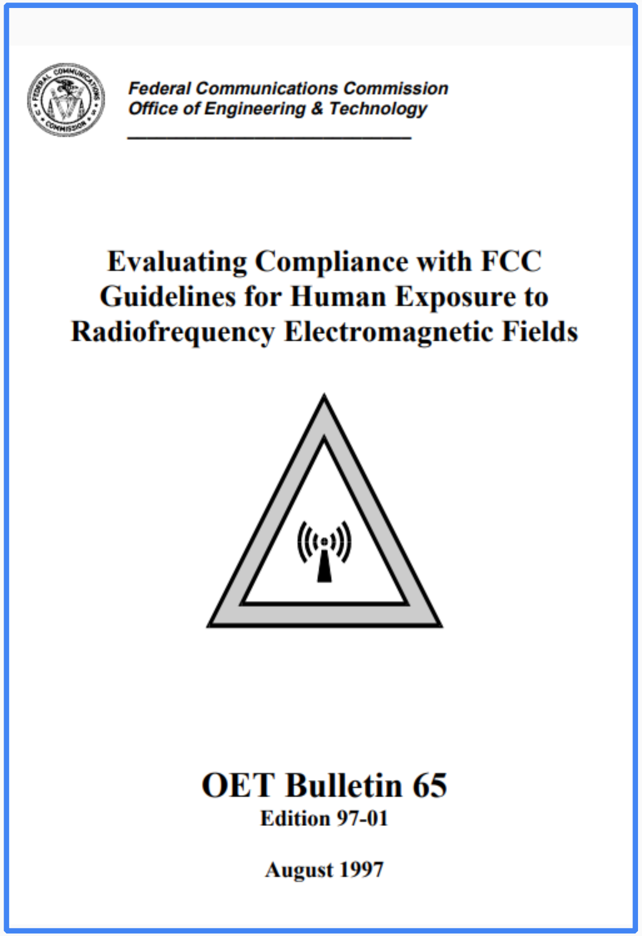
- Like all FCC licensees, amateur radio operators are required to comply with the FCC's guidelines for safe human exposure to RF fields.
- Studies by the FCC and others have shown that most amateur radio transmitters would not normally expose persons to RF levels in excess of safety limits.
- As long as appropriate distances are maintained from amateur antennas, exposure of nearby persons should be well below safety limits.
- ***However, these rules are changing! There will be no more blanket exemption!***

How to calculate RF Exposure

What is OET-65?

From the FCC Website:

- **Evaluating Compliance With FCC Guidelines for Human Exposure to Radio frequency Electromagnetic Fields**
- This revised OET Bulletin 65 has been prepared to provide assistance in determining whether proposed or existing transmitting facilities, operations or devices comply with limits for human exposure to radio frequency (RF) fields adopted by the Federal Communications Commission (FCC) The bulletin offers guidelines and suggestions for evaluating compliance.
- However, it is not intended to establish mandatory procedures, and other methods and procedures may be acceptable if based on sound engineering practice.


Federal Communications Commission
Office of Engineering & Technology

Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields

OET Bulletin 65
Edition 97-01

August 1997

What is a Controlled Environment?

From OET 65:

- In general, a controlled environment is one for which access is controlled or restricted. In the case of an amateur station, the licensee or grantee is the person responsible for controlling access and providing the necessary information and training.

Controlled Environments

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (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

f = frequency in MHz

† = plane-wave equivalent power density (see note)

Note: Equivalent far field strength that would have the E-field or H-field components calculated or measured.
Equivalent far field density for near and far fields can be calculated using

Power Density = $|E_{total}|^2/3770$ mW/cm^2 or Power Density = $|H_{total}|^2/37.7$ mW/cm^2

What is an Uncontrolled Environment?

From OET-65:

- General population/uncontrolled exposure limits apply to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure.
- Therefore, members of the general public always fall under this category when exposure is not employment-related, as in the case of residents in an area near a broadcast tower.
- Neighbors of amateurs and other non-household members would normally be subject to the general population/uncontrolled exposure limits.

Uncontrolled environments

Frequency Range (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Power Density (mW/cm^2)	Averaging Time (minutes)
0.3-3.0	614	1.63	100 †	30
3.0-30	842/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 (see note)

Note: Equivalent far field strength that would have the E-field or H-field components calculated or measured. Equivalent far field density for near and far fields can be calculated using

$$\text{Power Density} = |E_{total}|^2/3770 \text{ mW/cm}^2 \quad \text{or} \quad \text{Power Density} = |H_{total}|^2/37.7 \text{ mW/cm}^2$$

What are the variables for RF Exposure?

Frequency

- Exposure level varies with frequency

For example, it is strictest in the VHF area

Power Level

- Exposure level increases with RF output power

Duration of Exposure

- Exposure level increases with more transmitter time

Building materials?

Antenna patterns?

Let’s do some calculations!

Start here:

From Comet GP-3 Sheet

Collect this information:

- The data sheet for your antenna
- The length and type of your coax
- The maximum power output of your radio

<u>Specifications:</u>

Frequency & Gain	:	146MHz/4.5dBi 445MHz/7.2dBi (7.5dBi)
Impedance	:	50 Ohm
V.S.W.R.	:	Less than 1.5
Max Power	:	200 Watt
Weight	:	1.15 Kg
Connector	:	M (N) - type
Length	:	1.78 m

dBi vs dBd

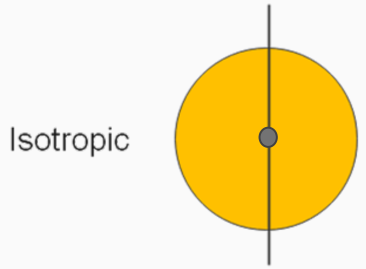
dBi = gain of an antenna above a theoretical isotropic radiator

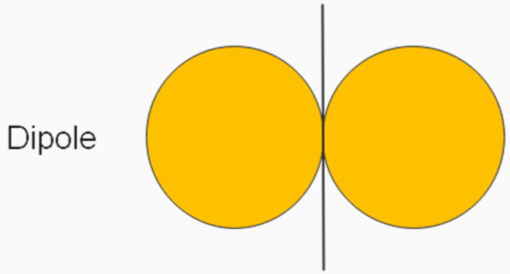
dBd = gain of an antenna above standard half-wave dipole

Antenna calculators typically want antenna gain in dBi

To convert dBd to dBi, add 2.15 dB to the dBd value

- Example–An antenna gain is specified as 3 dBd
- The ARRL RFR calculator wants the value in dBi
- 3 dBd + 2.15 = 5.15 dBi





Calculating Cable Loss

- First, look up the type of cable and calculate the loss in dB from manufacturers data
- There are several good places to get this information on line
  - Search for: Transmission Line Loss Calculator
- Then convert your line loss in dB to power loss
- Use formula on the right or get this data on line
  - Search for: Decibel Calculator

Don't panic!--I will show you a simple way to do this later!

dB to power formula:

N (dB) = 10 $\log_{10}$ ($Power_{out}$/$Power_{in}$)

power to dB formula:

$Power_{in}$ x $10^{(N/10)}$ = $Power_{out}$

Example: A system with 50 watts in, and 3 dB of loss, what's the power out?

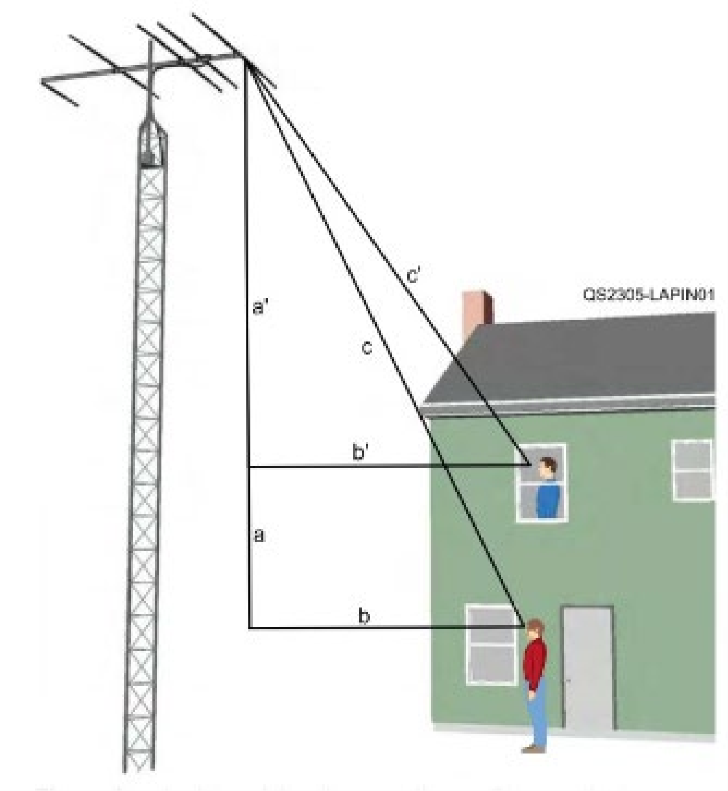
50 (watts in) x $10^{(-3\ dB/10)}$ = 25 (watts out)

(Note the negative number here)

Think about distances from many angles!

All potential directions need to be looked at!

Where could someone be in danger?



Courtesy ARRL QST May 2023 by N9GL

Using the ARRL Calculator

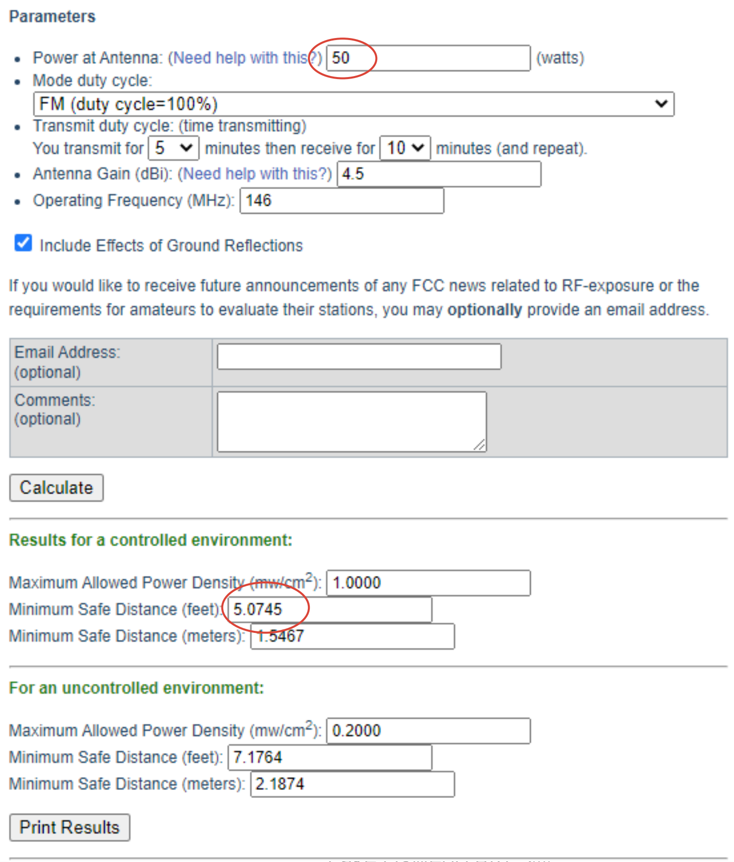
Fortunately, the ARRL has a very easy to use calculator:

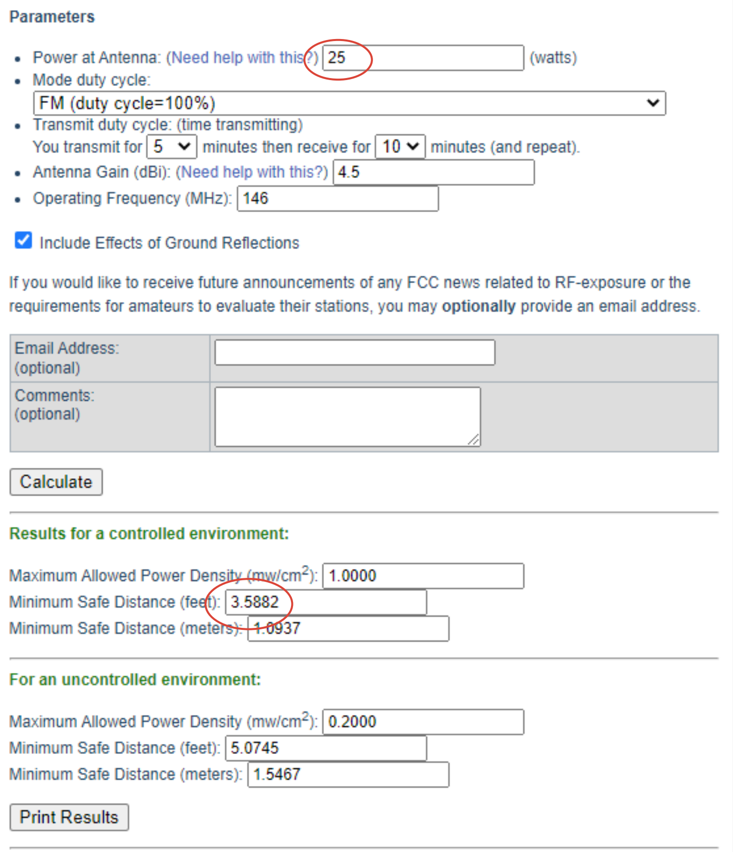
- Power at Antenna: (Need help with this?) [ ] (watts)
- Mode duty cycle:
  [Conversational SSB, no speech processing (mode duty cycle=20%) ▾]
- Transmit duty cycle: (time transmitting)
  You transmit for [5 ▾] minutes then receive for [10 ▾] minutes (and repeat).
- Antenna Gain (dBi): (Need help with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

☑ Include Effects of Ground Reflections

Do a simple calculation first!

- Using the ARRL RF Exposure Calculator, just enter the maximum output of your radio and the antenna gain in dBi
- This give us a worst case calculation
- Notice the distance is likely safe in both cases (5 feet vs. 3.5 feet)
- Right shows no cable coax cable loss (0 watts lost)
- Left shows 3 dB of cable loss (25 watts lost)



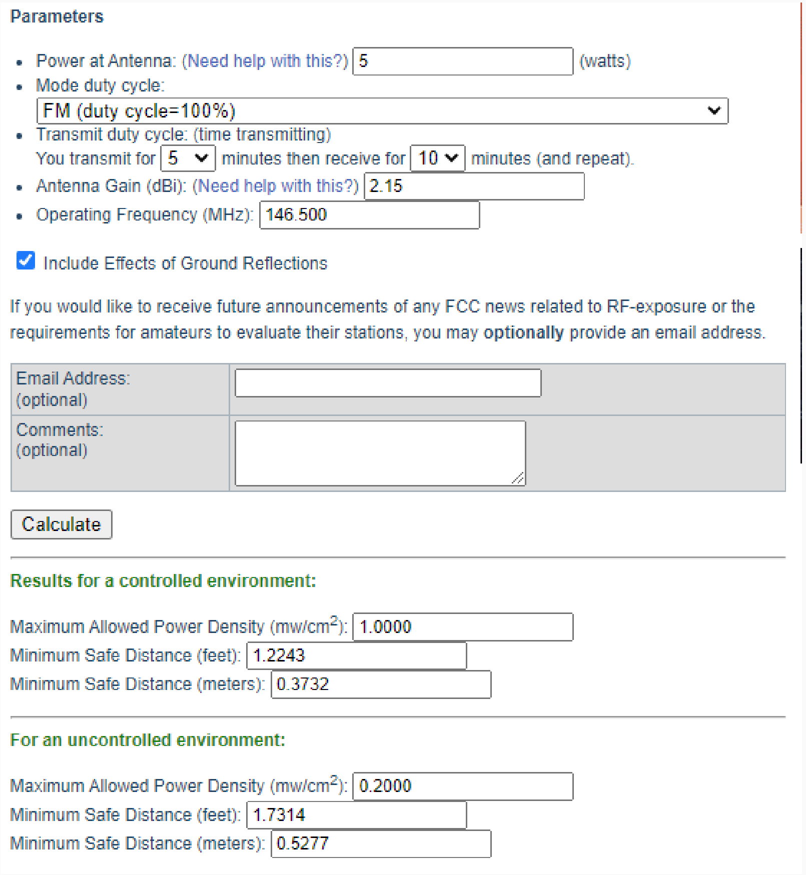


Example 1—Portable Radio RFR

Typical 5-watt handheld with unity gain antenna (0 dBd)

- 2.15 dB (correction factor for dBd* to dBi**)
    - Coax loss = 0 dB (there is not coax on a portable

- *dBd—Decibel reference to standard dipole
- **dBi—Decibel reference to theoretical isotropic radiator



Parameters

- Power at Antenna: (Need help with this?) 5 (watts)
- Mode duty cycle:
  FM (duty cycle=100%)
- Transmit duty cycle: (time transmitting)
  You transmit for 5 minutes then receive for 10 minutes (and repeat).
- Antenna Gain (dBi): (Need help with this?) 2.15
- Operating Frequency (MHz): 146.500

☑ 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

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 1.0000
Minimum Safe Distance (feet): 1.2243
Minimum Safe Distance (meters): 0.3732

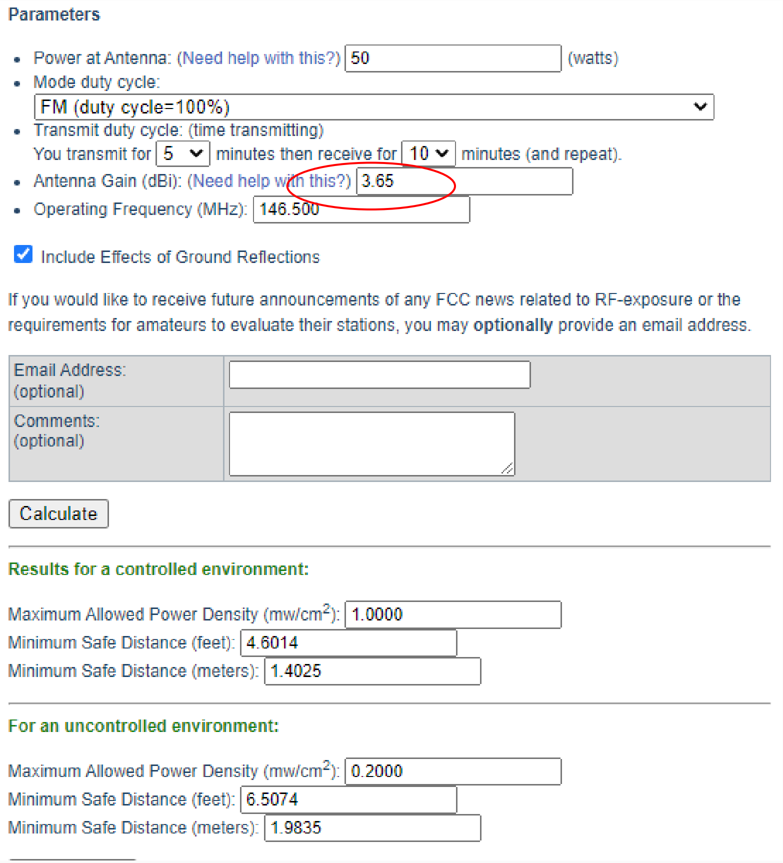
For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 0.2000
Minimum Safe Distance (feet): 1.7314
Minimum Safe Distance (meters): 0.5277

Example 2—Roof Top 2 Meter RFR

3 dBd gain antenna on roof of my house with 100 feet of LMR-400

- Converting coax loss from dB to power loss requires math
    - Here is a quick hack–Keep coax loss in dB. Subtract the coax loss from your antenna gain and enter that value as a reduced antenna gain value
    - This gives identical results to doing the dB loss to power loss conversion
- 2.15 dB (correction factor for dBd to dBi)
- Plus 3.0 dB gain for my antenna
- Minus 1.5 dB loss in my LMR-400 cable
- Antenna gain equals 3.65 dBi



Example 3—Mag Mount Mobile RFR

3 dBd gain antenna on the roof of my car:

- 2.15 dB (correction factor for dBd to dBi)
- Plus 3.0 dB gain for my antenna
- Minus 1.2 dB loss in my RG-58a cable
- Antenna gain equals 3.95 dBi

Parameters

- Power at Antenna: (Need help with this?) 50 (watts)
- Mode duty cycle: FM (duty cycle=100%)
- Transmit duty cycle: (time transmitting)
  You transmit for 5 minutes then receive for 10 minutes (and repeat).
- Antenna Gain (dBi): (Need help with this?) 3.95
- Operating Frequency (MHz): 146.500

☑ Include Effects of Ground Reflections

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Email Address: (optional)	
Comments: (optional)	

Calculate

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 1.0000
Minimum Safe Distance (feet): 4.7632
Minimum Safe Distance (meters): 1.4518

For an uncontrolled environment:

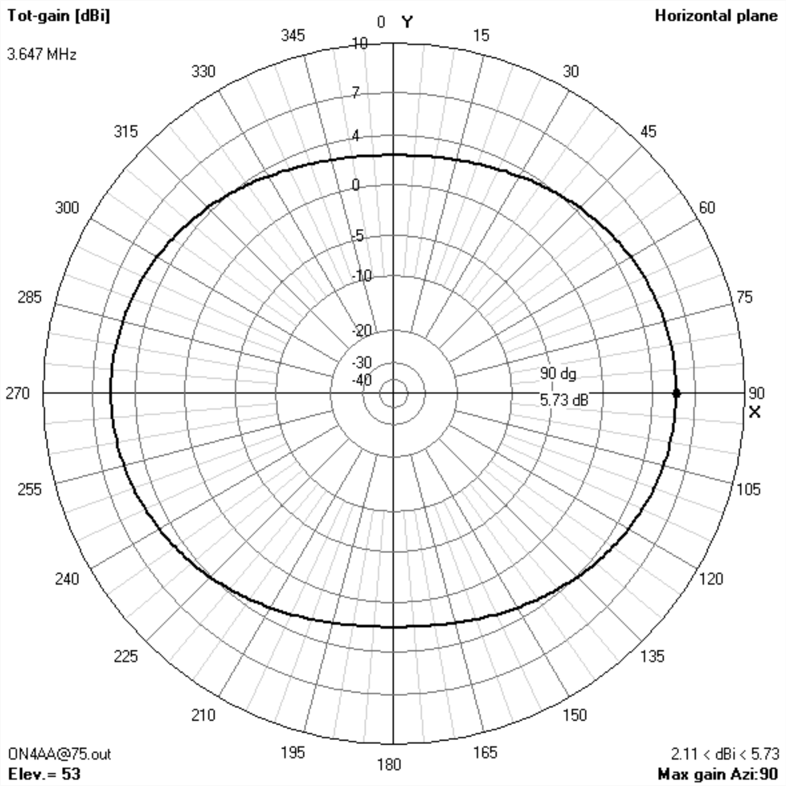
Maximum Allowed Power Density (mw/cm^2): 0.2000
Minimum Safe Distance (feet): 6.7361
Minimum Safe Distance (meters): 2.0532

Example 4—What about HF?

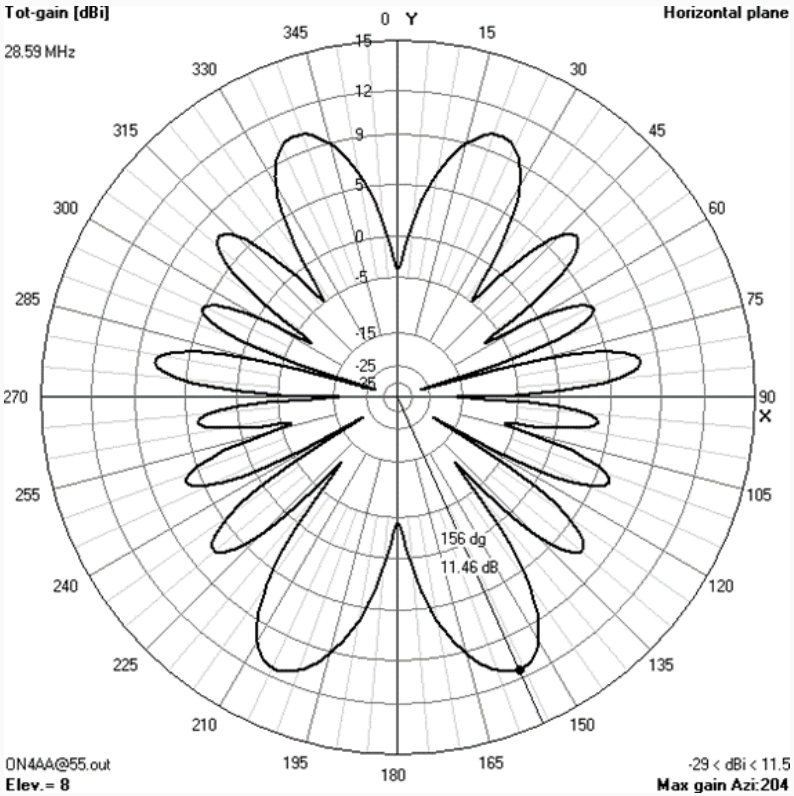
This is where things get tricky!

- HF antennas do not typically have uniform designs
- Dipoles, verticals, Off Center Fed Dipole (OCFD), beams, etc.
- Pattern and gain change dramatically with frequency, elevation above ground, etc.
- You must know the maximum gain on a given frequency to properly analyze
- Example—Same antenna, two very different patterns

Example 4—What about HF? (OCFD)



80 Meters

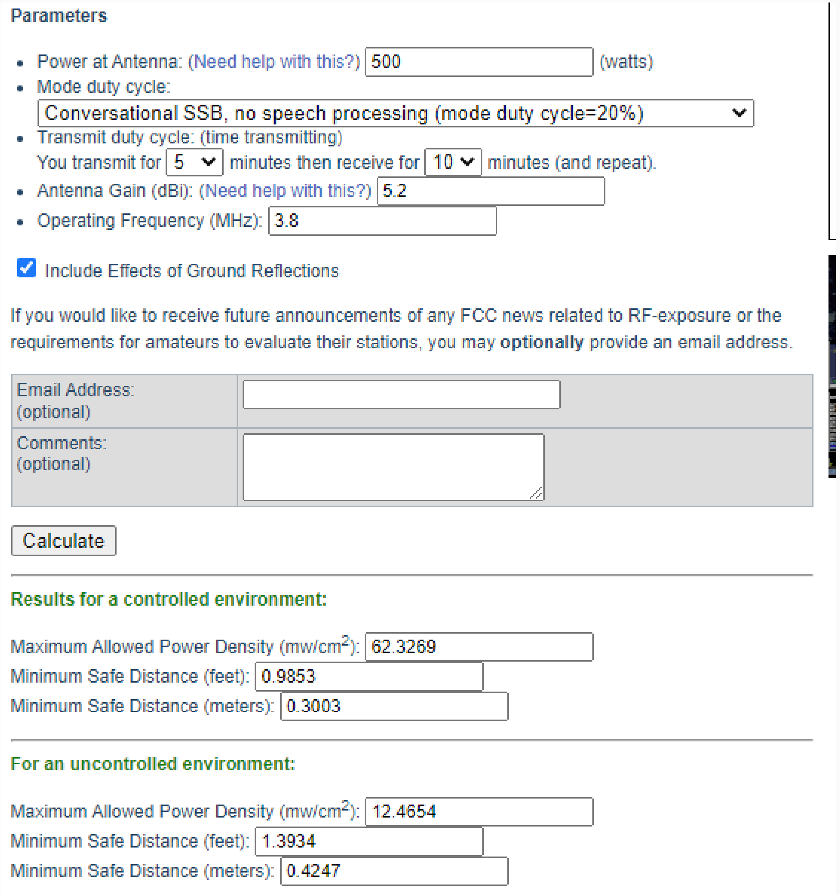


10 Meters

Example 4—80 Meter OCFD RFR

From the 80 meter pattern--

- 5.73 dBi max gain
- 0 dB (correction factor for dBd to dBi)
- Minus 0.5 dB loss in my RG-8X cable
- Antenna gain equals 5.23 dBi



Parameters

- Power at Antenna: (Need help with this?) 500 (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?) 5.2
- Operating Frequency (MHz): 3.8

☑ 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

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 62.3269
Minimum Safe Distance (feet): 0.9853
Minimum Safe Distance (meters): 0.3003

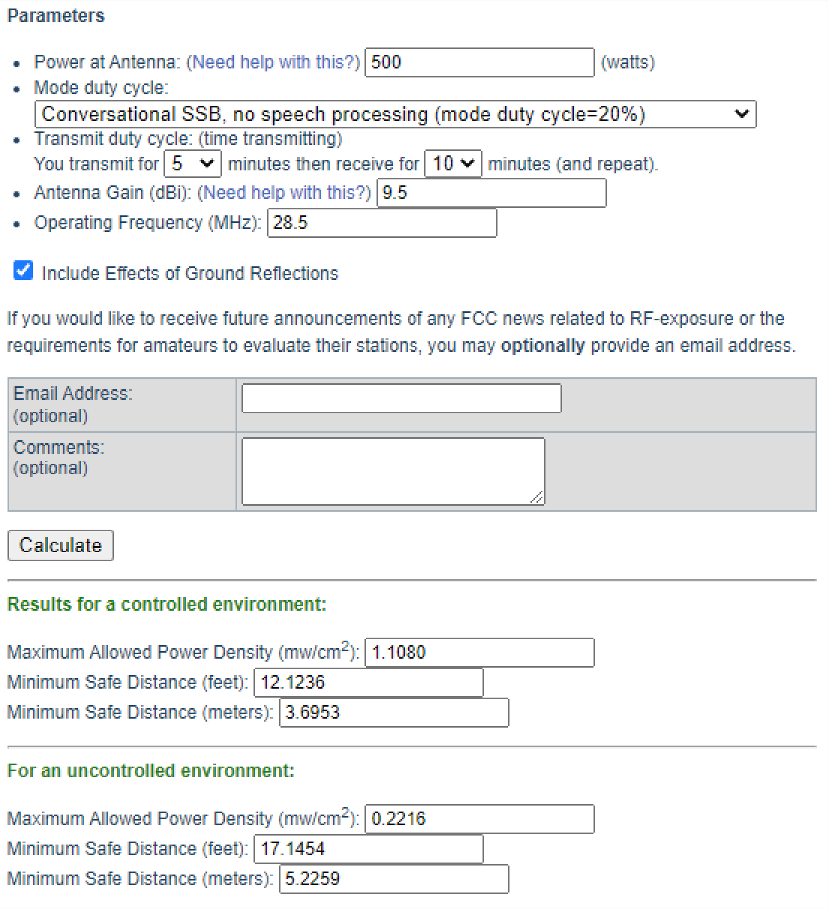
For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 12.4654
Minimum Safe Distance (feet): 1.3934
Minimum Safe Distance (meters): 0.4247

Example 4—10 M OCFD RFR

From the 10 meter pattern

- 11.5 dBi max gain
- 0 dB (correction factor for dBd to dBi)
- Minus 2.0 dB loss in my RG-8X cable
- Antenna gain equals 9.5 dBi


Parameters

- Power at Antenna: (Need help with this?) 500 (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?) 9.5
- Operating Frequency (MHz): 28.5

☑ 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

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 1.1080
Minimum Safe Distance (feet): 12.1236
Minimum Safe Distance (meters): 3.6953

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 0.2216
Minimum Safe Distance (feet): 17.1454
Minimum Safe Distance (meters): 5.2259

Example 5—KA6UGS Calculator

Calculates with built in coax selector and dBi or dBd!

- 80 Meter OCFD
- 5.73 dBi max gain
- 0 dB (correction factor for dBd to dBi)
- Automatic calc of line loss
- I must do an RF analysis or raise my antenna!

Amateur Radio RF Environment Evaluation Exemption Calculator

Optional Information	KD7DNM	80 M OCFD
Enter Frequency in MHz		**3.800**
Calculated Minimum Distance Required (Feet)		**41.2**
Enter Distance to Antenna (Feet) Note: Minimun Distance 7.87"		**18**
Calculated - Does Exemption Apply?		**Exemption Does Not Apply**
Select Coax Type		**Belden 9258 RG-8X**
Enter Length of Coax in feet		**100**
Enter Transmitter Power in Watts		**500**
Select dBi or dBd and Enter Antenna Gain	**dBi**	**5.7**
Calculated - Effective Radiated Power (ERP) (Watts)		**999**
Calculated - Maximum Allowed ERP (Watts)		**7,195**

The Amateur Radio RF Environment Exemption Calculator determines if the FCC Exemption to Routine Evaluation applies. It also calculates the maximum allowed Effective Radiated Power (ERP). Enter the frequency and distance to the antenna. If the calculator indicates that the exemption applies, select the type of coaxial cable, enter the cable length, transmitter power and antenna gain. The calculator displays the station's ERP and the maxium allowed power. Adjust transmitter power may be adjusted to keep the station's ERP below the maximum allowed.

Note: Stations, not qualifying for an exemption, may still meet the FCC Maximum Permissible Exposure (MPE) limits by perfoming a RF environmental analysis. A suggested resource, with more information is: www.arrl.org/rf-exposure.

Calculation formulas: The exemption applies if, R, the distance between the antenna and human exposure (meters) is greater than the wavelength/2π. The maximum allowed ERP is determined by the adjacent formulas, where "f" is frequency (MHz).

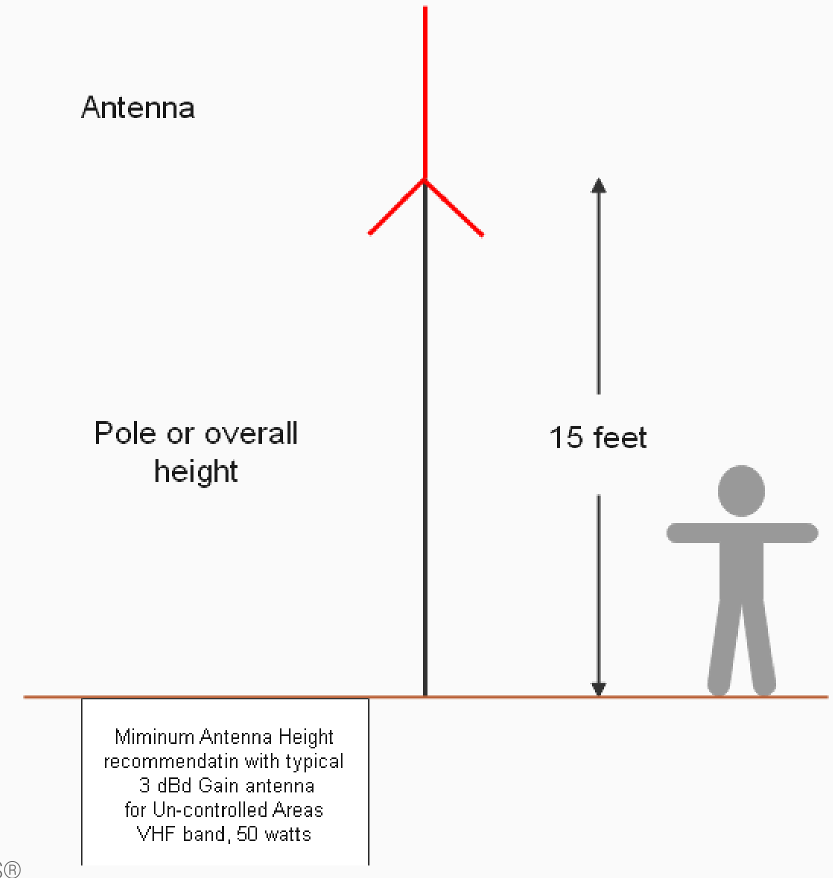
Frequency (MHz)	Maximum ERP (Watts)
0.3 - 1.34	1,920 * R^2
1.34 - 30	3,450 * R^2 / f^2
30 - 300	3.83 / R^2
300 - 1,500	0.0128 * R^2 *f
1,500 - 100,000	19.2 * R^2

This calculator is being made available in support of Amateur Radio activities.
The author assumes no liability or responsibilities for errors or omissions.
Rev 3.7 Authored by KA6UGS. For questions email: ka6ugs@arrl.net

LO ARES Minimum Antenna Distances

Our guidelines

- 15 feet minimum height from the base of an antenna which operates on any VHF radio when connected to a 50-watt radio
- No indoor use of antennas connected to a 50-watt radio in an uncontrolled environment



What about building materials?

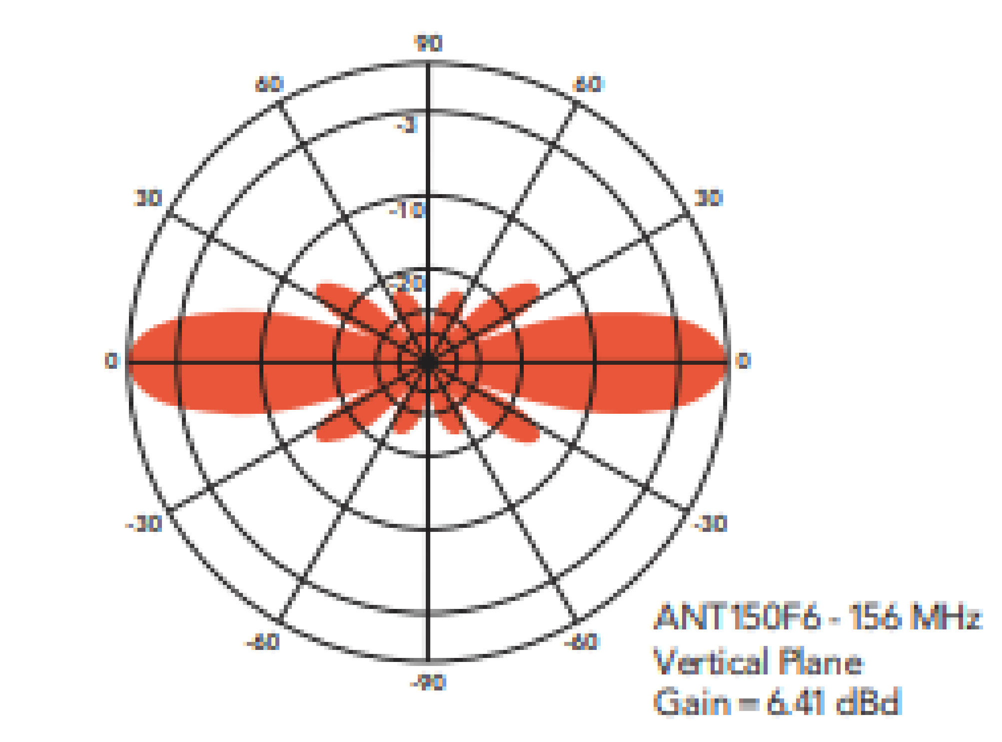
Approximate attenuation of various materials in dB at 500 MHz

- Typical brick/concrete wall 3-10 dB
- Composite roofing 2-6 dB
- Foil backed insulation 10-15 dB
- Wood wall 3-5 dB
- Metal coated windows 15-40 dB

Source–Various articles on line. Nothing exact at amateur radio frequencies

What about the antenna pattern?

- Yes, you can use the antenna pattern to calculate RFR, but that adds a lot of complexity
- Always run the antenna as if it is running max power in all directions first. If it meets your requirements, you are done.
- If it does not meet your requirements, then you could use the antenna manufacturers data to determine RFR in various directions
- Note gain is around 13 dB less than full at downward angles over 15 degrees on this antenna



Changes have come for Amateur Radio Operators!

New Regulations are here

- No RF station is exempt from compliance with the FCC rules and the new established MPE limits
- RF exposure limits are not changing, but exemptions are no longer automatic
- Amateur radio operators had until **May 3, 2023** to comply with new requirements which means you must run your systems through a calculator
- Systems that are non-exempted require an “RF environmental assessment”
- Overexposure to RF must be avoided in controlled and uncontrolled situations
- Fortunately, nice calculators exist to help you

Amateur radio operators have until May 3rd, 2023, to meet the changed requirements, that is complete an environmental assessment of your station.

Amateur radio operators have until May 3rd, 2023, to meet the changed requirements, that is complete an environmental assessment of your station.

In Summary:

- Be aware that your radios do have the potential to hurt you, your family, and the public
- Amateur radio operators need to be aware of RFR hazards to protect themselves and the public
- The rules are changing, and you need to evaluate each of your transmission systems
- There will be no more blanket exceptions
- Calculators are available to make this task easier
- Perform an analysis on each of your antenna/radio combinations
- Ask for help if you need it

Resources

- FCC website regarding RFR:
- https://www.fcc.gov/engineering-technology/electromagnetic-compatibility-division/radio-frequency-safety/faq/rf-safety#Q1
- OET-65
- https://www.fcc.gov/general/oet-bulletins-line#:~:text=This%20revised%20OET%20Bulletin%2065,The%20bulletin%20offers%20guidelines%20and
- ARRL RFR Calculator
- http://arrl.org/rf-exposure-calculator
- KA6UGS Exemption and Exposure Calculator
- https://ka6ugs.com/

About Lake Oswego ARES and Contact Information

About LO ARES

The mission of Lake Oswego ARES is to provide expertise to establish emergency and/or auxiliary communication systems, equipment or service for the Lake Oswego Fire Department and City of Lake Oswego during local or regional communication system outages or overloads. This may include the operation of amateur radios and relevant computer systems at strategic city assets or in the field.

Lake Oswego ARES is a sub-unit of Clackamas County ARES.

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