

Amateur Radio RF Exposure

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ARRL
the national association for
amateur radio®



- I) FCC RF Exposure Rules and Guidelines
- II) Exposure Analysis
- III) Examples

**What Will You
Learn Today?**



What Just Happened?

A new Report and Order just came into effect.

A few RF Exposure Rules changed May 3 2021

Just an analysis change

Most ham stations are compliant already



Cliffs Notes Summary

- If you evaluated before May 3, you can wait two years to re-evaluate.
- If your station power was increased or antennas changed, just re evaluate.
- Use easy online calculators to evaluate
- You may now leave this meeting! 😊



Good Folks RF-Exposed!

- Ed Hare W1RFI
 - Wrote the book RFI Exposure and You in 1998
 - ARRL Lab supervisor
 - IEEE EMC Society VP for Standards
- Greg Lapin N9GL
 - Chair ARRL RF Safety committee
 - IEEE Committee on Man and Radiation
 - FCC tech advisory council
 - Consultant on RF exposure issues



Who Am I?

- Dan Brown W1DAN
 - A guy with ham antennas in Natick, MA
 - Eastern Massachusetts ARRL Technical Coordinator
 - <https://ema.arrl.org/>
 - Wellesley Amateur Radio Society President
 - <https://ema.arrl.org/wellesley-amateur-radio-society/>
 - Learning as we go!

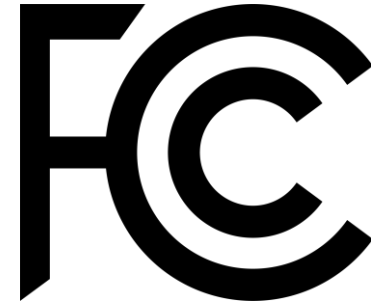


RF Exposure Is....

- Tissue heating due to the exposure of high levels of radio frequency electromagnetic energy.
 - Warms up areas of the body
 - Body may not be able to dissipate the heat
 - May damage tissue if a very high field
 - Guidelines were created in 1985 by
 - National Council on Radiation Protection and Measurements
 - IEEE
- 1998 first FCC exposure rules came into effect
- 2019 new rules created, but delayed until May 3, 2021



I) FCC Rules and Guidelines



- FCC Report and Order 19-126 (new)
 - Rules for RF exposure (not just Amateur)
 - Issued December 2019
 - Approved April 2021
 - Active May 3 2021
 - Past exposure standards maintained
- FCC 47CFR parts 1,2, 97 (not new)
 - Our Amateur Radio service regulations
- OET Bulletin 65 (not new)
 - How to determine RF exposure compliance
 - 'Not just for hams
 - OET-65B "tuned for hams"



Goals....

- Limit human RF exposure:
 - Stay below a safe threshold
 - Radio Amateurs-Occupational/controlled-higher threshold, shorter time
 - General Population/uncontrolled-lower threshold
 - OLD NEWS!
- We must evaluate RF exposure
- I think should have documentation available showing compliance.
- If out of compliance, correct



New FCC Report and Order 19-126

- Current exposure standards maintained.
- FCC R&O 19-126 harmonizes exposure rules across all services.
 - Biggest change is the categorical exclusion and table are gone.
- Hams now use a formula-based evaluation-like other radio services do.
- Limits for Maximum Permissible Exposure (MPE) have not changed.
- Exemption available.
- If a radio antenna is within 20cm of body, need RF field measured or modeled (i.e. 2M HT)
- Mobile and portable transmitters included (mobile, HTs, POTA, SOTA)
- Must be able to prove your station is safe-repeaters too.
- Can determine compliance any reasonable way.



Who Must Comply?

- New or changed stations must be in compliance now.
- Existing stations who had complied under old rules have until May 3 2023 to evaluate.
 - Valid until you change your station.
 - If you relied on the categorical exclusion table to avoid performing evaluations, the FCC is giving you 2-years to do an eval.
- ARRL is assisting the FCC and is making tools for us.
- ARRL FAQ sheet available.



OET-65B Table-1 GONE-now calculate!

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)	<u>non-building-mounted antennas:</u> height above ground level to lowest point of antenna < 10 m <u>and</u> power > 500 W ERP <u>building-mounted antennas:</u> power > 500 W ERP

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

Exemptions

- New R&O 19-126 Table 2: exemptions based on frequency, power and distance from the antenna to the nearest person.
 - If below a *Threshold ERP*, you are good!
 - If under 1mW, no need to eval.
- If you don't qualify for an exemption, you must perform a full exposure analysis.



FCC 19-126A1 Table 2-MPE-based far-field exemptions

Table 2. Single RF Sources Subject to Routine Environmental Evaluation under MPE-Based Exemptions, $R \geq \lambda/2\pi$

Transmitter Frequency	Threshold ERP
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	$19.2 R^2$
<i>Note:</i> Transmitter Frequency is in MHz, Threshold ERP is in watts, R is in meters, f is in MHz.	



Maximum Permissible Exposure (MPE)

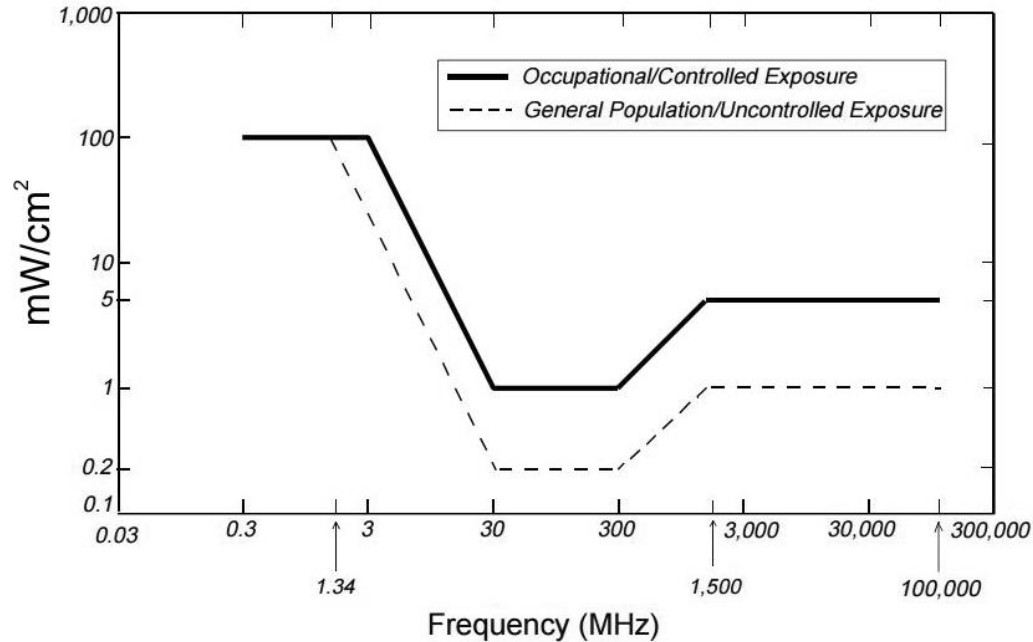
- MPE cannot be exceeded (not new!)
 - RF in body causes heat
 - Varies with frequency
 - Measured in mW/cm^2
 - Averaged over time
 - 30-minutes for uncontrolled environments (general population)
 - 6 minutes for controlled environments (hams)
 - No reset period
- Based on Specific Absorption Rate (SAR).
 - See OET-65C if interested



OET-65 MPE Chart (old news)

Figure 1. FCC Limits for Maximum Permissible Exposure (MPE)

Plane-wave Equivalent Power Density



II) Exposure Analysis

- For stations that have not been grandfathered, you now must perform your own exposure analyses.
- Grandfathered stations may do within 2 years.
- Do not have to submit the results to the FCC.
- If you change your station, redo.
- Use any valid method.
- Documentation is not mandated.
- If an event occurs (i.e. a complaint), you must show your exposure compliance to the FCC.



You're Hot!

- Human tissue is most sensitive to VHF
 - VHF (2M HT) is worse case
 - Older HT's grandfathered
 - Newer HTs need modeling
 - Higher prices?
- SAR is used above 300MHz
 - Impractical for hams



MPE Limits for Occupational/Controlled

Table 1. 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

MPE Limits for General-Population/ Uncontrolled

(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

Want to measure your RF field?

- Accurate unit, but environment affects results
- NARDA Radman 2XT
 - \$900
 - Others available
 - Not required
 - Most folks will calculate



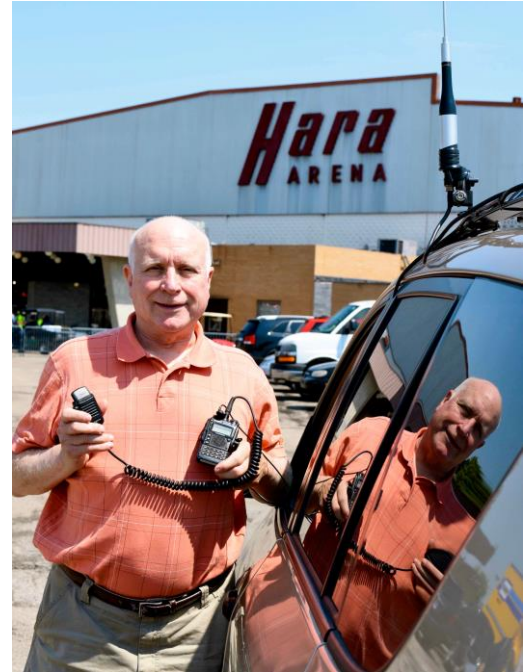
Modeling

- EZNEC (<https://www.eznec.com>)
 - Antenna modeling, good for hams (beams)
 - Might be needed for more accurate results
 - Ground-reflections
- SAR
 - UHF and higher
 - Expensive, HTs and cell phones
- FDTD
- FEM



Feedline

- If feedline is matched to antenna, it does not radiate
 - Coax or ladderline
- Just need to determine loss.



OET-65 Equations

- Allow you to predict your safe field strength for you and others.
- Result is *power density* at a certain distance from your antenna.
 - Measured in Watts per meter-squared
- Reasonable determination of RF safety
 - Hopefully below safe MPE
- Don't bother, just use online calculators!



OET-65 Equations

$$S = \frac{PG}{4\pi R^2} \quad 3)$$

where: S = power density (in appropriate units, e.g. mW/cm²)
P = power input to the antenna (in appropriate units, e.g., mW)
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

or:

$$S = \frac{EIRP}{4\pi R^2} \quad (4)$$

where: EIRP = equivalent (or effective) isotropically radiated power



Average Power

- Based on mode(duty cycle) and time (transmit percentage)
- Averaging time can halve the exposure. Use 30-minute (general population) standard
- Time
 - 6 minutes for controlled
 - 30 minutes for uncontrolled
- Duty Factor
 - FT8 is 50% (half-time tx)
 - See table at right.

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



Fun RF Exposure Calculators!

- Paul VP9KF:
 - http://hintlink.com/power_density.htm
 - Shows compliance at a given distance
- Lake Washington Ham Club and Wayne N6NB:
 - <http://www.lakewashingtonhamclub.org/resources/rf-exposure-calculator/>
 - Shows distance to compliance
- Ham Radio School Excel Sheet (save XLS file):
 - <https://hamradioschool.com/rf-exposure-calculator/>
 - Shows MPE and compliance for a given distance
- These calculators are easier to use than solving the OET65 calculations by hand.
 - Note ERP and Average power
 - Note Meters or Feet



III) Example Calculations

- 10M SSB
- 20M Contest
- 2M Mobile



Example-1: 10M-SSB

100w SSB radio

PEP

- Will convert to Average

Dipole antenna

Unity Gain

- 2.2dBi

10M (28.5MHz)

100-feet RG58

- 2dB loss

Using Hintlink online calculator

http://hintlink.com/power_density.htm



Example 1 Values

Calculate Radio Frequency Exposure

The ERP at the antenna:

In watts

The antenna gain in dBi:

Enter 2.2 for dipoles; add 2.2 for antennas rated in dBd

The distance to the area of interest:

From the centre of the antenna, in metres

The frequency of operation:

In MHz

Ground Reflection Effects

In most cases, the ground reflection factor is needed to provide a truly worst-case estimate of the compliance distance in the main beam of the antenna. Including the ground reflection effects may yield more accurate results especially with very low antennas, non-directional antennas, and calculations below the main lobe of directional antennas.

Do you wish to include effects of ground reflections? ☒ Yes ☐ No



You May Operate 10M SSB!

Calculation Results

Average Power at the Antenna	62.55 watts
Antenna Gain in dBi	2.2 dBi
Distance to the Area of Interest	9 metres 29.53 feet
Frequency of Operation	28.5 MHz
Are Ground Reflections Calculated?	Yes
Estimated RF Power Density	0.0262 mW/cm ²

	Controlled Environment	Uncontrolled Environment
Maximum Permissible Exposure (MPE)	1.11 mW/cm ²	0.23 mW/cm ²
Distance to Compliance From Centre of Antenna	1.4 metres 4.58 feet	3.1 metres 10.18 feet
Does the Area of Interest Appear to be in Compliance?	Yes	Yes



Example-2: 20M-SSB Contest Station

1,500w SSB radio

PEP

- Convert to average

Beam antenna

Three-element Yagi

- 9dB gain

20M (14.2MHz)

100 feet RG8 coax

- 0.46dB loss

-

Using Lake Washington online calculator

<http://www.lakewashingtonhamclub.org/resources/rf-exposure-calculator/>



Example 2 Average Power

- (Using the Lake Washington Ham Club calculator)
- Average Power prep:
 - 1,500w PEP transmitter
 - RG8 coax loss at 14.2MHz = 0.46dB
 - 1,348 Watts at antenna
 - Times SSB duty cycle (20%)=269.64w "Average"
- Antenna gain 9dB



Example 2 Results-Good!

Parameters

● Average Power at Antenna (watts): 269.64

● Antenna Gain (dBi): 9

● Operating Frequency (MHz): 14.2

☐ Include Effects of Ground Reflections

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm²): 4.4634

Minimum Safe Distance (feet): 6.4112

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm²): 0.8927

Minimum Safe Distance (feet): 14.3359



Example-3: 2M-FM Mobile

50w FM radio

100% Duty

- FM mode
- Transmit % 0.5

5/8-wave vertical

4.4dBi gain

- On car roof

2M (147MHz)

5-feet of RG-58 coax

- 0.235dB loss

Using Ham Radio School Excel Spreadhseet

<https://hamradioschool.com/rf-exposure-calculator/>



Example-3 Values

Enter Values:		
Transmitter PEP output (W)	50	watts
Feedline length (ft)	5	feet
Feedline loss / 100 ft (dB)	0.7	dB
Operating Mode (select)	FM	mode
Transmit On Percentage (0 to 1)	0.5	
Transmitting Frequency (MHz)	147	MHz
Average Power into Antenna =	24.80	watts
(Calculated -- no value entry)		
Antenna Gain (dBi)	4.4	dBi
Distance to Area of Interest (ft)	8.7	feet



Example-3 Results-Need Distance

- A pedestrian needs to be 8.7 feet from your 2M antenna to be under 0.2mw/cm-sq.

		Controlled MPE	Uncontrolled MPE	
Power Density =	0.0773 mW/cm²	1.0000	0.2000	mW/cm ²
	In compliance?	Yes	Yes	
Power Density with Reflection =	0.1979 mW/cm²	1.0000	0.2000	mW/cm ²
	In compliance?	Yes	Yes	



Run Your Own Evaluations!

- Exercise the online calculator of your choice:
 - To learn how close folks can be
 - For all of your antennas, frequencies, modes and power levels.
 - Print and keep the results
 - Keep fresh beer cold for the FCC inspector



Mitigation

- It is our responsibility to make sure we do not overexpose ourselves or others to RF.
 - Restrict access to antenna
 - Mount antennas higher
 - Talk for shorter periods
 - Lower power
 - Pause operating when folks near antenna

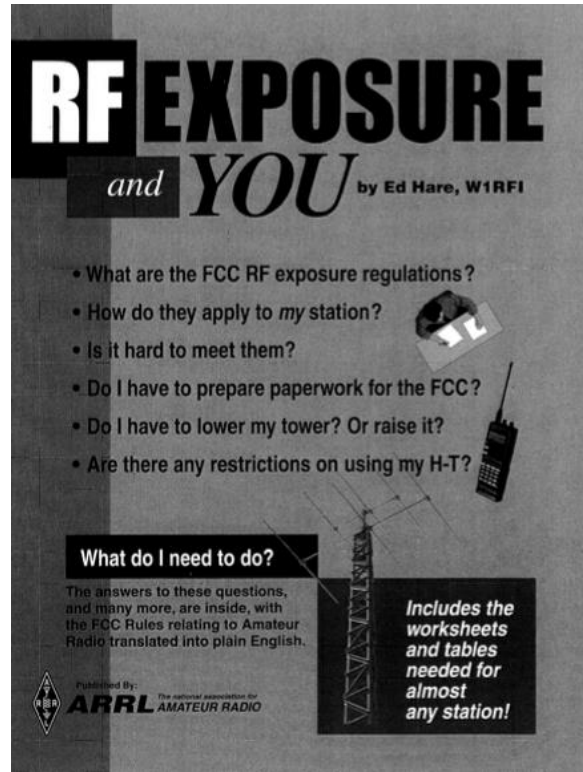


Need Help?

- ARRL Technical Information Service:
- <http://www.arrl.org/technical-information-service>
- Email tis@arrl.org



FREE BOOK PDF (1998 W1RFI)



Summary

- Note your station and antenna setup.
- Calculate RF field MPE's for the bands and modes you use
 - Use an online calculator
 - If out of compliance, remedy



A Few Web-Links

- ARRL RF Exposure page:
 - <http://www.arrl.org/rf-exposure>
- FCC R&O 19-126:
 - <https://docs.fcc.gov/public/attachments/FCC-19-126A1.pdf>
- FCC OET-65 Page:
 - https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65b.pdf
- Coax Loss Calculator:
 - https://www.qsl.net/co8tw/Coax_Calculator.htm
- Ed Hare's RF Exposure and You book:
 - <http://www.arrl.org/files/file/Technology/RFsafetyCommittee/RF+Exposure+and+You.pdf>
- Ria N2RJ's video:
 - <https://www.youtube.com/watch?v=kyLDC-H8kb0>



Thanks Goes To!

- Ed Hare W1RFI
- Greg Lapin N9GL
- Kris Bickell K1BIC
 - Life Long Learning Manager
 - Thanks for hosting us!
- Phil Temples K9HI
 - New England Vice Director
- And finally....
 - THANK YOU for joining us!



Questions?

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ARRL
the national association for
amateur radio®

