Amateur Radio RF Exposure

2021-Style!

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This Talk Based on…

- April 21 talk *FCC Radio Frequency Exposure Rules Become Effective on May 3* by Greg Lapin N9GL
  - Chair ARRL RF Safety committee
  - IEEE Committee on Man and Radiation
  - FCC tech advisory council
  - Consultant on RF exposure issues

  Also Ed Hare W1RFI

  ARRL Lab supervisor

  Wrote RF Exposure book in 1998

Who Am I?

- Dan Brown W1DAN
  - A guy with ham antennas in Natick, MA
  - Eastern Mass ARRL Technical Coordinator
  - Wellesley Amateur Radio Society President
  - Works with high-power UHF broadcast (60kW)
  - Learning as we go!
  - (images stolen from the ‘net)

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

FCC Rules and Guidelines

- FCC Report and Order 19-126
  - Rules for RF exposure (not just Amateur)
  - Created December 2019
  - Approved April 20, 2021
  - Active May 3 2021
- FCC 47CFR parts 1,2, 97
  - Our general regulations
- OET Bulletin 65 and 65B (revised 1997)
  - How to determine RF exposure compliance
  - 'Not just for hams

We need to

- 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 and should have documentation available showing compliance.

New FCC RF Exposure Rules

- Harmonizes exposure rules across all services.
  - Biggest change is the categorical exclusion and table are gone.
- Now use a formula-based evaluation.
- Limits for Maximum Permissible Exposure (MPE) have not changed.
- Exemption available
- If within 20cm of body, measured or modeled (i.e. 2M HT)
- Mobile and portable transmitters now included (Car, HTs, POTA, SOTA)
- Must be able to prove your station is safe-repeaters too

Who Must Comply?

- New or changed stations must evaluate and comply by May 3 2021.
- Existing stations who had complied under old rules have until May 3 2023 to evaluate.
  - Can use existing worksheets and table until May 3 2021 to determine if a station is exempt. 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 to revise these docs and is making tools for us.
- 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)	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).

Exemptions

- New exemptions based on frequency, max ERP, distance, and calculating a field strength
  - If under 1mW, don't bother.
- A new table of exemptions based on frequency, power (at the antenna), and distance from the antenna to the nearest person.
- If you don't qualify for an exemption, you must perform a full exposure analysis.

19-126A1 Table 2

- MPE-based exemptions

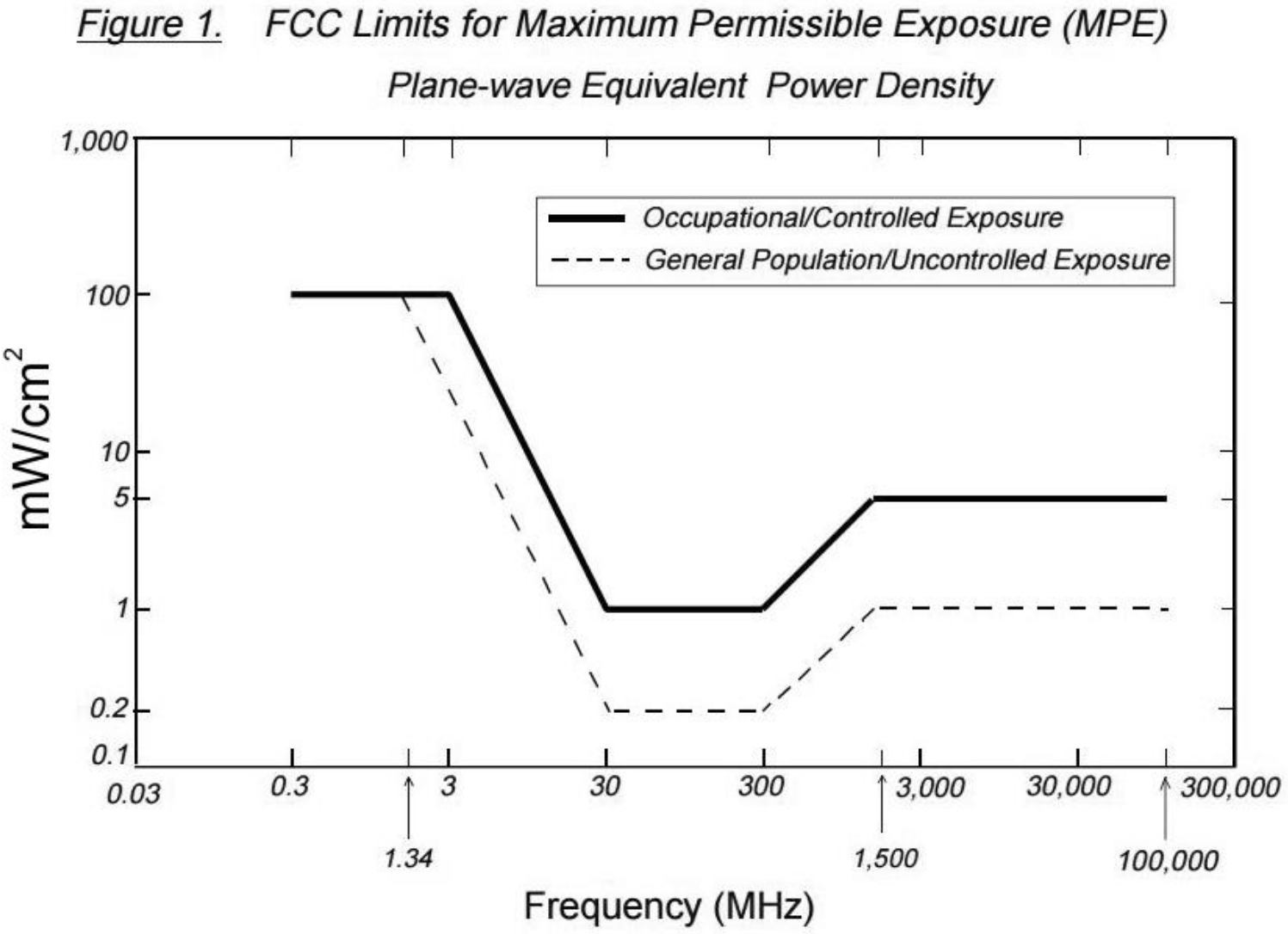
Table 2. Single RF Sources Subject to Routine Environmental Evaluation under MPE-Based Exemptions, $R \geq \lambda/2\pi$

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^2f
1,500 – 100,000	19.2 R^2
Note: Transmitter Frequency is in MHz, Threshold ERP is in watts, R is in meters, f is in MHz.	

Maximum Permissible Exposure

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

OET-65 Chart (old-news)



Exposure Analysis

- For stations that have not been grandfathered, you now must perform your own exposure analyses by May 3.
- Grandfathered stations may do within 2 years.
- Do not have to submit the results to the FCC.
- If you change your station, redo.
- Documentation not mandated.
- Use any valid method
- If an event occurs, 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 ones need modeling
    - Higher prices?
- SAR is used above 300MHz
  - Impractical for hams.

MPE Limits for Occupational/Controlled (hams)

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?

- Not accurate due to environment
- NARDA Radman 2XT
  - E-field 900KHz to 60GHz
  - H-field 27MHz-1GHz
  - $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
  - Pro
  - Expensive, HTs and cell phones
- FDTD-pro
- FEM-pro

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
- 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 (and SAR)

Power Density Equations

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

where: S = power density (in appropriate units, e.g. mW/cm^2)
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:

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

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

OET-65 Formula Variables

- Distance (R)
- Antenna Gain (G)
- Frequency (MHz)
- Power (W)
- Duty cycle (%)

- Result = Power Density (S)
  - Is it below MPE?

Duty Cycle

Averaging time can halve the exposure. 30 minute (general population) standard

Operating Duty Cycle of Modes

Mode	*Duty Cycle*
Conversational SSB	20%
Conversational SSB	40%
SSB AFSK	100%
SSB SSTV	100%
Voice AM, 50% modulation	50%
Voice AM, 100% modulation	25%
Voice AM, no modulation	100%
Voice FM	100%
Digital FM	100%
ATV, video portion, image	60%
ATV, video portion, black screen	80%
Conversational CW	40%
Carrier	100%

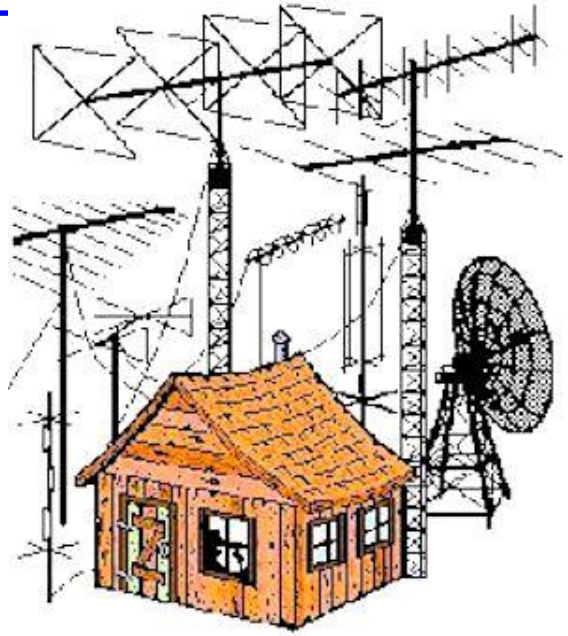
RF Exposure Calculators

http://hintlink.com/power_density.htm

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

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

- Easier to use than solving the O by hand.
- Note ERP and Average power



Example-1: 10M-SSB

- 100w PEP SSB radio
- Dipole antenna (unity gain)
- 100-feet of RG58 (2dB loss)
- 10M (28.5MHz)
- Distance 9 meters

Example 1 Values

Calculate Radio Frequency Exposure

The ERP at the antenna:
In watts — 62.55

The antenna gain in dBi:
Enter 2.2 for dipoles; add 2.2 for antennas rated in dBd — 2.2

The distance to the area of interest:
From the centre of the antenna, in metres — 9

The frequency of operation:
In MHz — 28.5

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

Calculate RF Power Density | Reset Values

FREEDOM!

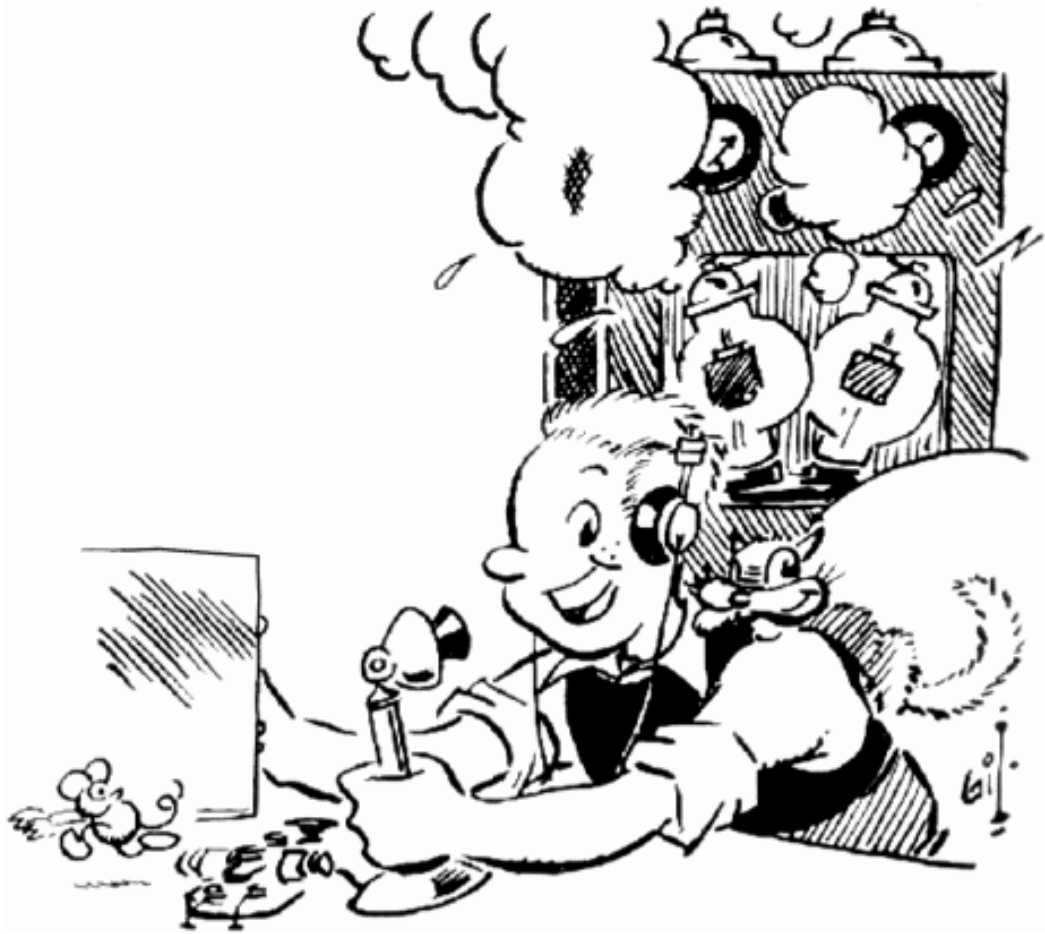
Calculation Results

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 contest station

- 1,500w PEP SSB radio
- Beam antenna
  - 9dB gain
  - Direction?
  - 100-feet of RG8
- 20M (14.2MHz)



Ex. 2 Calculation Prep

- (Using the Lake Washington Ham Club calculator)
- Average Power:
  - 1,500w PEP transmitter
  - RG8 coax loss at 14.2MHz = 0.463dB
  - 1,348.2 Watts at antenna
  - Times duty cycle (20%)=269.64w “Average”
- Antenna gain 9dB

Results 2

Parameters

- Average Power at Antenna (watts): 269.64
- Antenna Gain (dBi): 9
- Operating Frequency (MHz): 14.2

☐ Include Effects of Ground Reflections

Calculate

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm^2): 4.4634

Minimum Safe Distance (feet): 6.4112

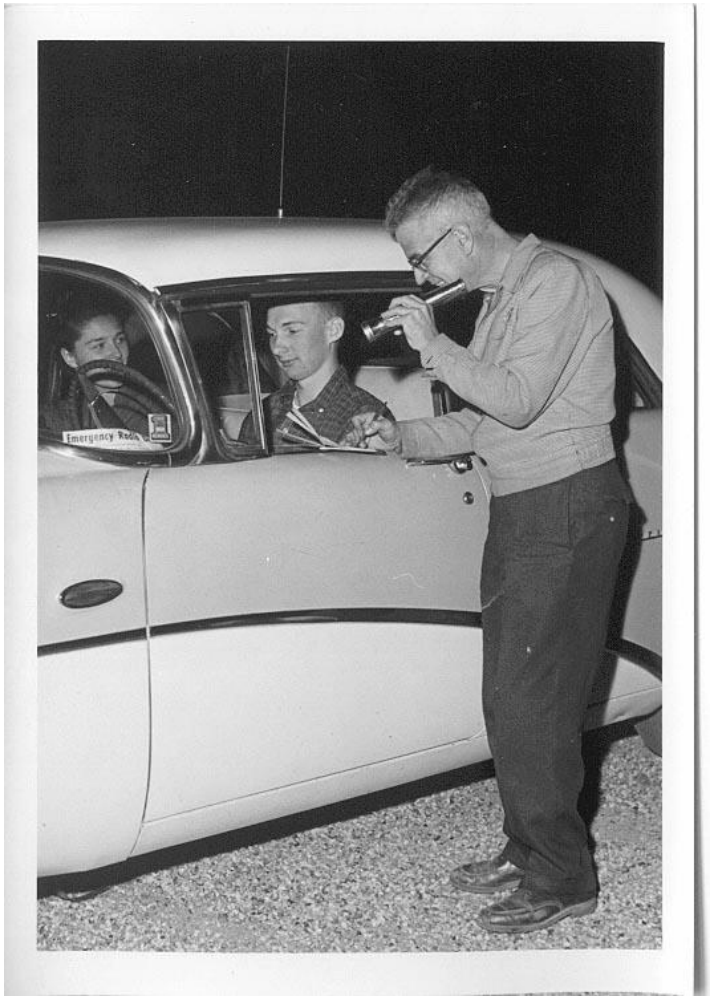
For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 0.8927

Minimum Safe Distance (feet): 14.3359

Example 3: 2M in car

- 2M FM Mobile station in Auto
- 50 Watts FM (50% duty)
- 5/8-wave roof antenna
  - 4.4dBi gain



Example 3 Values

- Using Ham Radio School Excel sheet:

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

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

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

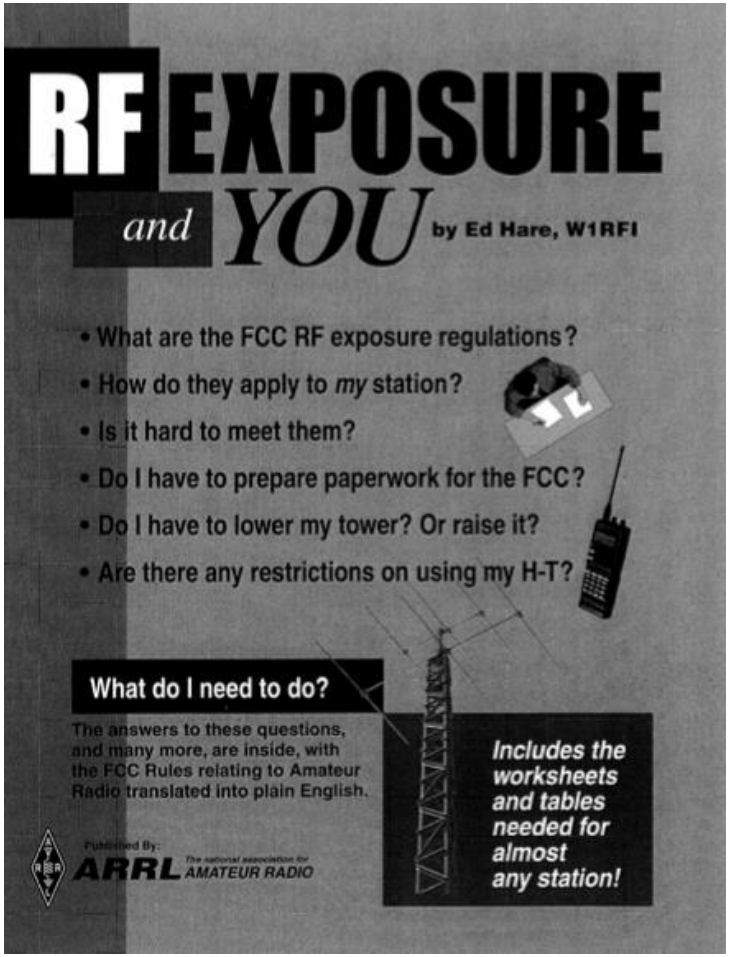
Run Your Own Calculations!

- Exercise the online calculator of your choice:
  - To know 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

Need Help?

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

FREE BOOK PDF (1998 W1RFI)



Review Of Our Goals

- 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

Summary

- Read *R&O 19-126* and *OET-65* (yawn).
- Read Ed's Book *RF Exposure And You*, noting recent changes in R&O and updated OET-65 dope.
- Note your station and antenna setup.
- Calculate RF fields for the bands and modes you use
  - Use online calculator, or
  - Use OET-65 formula
  - If out of compliance, remedy
- It is good to create a document showing your compliance, just in case the FCC stops by for a beer.

LINKS

- http://www.arrl.org/rf-exposure
- https://docs.fcc.gov/public/attachments/FCC-19-126A1.pdf
- https://www.fcc.gov/general/radio-frequency-safety-0
- https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65b.pdf
- http://www.arrl.org/files/file/Technology/RFsafetyCommittee/RF+Exposure+and+You.pdf

Lets Discuss!

- Questions, comments, or corrections?
- w1dan@arrl.net

Thank you and Stay RF-Safe!

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