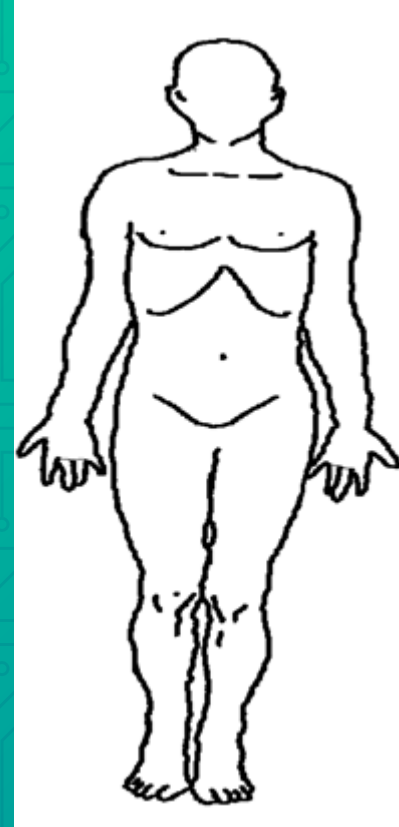


RF SAFETY & STATION EVALUATION

Jim Langsted KCØRPS
285 TechConnect Club
November 5, 2022

Biological Effects



Biological Effects of RF Exposure

- ① Whole Body Tissue Heating
- ① Localized Tissue Heating (extremities)
- ① Nerve Stimulation



How the Limits are Set

- ⦿ Temperature increase
 - ⦿ 1 °C increase
- ⦿ Specific Energy Absorption Rate (SAR) (W/kg)
- ⦿ Reference Levels
 - ⦿ E-field strength (V/m)
 - ⦿ H-field strength (A/m)
 - ⦿ Incident Power Density (W/m² or mW/cm²)

Whole Body Tissue Heating

- ⦿ Normal Body Temperature $\sim 37^{\circ}\text{C}$
- ⦿ 1°C increase – increased accidents
- ⦿ $>40^{\circ}\text{C}$ – heat stroke & death
- ⦿ Mechanisms
 - ⦿ Denaturing of proteins
 - ⦿ Cell membrane permeability changes
- ⦿ **Limit** - 1°C Body Core Temperature increase



Localized Tissue Heating

- ⦿ Evidence of damage $>41-43^{\circ}\text{C}$, increases with time
- ⦿ $>41^{\circ}\text{C}$ considered potentially harmful
- ⦿ **Limits**
 - ⦿ Head & Torso - 2°C increase
 - ⦿ Limbs - 5°C increase



Nerve Stimulation

- ① 100 kHz – 10 MHz range
- ① Sensory perception
 - ① Tingling
 - ① Warmth
- ① **Limit** has been incorporated here



Basic Restrictions (energy deposited)

Table 2. Basic restrictions for electromagnetic field exposure from 100 kHz to 300 GHz, for averaging intervals ≥ 6 min.^a

Exposure scenario	Frequency range	Whole-body average SAR (W kg^{-1})	Local Head/Torso SAR (W kg^{-1})	Local Limb SAR (W kg^{-1})	Local S_{ab} (W m^{-2})
Occupational	100 kHz to 6 GHz	0.4	10	20	NA
	>6 to 300 GHz	0.4	NA	NA	100
General public	100 kHz to 6 GHz	0.08	2	4	NA
	>6 to 300 GHz	0.08	NA	NA	20

^aNote:

1. “NA” signifies “not applicable” and does not need to be taken into account when determining compliance.
2. Whole-body average SAR is to be averaged over 30 min.
3. Local SAR and S_{ab} exposures are to be averaged over 6 min.
4. Local SAR is to be averaged over a 10-g cubic mass.
5. Local S_{ab} is to be averaged over a square 4-cm^2 surface area of the body. Above 30 GHz, an additional constraint is imposed, such that exposure averaged over a square 1-cm^2 surface area of the body is restricted to two times that of the 4-cm^2 restriction.



Reference levels have been derived from a combination of computational and measurement studies to provide a means of demonstrating compliance using quantities that are more-easily assessed than basic restrictions...

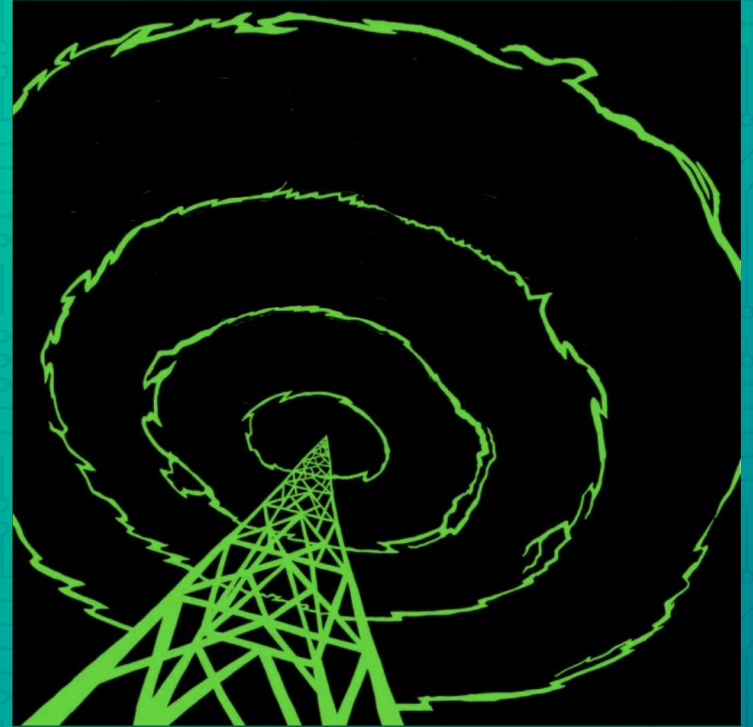
Maximum Permissible Exposure

TABLE 1 TO § 1.1310(E)(1)—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm ²)	Averaging time (minutes)
(i) Limits for Occupational/Controlled Exposure				
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
300–1,500 .....	.....	.....	f/300	<6
1,500–100,000 .....	.....	.....	5	<6
(ii) Limits for General Population/Uncontrolled Exposure				
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
300–1,500 .....	.....	.....	f/1500	<30
1,500–100,000 .....	.....	.....	1.0	<30

f = frequency in MHz. * = Plane-wave equivalent power density.

Station Evaluation



Station Evaluation

- Who
- What
- Why
- Where
- When
- How



Who

- FCC
- *More importantly:*
 - Operator
 - Family
 - Neighbors
 - Passers by



What

- ① Station Evaluation

Determine if the RF (electromagnetic fields) are within safe limits at all occupied locations both on and off your property.



Why – RF Safety

- ① Exposure to the Operator and their Family
 - ② Controlled Exposure
- ① Exposure to the General Public
 - ② Uncontrolled Exposure



Where

- ① Your antenna site(s)
 - ① Controlled locations
 - ① Uncontrolled locations



When

- ⦿ Before May 3, 2023
 - ⦿ Sooner rather than later
 - ⦿ You have had since May 3, 2020



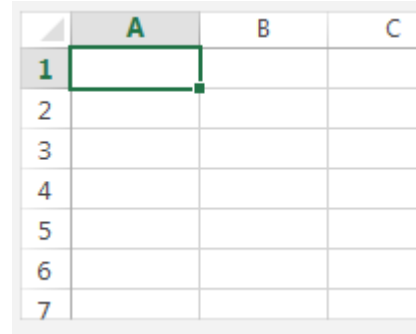
How

- ⦿ Exemption from evaluation
- ⦿ Evaluate with Online Calculator
 - ⦿ Quick & dirty
 - ⦿ More detailed
- ⦿ Modeling
- ⦿ Mitigation if necessary



Make a Table

- ⦿ Band
- ⦿ (Frequency (MHz))
- ⦿ Antenna
- ⦿ Distance from antenna to:
 - ⦿ Closest **Controlled** exposure location
 - ⦿ Closest **Uncontrolled** exposure location



	A	B	C
1			
2			
3			
4			
5			
6			
7			



Exemption from Evaluation

(but do you really want to?)

Table 1 — Single RF Sources Subject to Routine Environmental Evaluation under MPE-Based Exemptions, $R \geq \lambda/2\pi$

Transmitter Frequency	Threshold Effective Radiated Power (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 – 1500	$0.0128 R^2f$
1500 – 100000	$19.2 R^2$

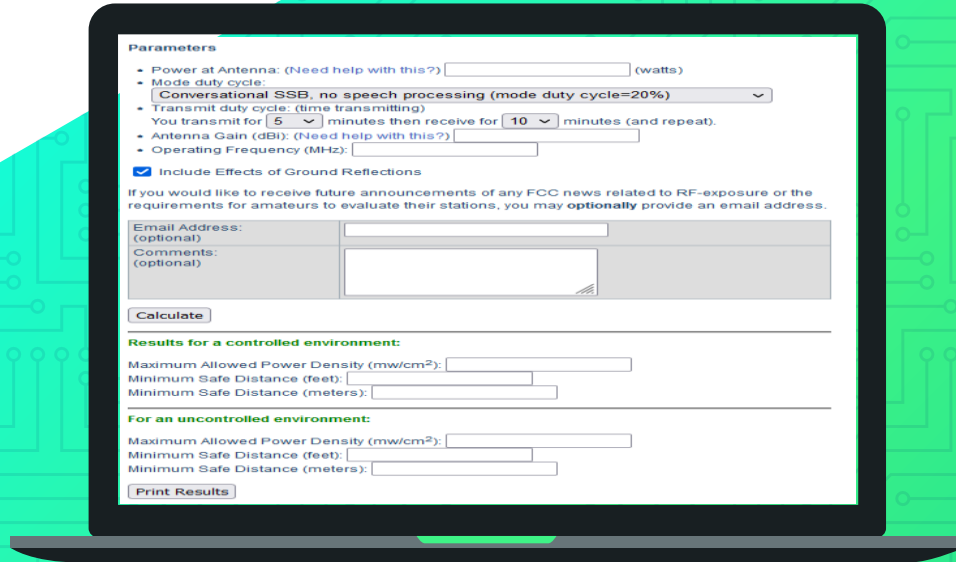
Note: Transmitter frequency is in MHz, threshold ERP is in watts, R is in meters, and frequency (f) is in MHz.

Using Table 1 for the frequency (f in MHz) and separation distance (R in meters) at which the RF source operates, single RF sources are exempt if the ERP (in watts) is no more than the calculated value prescribed for that frequency. For the exemption in Table 1 to apply, the separation distance in meters (R) must be at least $\lambda/2\pi$, where λ is the free-space operating wavelength. If the ERP of a single RF source is not easily obtained, then the available maximum (source-based) time-averaged power may be used in lieu of ERP if the device antenna(s) or radiating structure(s) do not exceed the electrical length of $\lambda/4$. If the ERP of the single RF source and transmitting antenna(s), including coherent array, exceeds the ERP threshold, then the RF source is not exempt, and the applicant must prepare an evaluation.



ARRL RF Exposure Calculator

Online tool to
determine Minimum
Safe Distances for your
station



The screenshot shows the ARRL RF Exposure Calculator web form. It includes input fields for Power at Antenna (watts), Mode duty cycle (dropdown menu), Transmit duty cycle (minutes), Antenna Gain (dBi), and Operating Frequency (MHz). There is a checkbox for 'Include Effects of Ground Reflections'. Below the form is a 'Calculate' button. The results section is divided into 'Results for a controlled environment' and 'For an uncontrolled environment', each with input fields for Maximum Allowed Power Density (mw/cm²) and Minimum Safe Distance (feet/meters). A 'Print Results' button is located at the bottom of the form.

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 minutes then receive for 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)

Results for a controlled environment:

Maximum Allowed Power Density (mw/cm²):

Minimum Safe Distance (feet):

Minimum Safe Distance (meters):

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm²):

Minimum Safe Distance (feet):

Minimum Safe Distance (meters):

<http://arrl.org/rf-exposure-calculator>



INSTRUCTIONS FOR USE

Go to ARRL Website (you don't have to be a member)

Search for "RF Exposure"

Click on the (top) "RF Exposure" link. Lots of good information and links to additional information

Click on the RF Exposure Calculator (on the left)

RF Exposure Calculator

Read the instructions (three paragraphs) and click on the **"View detailed instructions"** link.

Notice the "Here is an excellent coax loss calculator" link.



Parameters

- Power at Antenna: (Need help with this?) (watts)
 - Mode duty cycle:
 ▾
 - Transmit duty cycle: (time transmitting)
You transmit for minutes then receive for minutes (and repeat).
 - Antenna Gain (dBi): (Need help with this?)
 - Operating Frequency (MHz):
- Include Effects of Ground Reflections

Input Parameters Specific for your station



Calculator Parameters

- ⦿ Power at the antenna (need help with this?)
- ⦿ Mode Duty Cycle (pull-down menu)
- ⦿ Percentage of transmitting (transmit/receive pull-downs)
- ⦿ Antenna Gain (dbi) (need help with this?)
- ⦿ Operating Frequency
- ⦿ Effect of ground



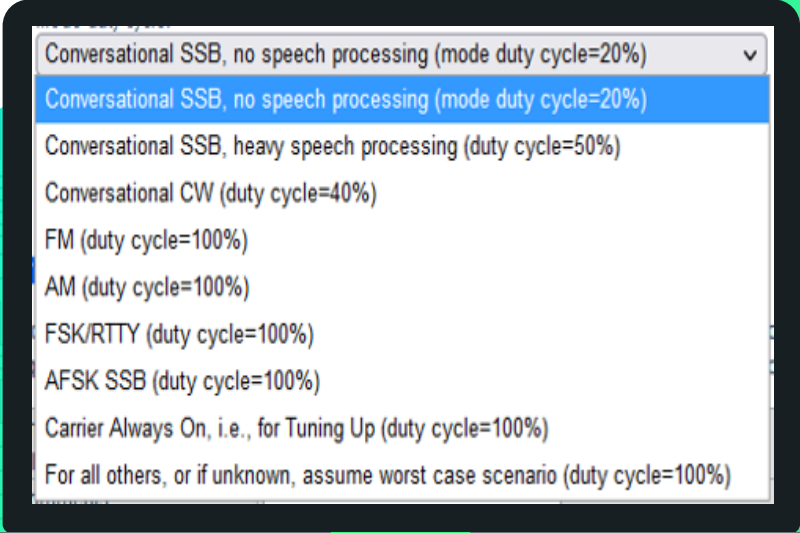
Set Parameters as Desired	
Line Type:	Belden 8215 (RG-6A) ▾
Line Length:	100 <input checked="" type="radio"/> Feet <input type="radio"/> Meters
Frequency:	10 MHz
Load SWR:	1 : 1
Power In:	100 W
<input type="button" value="Calculate"/>	

Results	
Matched Loss:	<input type="text"/> dB
SWR Loss:	<input type="text"/> dB
Total Loss:	<input type="text"/> dB
Power Out:	<input type="text"/> W

Power at the antenna

- Transmitter power minus feedline losses
- Needs SWR at antenna
- Feed Line length





Conversational SSB, no speech processing (mode duty cycle=20%)
Conversational SSB, no speech processing (mode duty cycle=20%)
Conversational SSB, heavy speech processing (duty cycle=50%)
Conversational CW (duty cycle=40%)
FM (duty cycle=100%)
AM (duty cycle=100%)
FSK/RTTY (duty cycle=100%)
AFSK SSB (duty cycle=100%)
Carrier Always On, i.e., for Tuning Up (duty cycle=100%)
For all others, or if unknown, assume worst case scenario (duty cycle=100%)

Mode duty cycle (Pulldown menu)

$$FT-8/FT-4 = 50\%$$



Percentage of Transmitting

- ① Number of minutes you transmit
- ② Number of minutes you receive

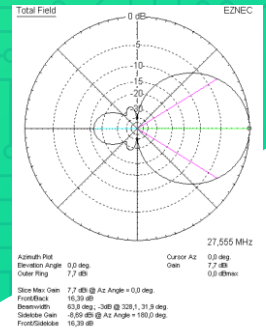


Antenna Gain (dBi)

- Antenna gain instructions
- Detailed antenna model
- Model from manufacturer
- This table
- OET-65B, *Additional Information for Amateur Radio Stations*

Antenna Type	Approx. Gain (dBi) *
Half wave dipole	2.15 dBi
10 element Yagi	15.1 dBi
2 element Yagi	5.9 dBi
3 element Yagi	8.1 dBi
4 element Yagi	9.1 dBi
5 element Yagi	10.1 dBi
6 element Yagi	11.1 dBi
8 element Yagi	13.1 dBi
Delta Loop	5.2 dBi
Four Square	5.2 dBi
G5RV	1.0 dBi
Hex Beam	5.0 dBi
Moxon	6.0 dBi
Quarter Wave Vertical	1.5 dBi
Windom (OCD)	2.0 dBi

Be careful with HF loop antenna



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)	<input type="text"/>
Comments: (optional)	<input type="text"/>

Calculate

Request for Updates

- Optional submission of e-mail address
- Calculate button



Results for a controlled environment:

Maximum Allowed Power Density (mw/cm²):

Minimum Safe Distance (feet):

Minimum Safe Distance (meters):

Results - Controlled

- Maximum allowed power density
- Minimum Safe Distance



For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm²):

Minimum Safe Distance (feet):

Minimum Safe Distance (meters):

Print Results

Results - Uncontrolled

- Maximum allowed power density
- Minimum Safe Distance
- Print Results button



Mitigation if Necessary

- ① Reduce transmitter power
- ① Move antenna
- ① Restrict access



Thank you!

