SFTARC

TECH NITE PRESENTATION

HOW TO DO

RF EXPOSURE EVALUATIONS FOR YOUR STATION

March 24, 2022

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What is this all about? Should I be concerned?

- The RF “exposure limits” have been with us since 1996.
- In 1996, the FCC gave us an exemption based upon power only
- It essentially allowed Amateurs a chance to not pay attention to distance from the antenna.

The main points I'll make tonight:

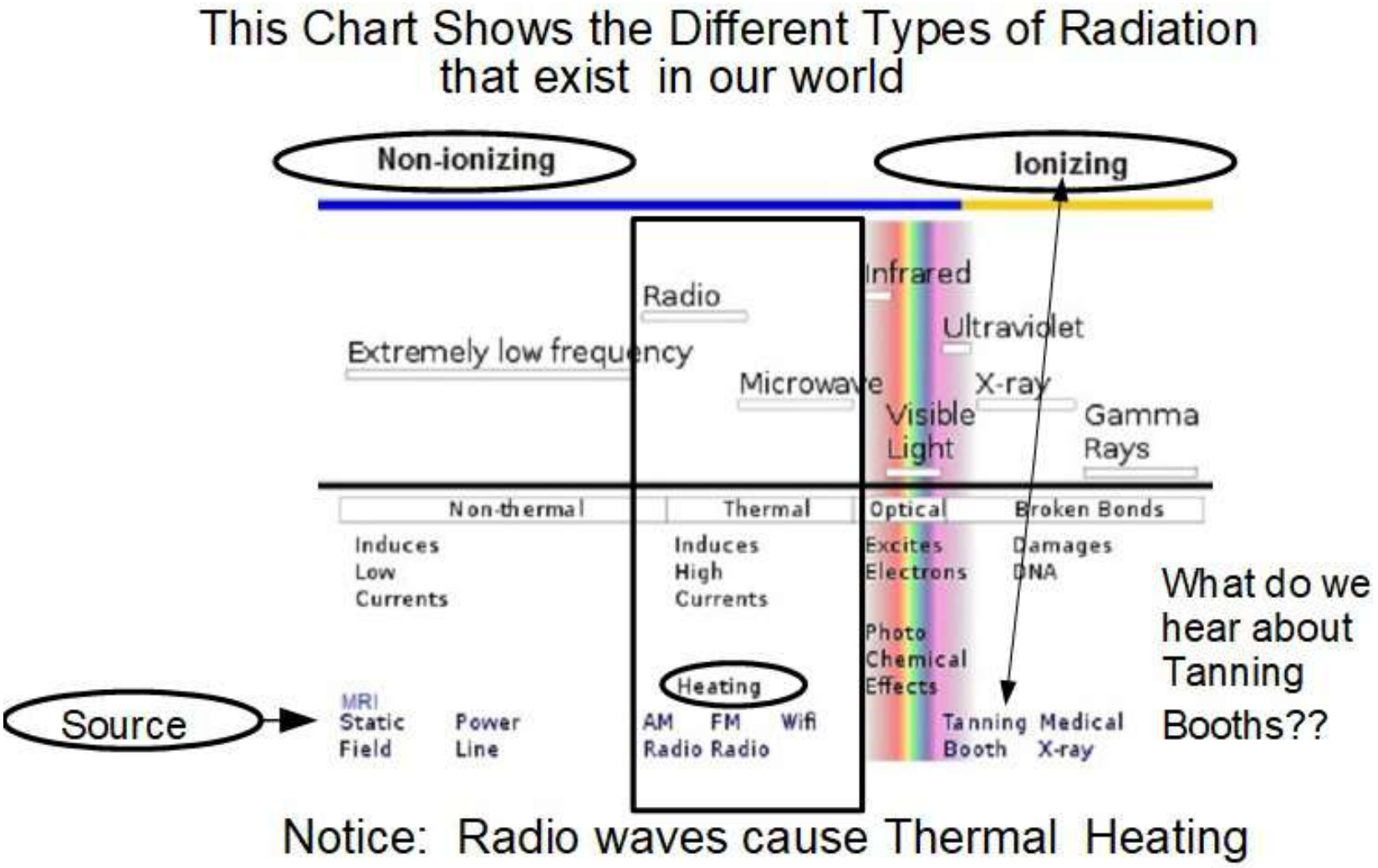
- Generally it's a good bet that you've been OK*
- You don't have much to be concerned about unless*
- * You've sat within feet of your antennas and / or
- Run very high power
- ***Distance*** away from the antenna is good and the most effective thing you can do to reduce RF exposure.

What is Radiation?
It Is All Around Us

- Radiation simply means:
  - An emission in all directions from a single point
- We have lots of “radiation” in our world
  - Steam radiators in homes
  - Car radiators
  - Light radiation from light bulbs
  - Sun light
  - etc.
- Some types continue to be tightly controlled to limit exposure
  - Medical X-ray and Medical nuclear radiation are examples
- **New FCC Rules Released:**
  - With the proliferation of *cell phones* and *wireless gadgets* RF radiation is now receiving a little more attention.
    - FCC ET Docket 19-226 Released Dec 4, 2019
    - FCC Report & Order 19-126 Released Apr 20, 2021
    - **New Rules became Effective May 3, 2021** for newly licensed stations.
    - **A 2yr transition period exits to May 3, 2023** for *already existing compliant & unchanged* stations.

What is RF Radiation?

It is NON-Ionizing – Causes Heating



Credit:: Wikipedia 2022 [Non-ionizing radiation]

You're Familiar With Microwave Oven RF Heating & Cooking

- We all know about the TIME and POWER settings on microwave ovens.
  - Usually we defrost with LOW POWER & LONG TIME
  - If we want to “Cook” our food, we want hi temperature using Hi Power & perhaps shorter time

- **So you're already acquainted with TIME and POWER**

They're part of RF EXPOSURE

You're Familiar With
Microwave Oven RF Heating & Cooking

Molecules vibrating at the ***frequency*** of the microwave oven causing friction between themselves generating heat.

Home work: View video link below

https://youtu.be/nLLH1amhAgU

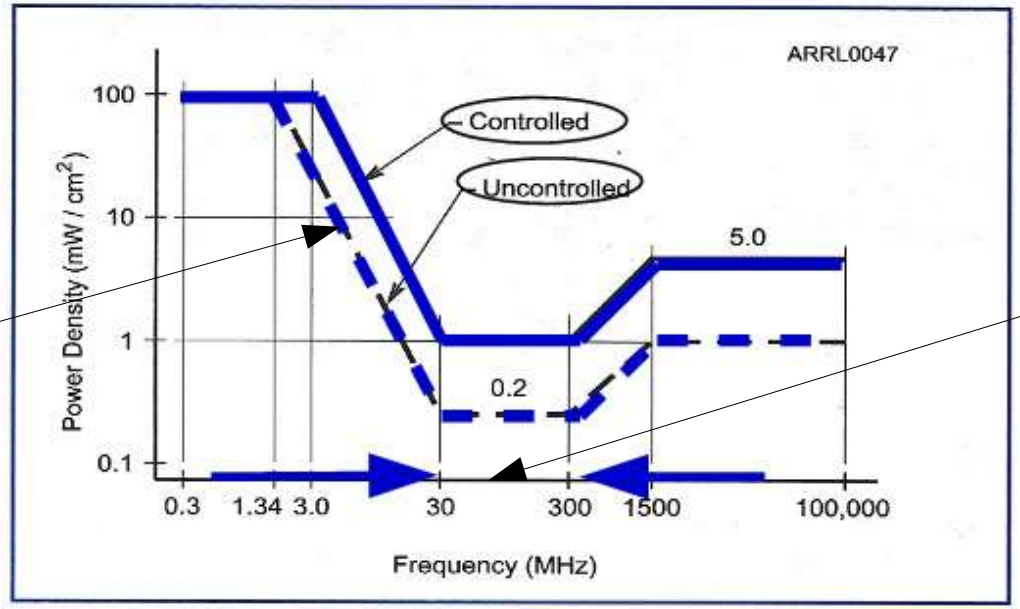
Why Is RF Usually Not Hazardous?

- Exposure to RF at low levels is not hazardous.
- At high levels and at some frequencies it can pose a problem.
- The FCC established MPE back in 1996

  MPE is the maximum permissible exposure to which a human may be exposed.
- Based upon scientific & medical evaluations and recommendations by:
  - American National Standards Institute (ANSI),
  - Institute of Electrical and Electronics Engineers, Inc. (IEEE)
  - National Council on Radiation Protection and Measurements (NCRP)
  - Food and Drug Administration (FDA),
  - Environmental Protection Agency (EPA),
  - Occupational Safety and Health Administration (OSHA),
  - National Institute for Occupational Safety and Health (NIOSH)
  - others

Graph of FCC MPE Limits

Less exposure Is allowed for uncontrolled areas(dashed)



Least exposure is allowed from 30MHZ to 300MHZ where wavelengths are similar to dimensions on humans.

Human body parts can resonate to RF and absorb power similar to how antennas work.

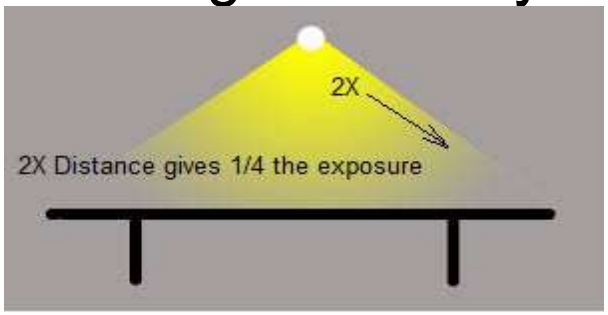
Controlled: → Your property (fenced land, house etc.)

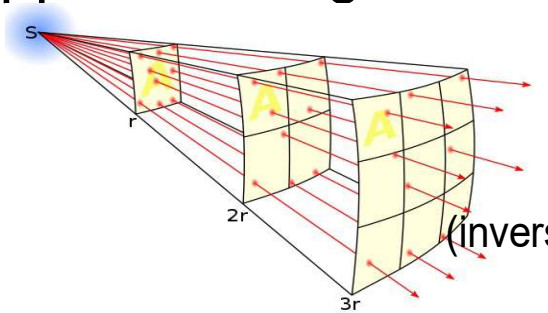
Uncontrolled: → Public property (sidewalks, streets, parks etc.)

Power Density

The intensity of RF is call Power Density

It is similar to the light intensity as you approach a light bulb.





(inverse square law)

When you get too close to an incandescent light bulb the

Increased Power Density feels hot.

Distance away from antennas has the same effect

2X the distance away gives ¼ th the exposure

Why Is RF Usually Not Hazardous?

These quantities are needed for estimating whether an RF signal exceeds the maximum permissible exposure (MPE):

- **DUTY CYCLE:** (**on vs off** transmitter time ; *"talk time" vs "listen time"*)
- **FREQUENCY:**
- **POWER:** (including antenna gain and / or feedline loss)
- **TRANSMISSION MODE:**

  (AM, FM, Digital, CW, SSB and how much compression is used)

  A calculated result is: **POWER DENSITY (mW/cm^2)**

  and is part of determining how far away the antnna should be from people.

An Easy Way To Perform RF Exposure Evaluation.

Let's get going with an EASY Way to do the Evaluation:

Easy to do
RF Exposure Evaluation

The Evaluation can be done in a variety of ways, however the easiest is to use an on-line calculator such the one provided by the ARRL :

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

You simply “fill-in” the boxes, click “calculate” and read the required antenna distances.

Your next task is to verify that your antenna **location** complies with the
Minimum Safe Distances for both **Controlled** and **Uncontrolled** environments.

Here is how it looks “on-line”

1) Power
2) Duty Cycle
3) Antenna Gain
4) Frequency
Have been typed in.

Then Click CALCULATE

The results Are shown below.

Print also

arrl.org/rf-exposure-calculator

Parameters

- Power at Antenna: (Need help with this?) 100 (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?) 2.15
- Operating Frequency (MHz): 14.3

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): 4.4012
Minimum Safe Distance (feet): 1.1672
Minimum Safe Distance (meters): 0.3558

For an uncontrolled environment:

Maximum Allowed Power Density (mw/cm^2): 0.8802
Minimum Safe Distance (feet): 1.6506
Minimum Safe Distance (meters): 0.5031

Print Results

<u>Controlled Envionment:</u>
People are safe:
If they are 1.1672 ft or more away from the antenna.

<u>Uncontrolled Envionment</u>:
People are safe:
If they are 1.6506 ft or more away from the antenna.

“Printed” Version

(with inputs and results colored)

RF Exposure Calculator

Parameters

- Power at Antenna: 100 (watts)
- Mode duty cycle:
  Conversational SSB, no speech processing (mode duty cycle=20%)
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Technology >> Radio Technology Topics >> Safety >> RF Exposure >> RF Exposure Calculator

Let's do some examples of various station set ups:

We'll go straight to the ARRL RF Calculator Website:

→ *We'll initially assume all power reaches the antenna (no coax loss).*

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

For conventional SSB, with no speech processing

NUMBER OF ELEMENTS	APPROX ANTICIPATED GAIN DB OVER DIPOLE
2	5
3	7.5
4	8.5
5	9.5
6	10.5
7	11.5

1) 100 W , 14. MHZ , Dipole: 2.2 db gain (2.2db gain above isotropic)

2) 100 W, 28 MHZ , Dipole: 2.2 db gain (2.2db gain above isotropic)

3) 1500 W, 52 MHZ, 5 El Yagi antenna 11.7db gain (9.5 db gain above dipole)

Result: Antenna must be 28.4 ft away for Controlled Environments & 40.2 ft away for Uncontrolled Environments (from the front of the Yagi antenna)

4) 1500 W, 52 MHZ, 7 El Yagi antenna12.7db gain (1db coax loss: 11.5-1=10.5db above dipole)

Result: Antenna must be 31.95 ft away for Controlled Environments & 45.18 ft away for Uncontrolled Environments (from the front of the Yagi antenna)

Document Your Evaluation

A good way to document your evaluation is to use the Work Sheets provided by ARRL.

The new FCC ruling make *some parts* of Work Sheet A not specifically applicable, but together the sheets capture and document your station information. You should re-do your evaluation and documentation anytime you make changes that effect exposure.

Even though the FCC rules do not mandate that amateurs keep records of their evaluations, it is non-the-less a good idea to keep information about your station evaluation. The FCC could inquire about the results of your evaluation, in response to a complaint or in relation to some other issue.

Note:

These sheets were created prior to the FCC Rule change - some parts may no longer apply.

Worksheet A: Instructions — Categorical Exemption for Station Evaluation

Provided as a membership service by the American Radio Relay League, Inc., 225 Main St., Newington, CT 06111.

It is easy to determine if you need to do a routine station evaluation. The requirement to do a routine station evaluation is based on Table 1.1, showing peak envelope power (PEP) input to the antenna.

A, B, C: For your records, enter the call sign of the station (A) , the name of the station licensee (B) and station location (C) onto the top of the worksheet.

D. Enter the station operating frequency band being considered for evaluation (D).

E. Enter the maximum PEP output you use on that band (E).
(This can be determined by measurement or estimated from factors such as the rated output power of your transmitter. Alternatively, you can estimate from other factors. See Chapter 5, the section titled: "How to Calculate Peak Envelope Power to the Antenna.")

F, G. Enter your feed line type (F) and length (G).

H. Enter the specification for the loss in dB per 100 feet for your cable type. Use the manufacturer's specification or use the table in Chapter 5.

I. Divide the feed line length (G) by 100, then multiply the result by the specification for your feed line type for loss in dB per 100 feet. This will give you the total feed line loss in dB (I).

J. Enter the total feed line loss in dB (I) and convert it to a percentage (J).
(See the formulas or table in Chapter 5 or, optionally, you can use 0 dB for a conservative estimate. If you use 0 dB, skip to step J and enter 0%.)

K. Multiply the maximum transmitter PEP used on this band (E) by the percentage of power lost in the feed line (J). The result is the total power lost in the feed line (K).

L. Subtract the power lost in the feed line (K) from the transmitter PEP used on this band (E). The result is the PEP input to the antenna.

Compare the PEP input to the antenna (L) to the level in Table 1.1. If the power to the antenna is greater than the level in Table 1.1 for that frequency band, it will be necessary for you to perform a routine evaluation on your station. If your PEP to the antenna does not exceed the limits in Table 1.1, the rules do not require you to do a routine station evaluation on that band.

WORKSHEET A: CATEGORICAL EXEMPTION FOR STATION EVALUATION WORKSHEET

Provided as a membership service by the American Radio Relay League, Inc., 225 Main St., Newington, CT 06111.

Use this worksheet for each band you operate to determine if you need to do a station evaluation on that band.

(A): Station Call Sign: KDØABC (B) Station Licensee: JOE SMITH

(C) Station Location: 954, MOUNTAIN TOP RD. , DENVER, CO.

(D) Frequency Band: 3.9 MHZ

(E) Maximum Transmitter PEP used on this band: 100 W PEP

Refer to Table 1.1 — If the power on line (E) of this worksheet is less than or equal to the power limits given in the table for this band, you do not need to do an evaluation on this band. If the power exceeds the limits, continue with this worksheet.

Calculate Feed Line Loss in dB:

(F) Feed Line Type: RG-8 (G) Feed Line Length: 100 ft

(H) Enter Feed Line Loss in dB per 100 ft: 1 dB

(From Chapter 5 or manufacturers specification. You can use 0 dB for a conservative estimate. If you use 0 dB, skip to step J and enter 0%.)

(G) 100 Feed Line Length from (G) / divide by 100 × then multiply by (H) 1 dB loss in dB per 100 feet from (H) = equals (I) 1 dB Feed Line Loss in dB

Convert to percentage:

(I) 1 dB Feed Line Loss in dB from (I) = (J) 20.57 % Convert to percentage of power lost in the feed line. See Chapter 5 or use 0% as a conservative estimate.

See the free Ch 5 of the ARRL Handbook on the ARRL RF Exposure Website.

Power to antenna:

(E) 100 W PEP Maximum transmitter PEP used on this band from (E) × times (J) 20.57 % Percentage of power lost in the feed line from (J) = equals (K) 20.57 W PEP Power lost in the feed line

(E) 100 W PEP Maximum transmitter PEP used on this band from (E) – minus (K) 20.57 W Power lost in feed line = equals (L) 79.43 W PEP PEP input to the antenna

Input 79.43 on Sheet B

Conclusion and decision: This Categorical Exclusion is no longer allowed by the FCC Change. Ref: FCC Report & Order 19-126

~~Compare the power input to the antenna (L) to Table 1.1. If the power input to the antenna is less than or equal to this power level, you do not have to evaluate your station on this band.~~

Worksheet B: Instructions — Station Evaluation Worksheet

Provided as a membership service by the American Radio Relay League, Inc., 225 Main St., Newington, CT 06111

If you do have to do a station evaluation for one or more powers or modes, use this worksheet to guide you through the process. This single page worksheet and instructions will suffice for many stations. See Chapter 5 for multiple transmitter sites and repeaters.

A, B. For your records, enter the call sign of the station (A), the station licensee (B) onto the top of the worksheet.

C. Enter the frequency band being evaluated.

D. Enter the operating mode being evaluated.

E. Enter the maximum transmitter peak-envelope power being used on this band (E). (See Chapter 5, the section titled: "How to Calculate Peak Envelope Power to the Antenna.")

F. Enter the peak-envelope power input to the antenna from line L of Worksheet A (F).
(As a conservative first estimate, you can skip to steps J and K, using this power level.)

G. Enter the duty factor of the mode being evaluated (H):
(See the section in Chapter 5 titled: "Duty Factor," or use 40% for CW, 20-40% for SSB, 100% for FM or digital modes.)

H,I. Enter the maximum percentage of time the station could be on the air for controlled or uncontrolled exposure. (A good rule of thumb is to use 100% for controlled exposure, 67% for uncontrolled exposure. Also see the table in Chapter 5.)

J, K. Calculate average power.
(Multiply the PEP input to the antenna (F) by the duty factor of the mode being used (G) by the operating time percentage (H, I). The result is the average power to the antenna.

L. Refer to any of the evaluation methods described in the FCC's *OET Bulletin 65* of Chapter 5. Determine that the antenna is located far enough away from areas where people are present or that the field strength is below the maximum permissible exposure (MPE) limits in areas where people are present. Describe briefly the method used to perform this evaluation.

M. Record the results of your station evaluation. Your station evaluation for this band and mode is now complete. Although it is not required by FCC rules, it is recommended that you retain a copy of your station evaluation in your station records.

If the station is not in compliance under all circumstances of its expected operation, attach a separate sheet describing any limitations of methods that the station operator will use to ensure compliance if people are present in areas that could be out of compliance.

WORKSHEET B: STATION EVALUATION WORKSHEET

Provided as a membership service by the American Radio Relay League, Inc., 225 Main St., Newington, CT 06111.

Use this worksheet for each band, mode and antenna combination you use to determine if your station complies with the FCC regulations for RF exposure.

(A): Station Call Sign: KDØABC (B) Station Licensee: JOE SMITH

(C) Frequency Band: 3.8MHZ (75M) (D) Operating mode being evaluated: SSB

(E) Maximum Transmitter PEP used on this band: 100 W PEP

(F) PEP input to the antenna on this band (from line (L) on Worksheet A): 79.43 W PEP
For a conservative estimate, you could use your maximum transmitter PEP and skip to step (L) and use this power for your evaluation. If you "pass," you do not need to do the other steps.

Mode and duty factor:

(D) Operating mode being evaluated: SSB (G) Duty Factor for this mode: 20 %
(See Chapter 5 or use 40% for CW, 20% for SSB with no speech processing, 40% for SSB with heavy speech processing, 100% for FM or digital modes)

Maximum time the station could be transmitting in:
(H) 6-min period (controlled): 3 / 6 = 50 %

(I) 30-min period (uncontrolled): 15 / 30 = 50 %

Calculate average power — Controlled exposure:

(F) 97.43 W PEP (PEP input to the antenna from (F)) × (G) 20 % (Duty Factor from (G)) × (H) 50 % (Controlled operating time percentage) = (J) 9.743 W avg (Controlled average power input to the antenna)

Calculate average power — Uncontrolled exposure:

(F) 97.43 W PEP (PEP input to the antenna from (F)) × (G) 20 % (Duty Factor from (G)) × (I) 50 % (Uncontrolled operating time percentage) = (K) 9.743 W avg (Uncontrolled average power input to the antenna)

(L) Refer to any of the evaluation methods in FCC's *OET Bulletin 65* or Chapter 5. Determine if the antenna is located far enough away from areas where people are present or that the field strength is below the maximum permissible exposure (MPE) limits, based on the frequency, mode, average power and antenna type being used.

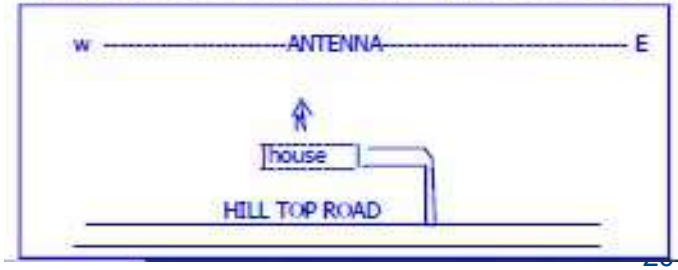
(M) Describe the method used to do the evaluation: ARRL ON-LINE CALCULATOR

Using this method, did your station exceed the FCC RF exposure limits? (Y/N)

Controlled exposure: Y (Y/N) Uncontrolled exposure: Y (Y/N)

If the station is not in compliance under all circumstances of its expected operation, attach a separate sheet describing any limitations of methods that the station operator will use to ensure compliance if people are present in areas that could be out of compliance.

The Dipole Antenna is located 40ft behind the house and supported by poles East by West. It is 40ft high off the ground.



Background on calculation formulas

The following slides provide some background Information on how power, transmission mode, duty cycle, as well as antenna gain are used in formulas to determine actual power at the antenna.

Emission
Duty Cycle

Along with operational duty cycle(talk / listen), the different different transmission modes have different **Emission Duty** Cycles .

Operating Duty Cycle of Modes Commonly Used by Amateurs

Mode	*Duty Cycle*	*Notes*
Conversational SSB	20%	1
Conversational SSB	40%	2
SSB AFSK	100%	
SSB SSTV	100%	
Voice AM, 50% modulation	50%	3
Voice AM, 100% modulation	25%	
Voice AM, no modulation	100%	
Voice FM	100%	
Digital FM	100%	
Analog ATV, video image	60%	
Analog ATV, video black screen	80%	
Digital ATV	100%	
Conversational CW	40%	
Carrier	100%	4
Digital (PSK31, RTTY)	100%	

Note 1: Includes voice characteristics and syllabic duty cycle. No speech processing.

Note 2: Includes voice characteristics and syllabic duty cycle. Heavy speech processor employed.

Note 3: Full-carrier, double-sideband modulation, referenced to PEP. Typical for voice speech. Can range from 25% to 100%, depending on modulation.

Note 4: A full carrier is commonly used for tune-up purposes.

Calculating Average Power Output (to the antenna)

Average Power Output =Transmitter PEP X Emission Duty Cycle X Operating Duty Cycle

Example 1:
A 150W PEP SSB station without speech compression, transmitting and listening equal amounts has:

Average Power Output = 150.W x 20.% x 50.% = 15.W
(150.W x 0.2 x 0.5 = 15.W)

Calculating Average Power Output

Example 2:

A 100W SSB station using AFSK to transmit a digital signal, listening for only ¼ of the time:

Average Power = 100W x 75.% x 100. % = 75.W
= (100W x 0.75 x 1. = 75.W)

Note: Many on-line calculators provide a box for Operating Duty Cycle as well as Mode Duty Cycle

Antenna System Effect On Exposure

You must also take into account the amount of gain your antenna provides, (and you are allowed to account for any losses from the feed line).

Example :

What if the station in Example 1 had an antenna with 6dB of gain:

Decibel	Change in Power	Observed Effect	Example
1 dB	About 20%	Hardly perceivable	1 W → 1.2 W
3 dB	Factor of 2	Just noticeable	1 W → 2 W
6 dB	Factor of 4	Significant	1 W → 4 W
10 dB	Factor of 10	Quite significant	1 W → 10 W
15 dB	Factor of 32	Very significant	1 W → 32 W
20 dB	Factor of 100	Huge difference	1 W → 100 W
30 dB	Factor of 1000	Extreme difference	1 W → 1000 W

Effective Radiated Power = transmitter power x gain

=150W PEP x 4

= 600W PEP Effective Radiated Power

Resulting in:(Example 1)

Average Power Output = 600.W x .2 x .5 = 60.W

Note: Many on-line calculators provide an entry box for antenna gain (coax loss dB can subtracted from the antenna gain dB)

Licensed Amateur Radio Operators:

Your License requires you to keep yourself, family and the public safe.

Rise to the trust placed in you

Do your RF Exposure Evaluation

Links for Additional Reading

The following links will provide additional background on RF Exposure.

A great place to begin (and return) is the ARRL Safety Page on RF Exposure.

Credits & Links:

1) ARRL RF Safety Page
http://www.arrl.org/rf-exposure

2) RF Exposure and You by Ed Hare, W1FI an ARRL Book (free download):
http://www.arrl.org/files/file/Technology/RFsafety
(http://www.arrl.org/files/file/Technology/RFsafety)Committee/RF+Exposure+and+You.pdf

3) ARRL ON-Line RF Exposure Calculator:
http://www.arrl.org/rf-exposure-calculator

4) ARRL HandBook Ch 5 coverage on RF Exposure:
http://www.arrl.org/files/file/Technology/RFsafetyCommittee/28RFSafety.pdf

5) ARRL RF Exposure Worksheets A and B:
http://www.arrl.org/files/file/Technology/tis/info/pdf/rfex1_2.pdf

6) FCC ET Docket No. 19-226 (Initiation of New RF Exposure Rules):
https://docs.fcc.gov/public/attachments/FCC-19-126A1.pdf

Links for Additional Reading (cont.)

7) ET Docket Nos. 03–137, 13–84, 19–226; DA 21–363; FR ID 20760 (**Release of new FCC Rules**)
https://www.govinfo.gov/content/pkg/FR-2021-04-20/pdf/2021-07720.pdf

8)ARRL QEX Article (Handheld Transceivers): Exposure Considerations Based on SAR
http://www.arrl.org/files/file/QEX_Next_Issue/2021/07%20Jul-August%202021/07%20JulAug21%20QEX%20Tell.pdf

9)QST Article RF Safety at Field Day
http://www.arrl.org/files/file/Technology/tis/info/pdf/9906048.pdf

10) FCC Report and Order FCC 96-326, 1996 (Initial Relese of RF Exposure Rules):
https://transition.fcc.gov/Bureaus/Engineering_Technology/Orders/1996/fcc96326.pdf

11)FCC Publication: OET BULLETIN 56, 4th Edition:
Questions and Answers about Biological Effects and Potential Hazards of Radio Frequency Electromagnetic Fields
https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet56/oet56e4.pdf

12)FCC OET Supplement B Bulletin 65 (**Additional Information for Amateur Radio Stations**):
https://transition.fcc.gov/bureaus/oet/info/documents/bulletins/oet65/oet65b.pdf

13)FCC OET Supplement C Bulletin 65 (Mobile and Portable Devices):
https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet65/oet65c.pdf

14)FCC Policy on Human Exposure to Radio Frequency Electromagnetic Fields
https://www.fcc.gov/general/radio-frequency-safety-0