Maximum Permissible Exposure (MPE)

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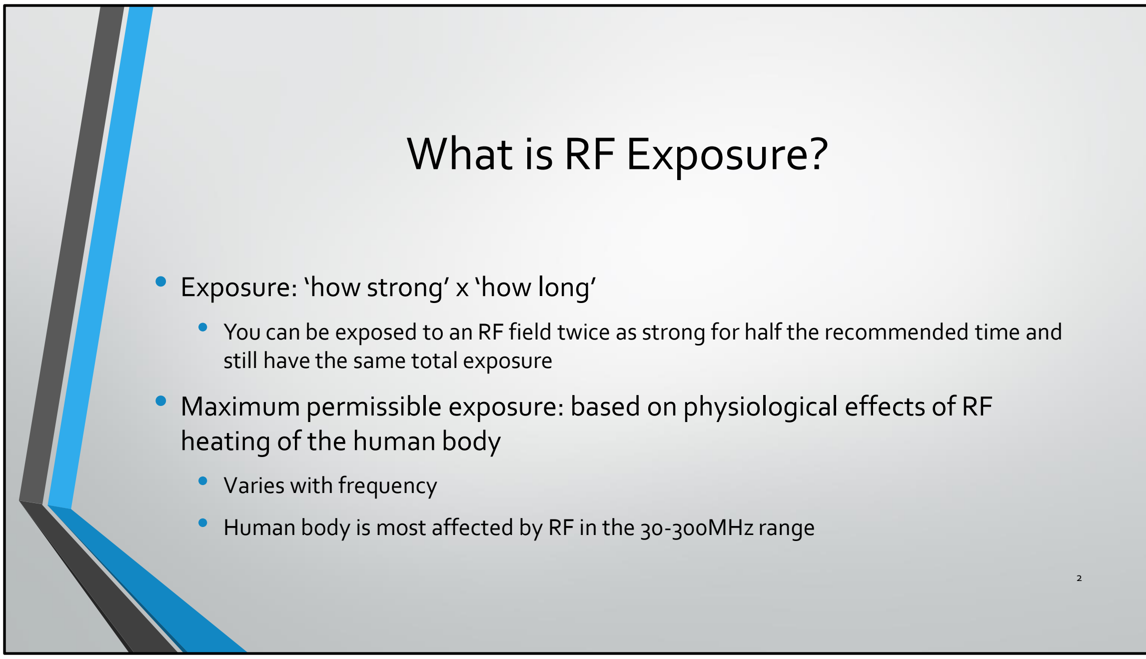
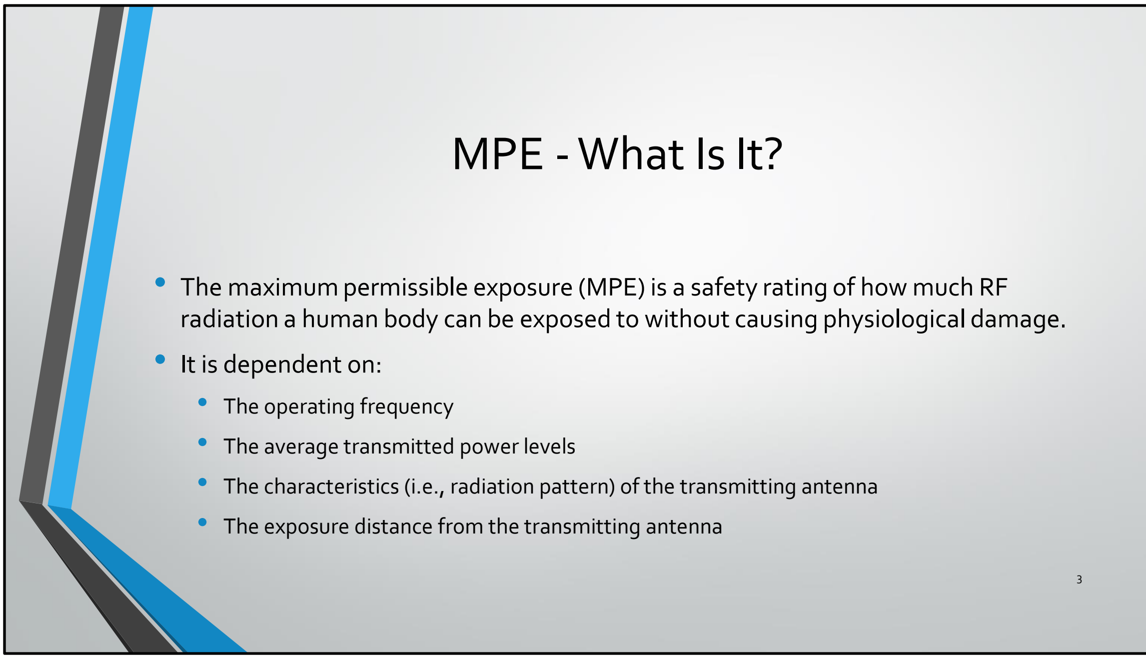
This presentation is designed to introduce hams to the latest FCC rules and regulations regarding maximum permissible exposure compliance.



So, what is RF exposure?

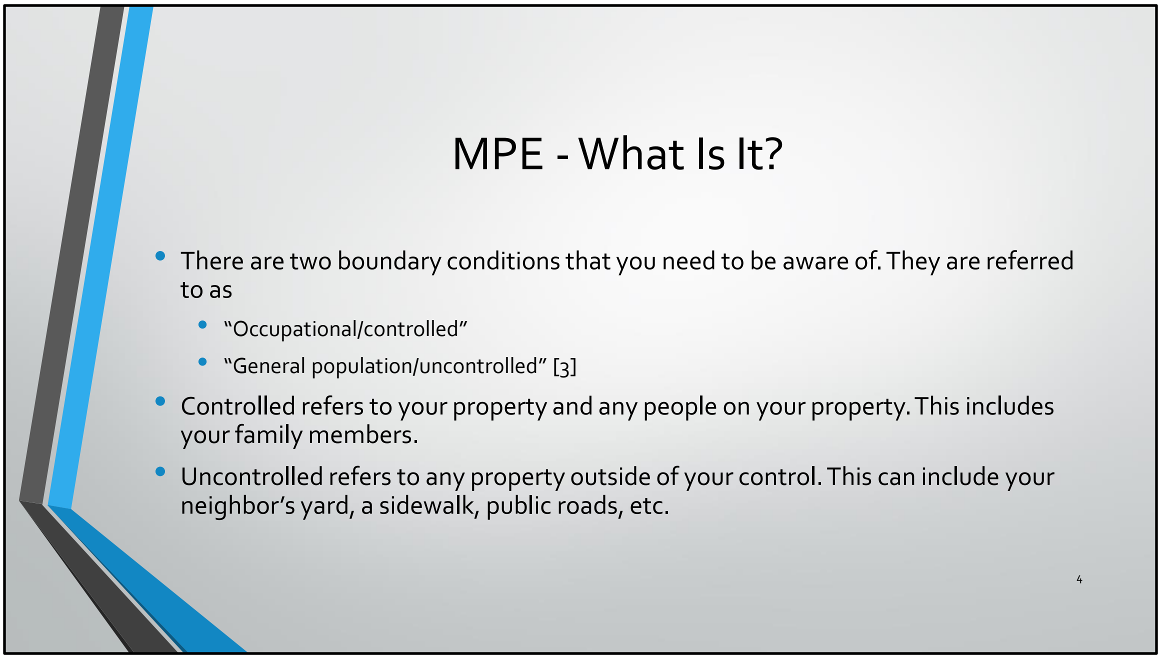
Exposure is really a measure of how strong the signal is versus how long you're exposed to it. In other words, 'how strong' times 'how long' is your exposure. For RF fields, you can be exposed to a field that's twice as strong for half the recommended time period and still have the same total exposure.

The maximum permissible exposure numbers and ratings that are assigned come from physiological effects of RF heating on the human body. This varies with frequency, but one thing to be aware of is that the human body is most affected by RF that is in the 30 to 300 MHz range. We'll show graphs later that explain this in more detail.



The maximum permissible exposure is a safety rating derived from EPA and other medical studies for how much RF radiation a human body can be exposed to without causing physiological damage. This means things like burns to the skin, deep tissue, and vital organs.

It's dependent on the operating frequency, the average transmitted power level, the characteristics of the transmitting antenna (particularly the radiation pattern and how energy is being directed towards you) and the distance from the antenna to where the individual is located.

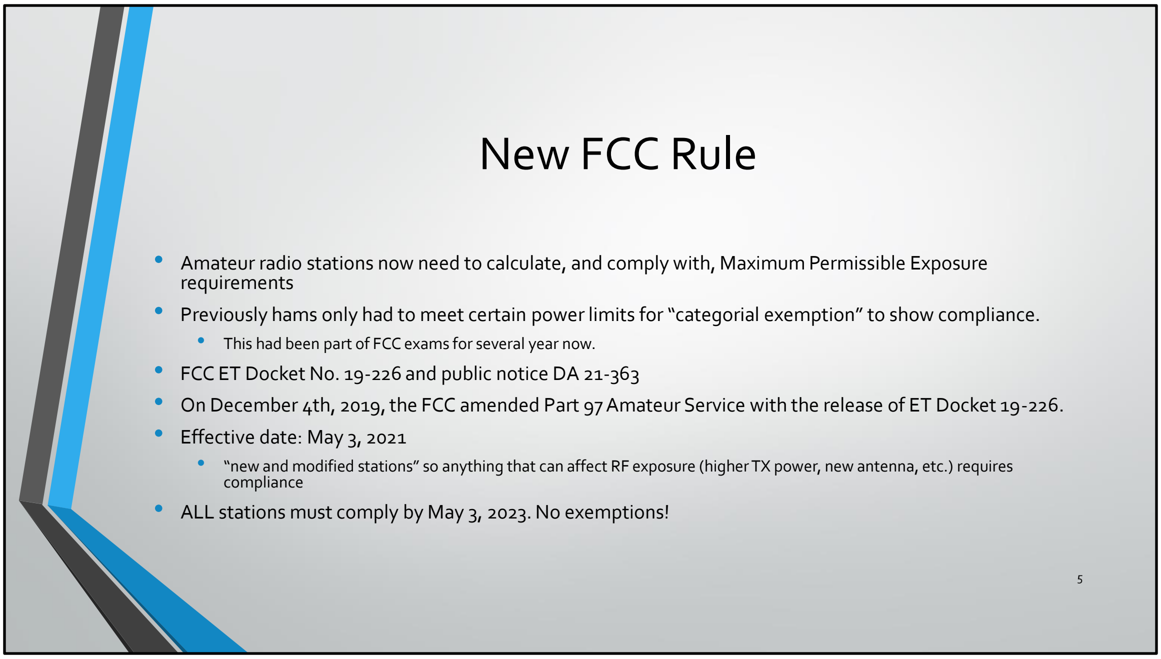


For maximum permissible exposure ratings, there are two terms you should be aware of. FCC documentation for maximum permissible exposure uses two terms to describe the exposure scenarios: "occupational" or "controlled" and "general population" or "uncontrolled."

Occupational or controlled refers to workers or individuals that are in the presence of an RF environment which is controlled by the person or company operating the equipment.

General population or uncontrolled means the general public is somewhere around the antenna but you, as the owner of the equipment, do not have direct control over where people go. Scenarios can include public sidewalks, public roads, etc.

Controlled environments pertain to your property. For amateur radio evaluations, your family members are considered aware of the potential for RF radiation in the controlled environment.

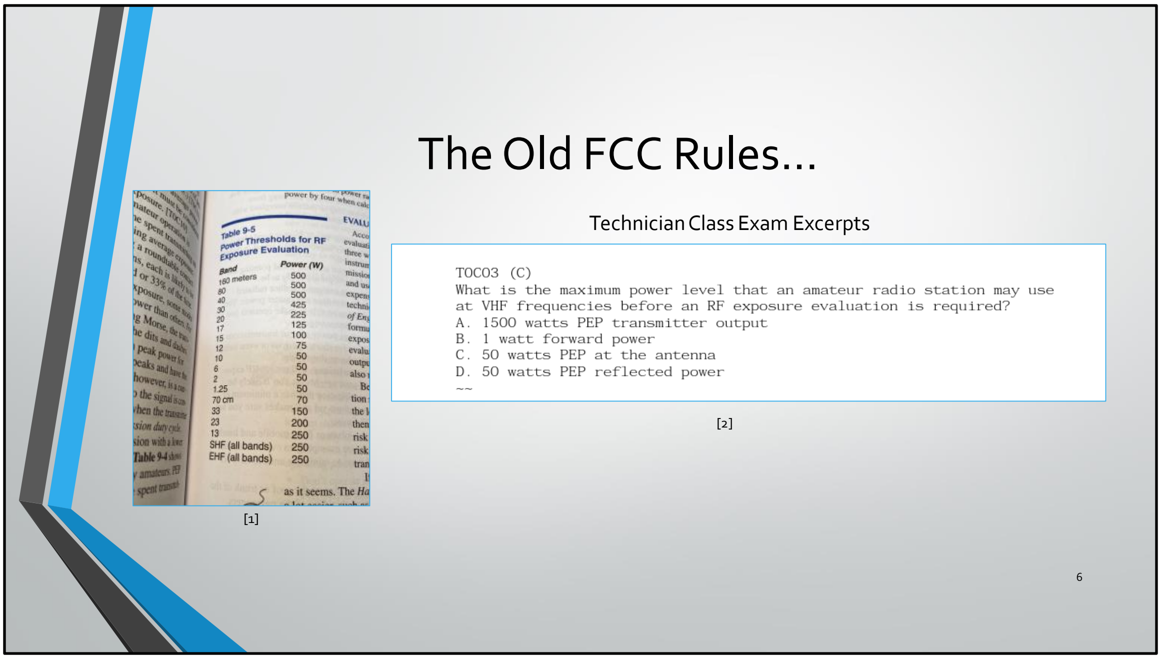


Under the new FCC rules, you now need to comply with the maximum permissible exposure requirement.

In the past, hams only had to meet certain power limit restrictions under what was called a "categorical exemption." This is something that has been taught in the license manuals and has been on our exams for several years.

The categorical exemption has now been removed, so the previous power-only limitations are no longer applicable. The two FCC documents cited describe the changes regarding maximum permissible exposure compliance.

The effective date for these changes was May 3, 2021. **To comply with the new regulations, you need to conduct these assessments by May 3, 2023.**



Under the old rules we focused strictly on our frequency of operation and our power levels. If you were running less than the specified power, you were considered exempt from having to conduct an analysis.

The excerpts from the ARRL license manual, and the Technician Class exam pool for 2018-2022 describe what was previously taught.

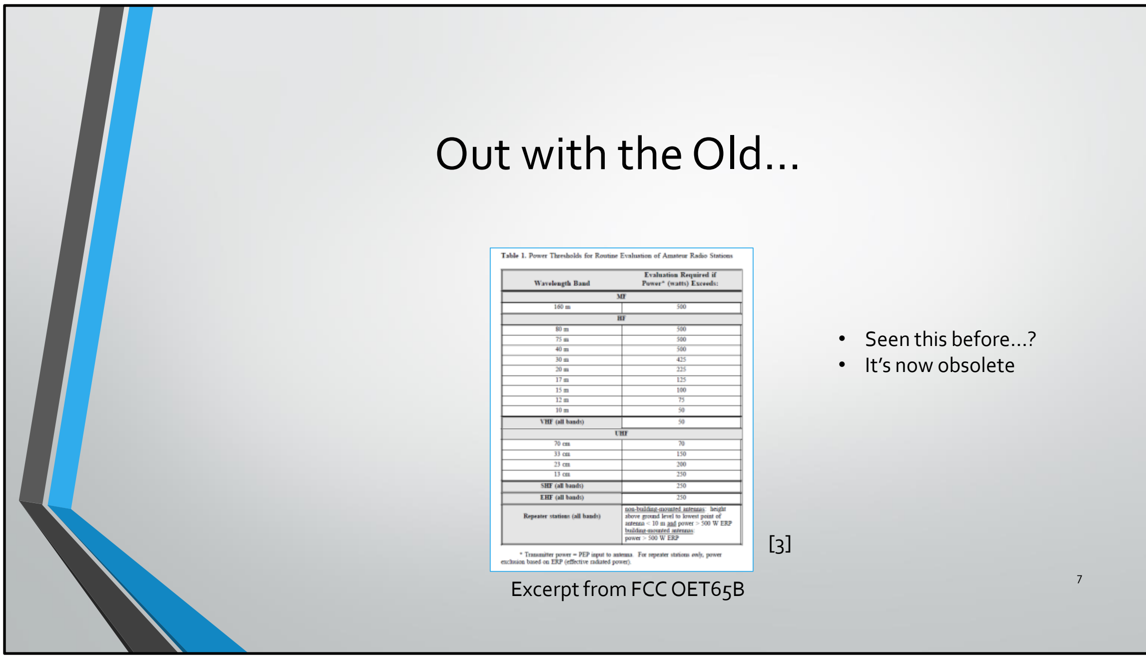


Table 1. Power Thresholds for Routine Evaluation of Amateur Radio Stations

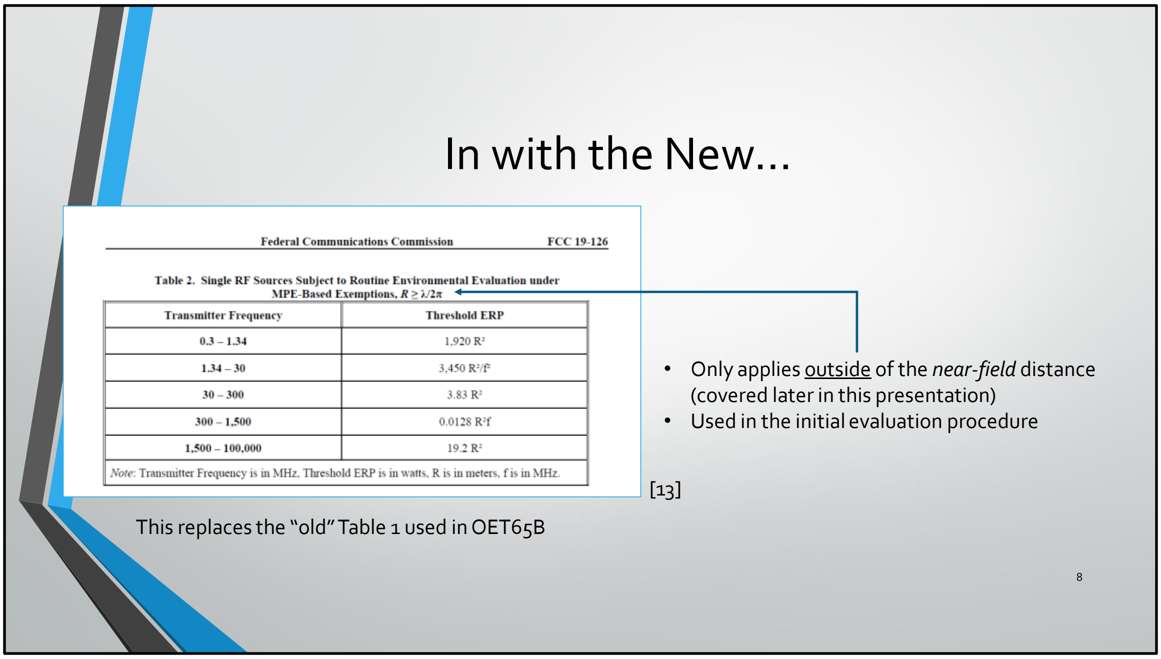
Wavelength Band	Evaluation Required if Power* (watts) Exceeds:
MF	
160 m	500
HF	
80 m	500
75 m	500
40 m	500
30 m	425
20 m	225
17 m	125
15 m	100
12 m	75
10 m	50
VHF (all bands)	50
UHF	
70 cm	70
33 cm	150
23 cm	200
13 cm	250
SHF (all bands)	250
EHF (all bands)	250
Repeater stations (all bands)	non-building-mounted 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).

Excerpt from FCC OET65B

You may have seen this table before. It's essentially the same as what was shown in the previous slide. At the bottom of the table is a minor comment on how power levels for repeaters are calculated.

This table, and the old power-only considerations for exemption are now obsolete.



Federal Communications Commission FCC 19-126

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.	

The old Table 1 has been replaced by this new Table 2 in FCC document 19-126. Notice that discrete power levels are no longer shown. Instead, the effective radiated power levels vary with the distance from the antenna and the frequency of operation.

The new table represents the effective radiated power levels that "exempt" you from having to complete a routine MPE evaluation. It's best to treat this table as an initial go/no-go assessment for the evaluation requirement.

There is a key concept that needs to be understood when using this table. The arrow points to a line that shows the formula $R \geq \lambda/2\pi$. This distance is frequency dependent, so the criteria for using this table is also frequency dependent.

Your first step is to determine if your distance to the antenna is greater than or less than the calculated distance R. If your distance is less than R, you are in a region known as the near-field. If your distance is greater than R, you are in a region known as the far-field. We will discuss the importance of these distinctions in subsequent slides.

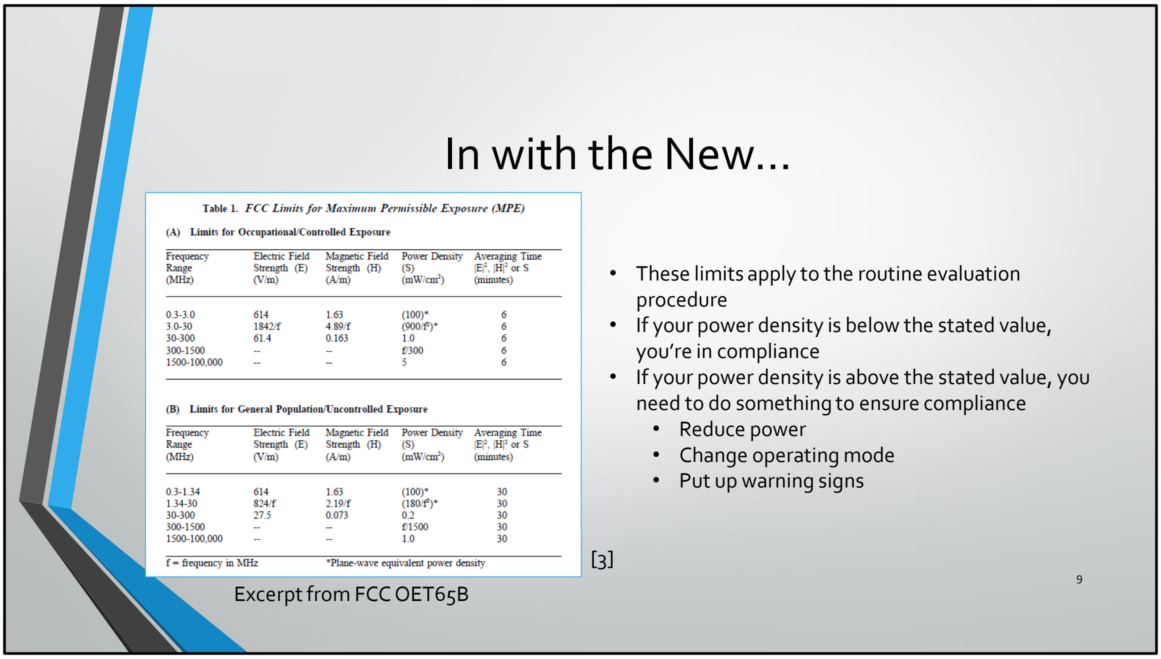


Table 1. *FCC Limits for Maximum Permissible Exposure (MPE)*

(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/cm²)	Averaging Time $\lvert E\rvert^2$, $\lvert H\rvert^2$ 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

(B) Limits for General Population/Uncontrolled Exposure

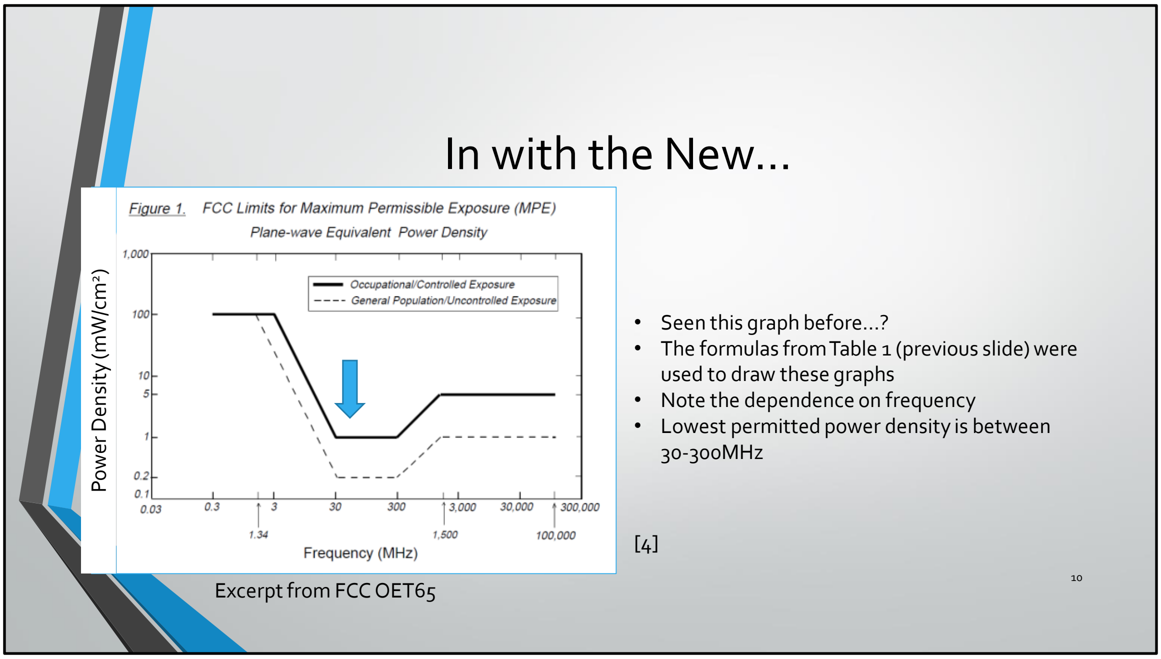
Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm²)	Averaging Time $\lvert E\rvert^2$, $\lvert H\rvert^2$ or S (minutes)
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	$(180/f^2)$*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

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

Regardless if you're in the near-field or the far-field these are the actual power density levels that need to be complied with.

The power density values are the key numbers that we're going to be calculating. The power density varies with frequency in a few instances and is constant in others. The two parts of the table relate to the permissible power densities in the controlled and uncontrolled scenarios we previously mentioned. The uncontrolled scenario's power density values are more stringent than in the controlled scenario.

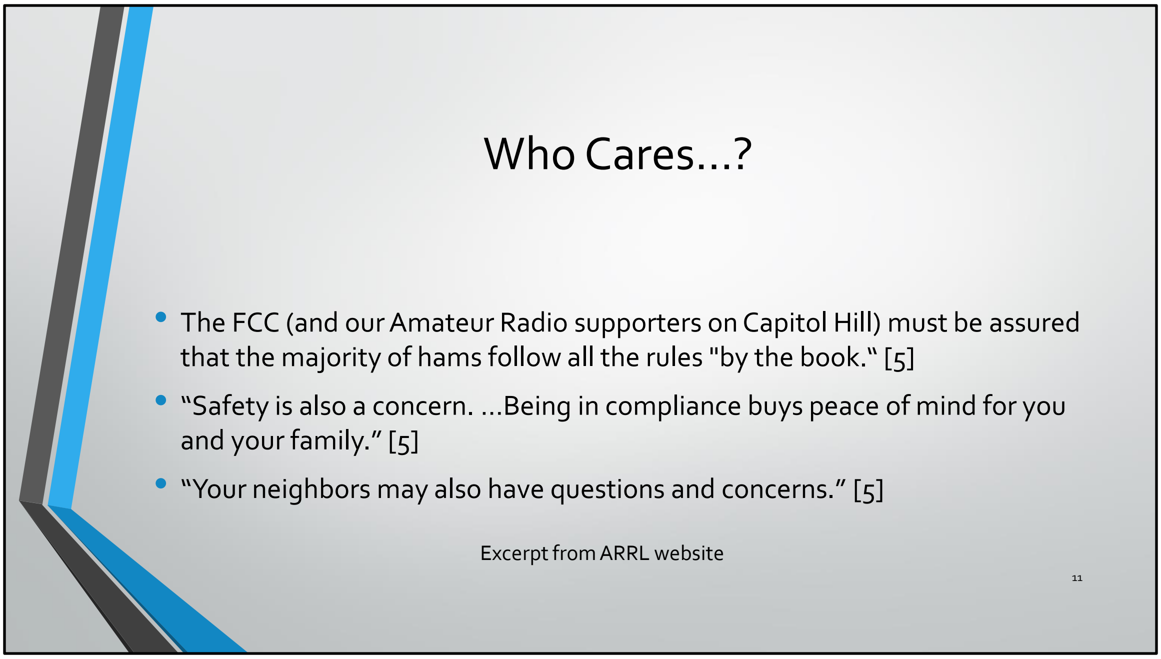
If you comply with these power density requirements, you're "good to go" but if you are operating at power densities above these values, you're going to need to make some changes. This might (unfortunately) involve reducing your power, restricting the operating mode, or putting up warning signs.



You may have seen this graph before. It's a graph of the maximum permissible exposure levels using the formulas in the prior table. Notice that the lines vary with frequency.

There are two lines on the graph. One is for the controlled exposure environment (solid line); the other is for uncontrolled exposure (dashed line). You can operate with higher power densities in the controlled scenario as opposed to the uncontrolled scenario.

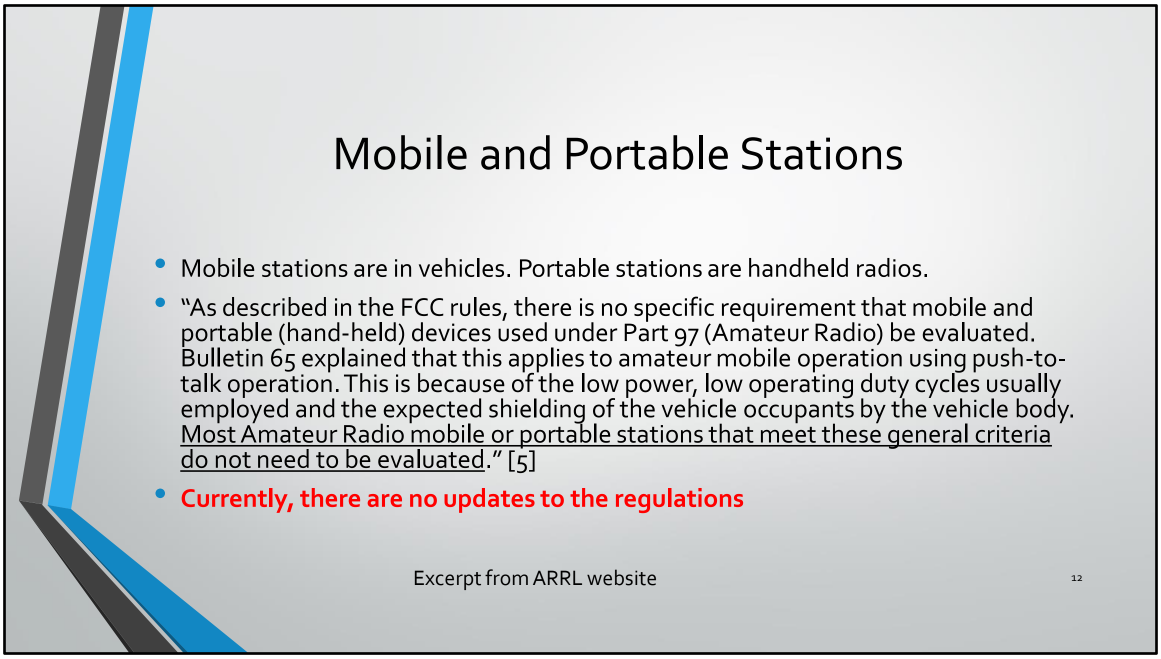
These levels vary with frequency, but if you look where the arrow is pointing, the frequency range of most concern falls between 30-300MHz. The absorption of RF energy by the body is greatest within this frequency range.



So, you look at this and you just ask yourself, who cares?

Well, guess what; we're required to do the calculations now. We're required to do our homework.

These quotes come from the ARRL website. The League is looking at the potential benefit to the amateur radio community if we comply by conducting these calculations just like all the other licensed radio services under the FCC's jurisdiction. It helps us in seeking recognition for the Amateur Radio Service and in getting political sponsors to support ham radio. The calculations verify that you are being careful with your own safety and the safety of your family members. And, in case you have a crazy neighbor who starts asking questions, you would be able to say I did the analysis per FCC requirements and you're safe.

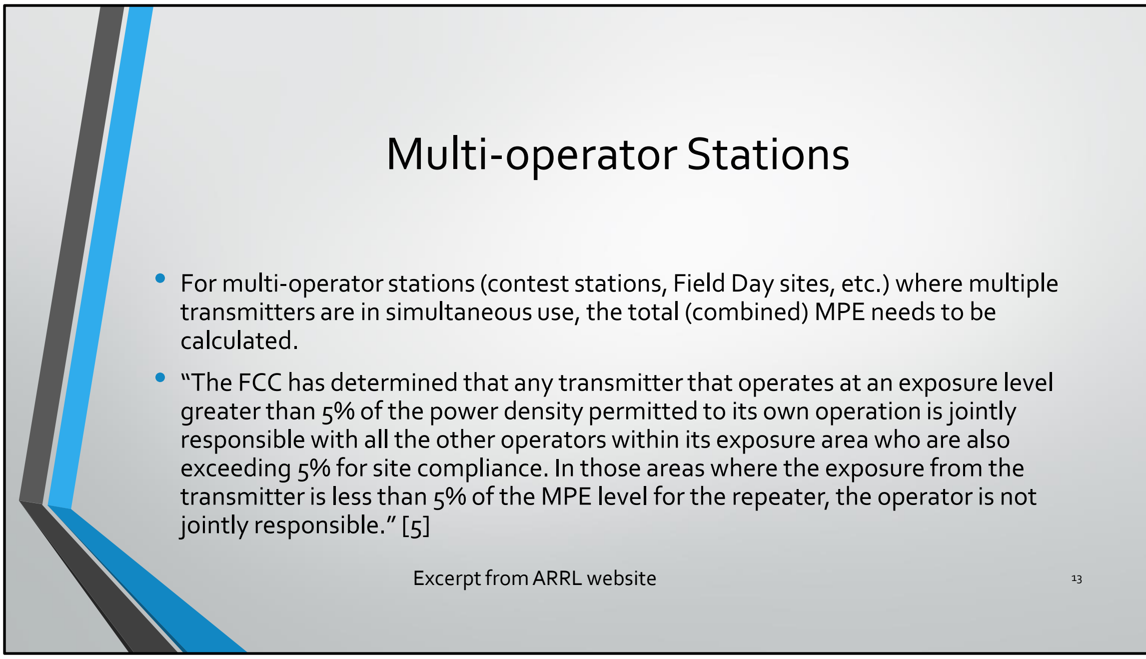


In the FCC rules mobile stations refer to radios installed in vehicles. “Portable stations” refer to handheld radios as opposed to taking a radio out in the field and putting up a temporary antenna.

If you wade through all this legal jargon, mobile and portable stations are (thankfully) exempt from the evaluation criteria.

The FCC’s justification is that in using push-to-talk operation, your average transmission activity is very low, hence the average ERP is low. With a mobile rig, you’re driving past an area, so somebody is not continuously exposed to the RF coming from the vehicle. The same can be said for handheld operation.

At this moment there are no updates to the regulations. The descriptions here follow what's in the FCC bulletins that have been around since 1997. I would expect, at some point in the future, the FCC will be revisiting this topic.

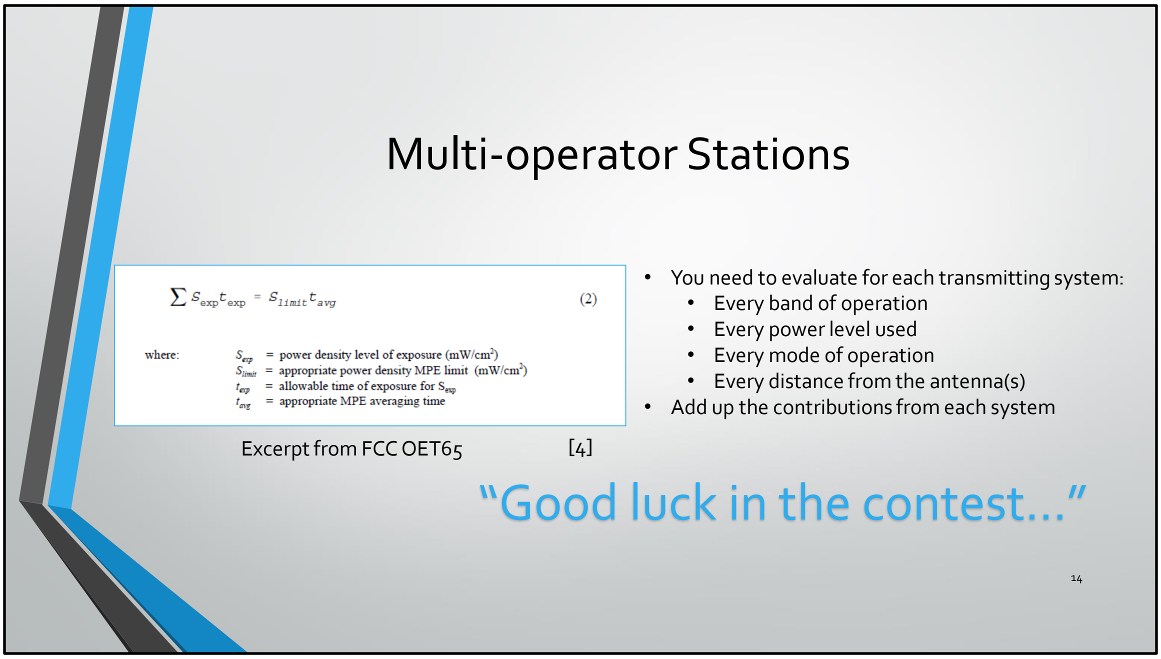


In addition to evaluating your own station, you need to evaluate multi-operator stations as well. This would include contest stations and even Field Day sites; any place where you have multiple transmitters operating simultaneously.

The calculations are the same for each of the operating positions, but you combine the results to assess the aggregate exposure level.

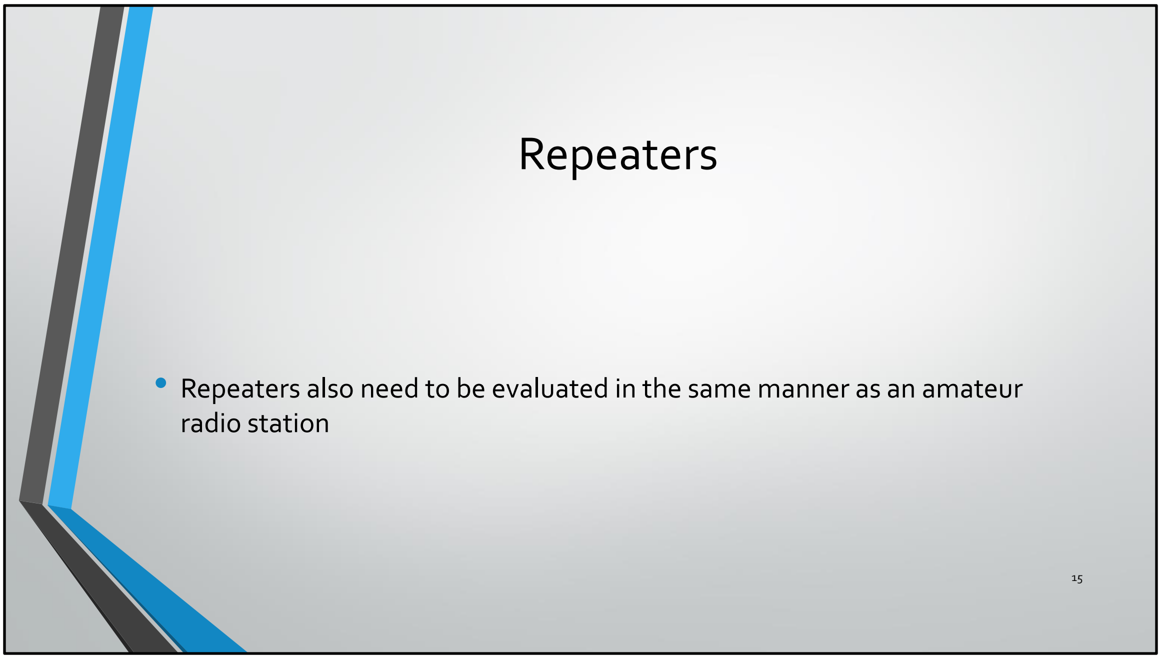
Weeding through the legal jargon, evaluate each operating position for it's "maximum generating" capability. Then, if you operate for less than 5% of that level, you don't need to add it to the overall aggregate exposure calculation.

Now, let's think about how this would apply in a Field Day scenario. Let's say you're operating 2A and have stations running SSB on 80 meters and PSK31 on 40 meters. Those two operating positions are assumed to be in use throughout the contest. If an occasional visitor wanted to operate the GOTA station on 20 meters, it (most likely) won't have to be included in the calculations. For the 80-meter and 40-meter stations, just perform the calculations under their normal operating assumptions. Add the two power density values and ensure that the aggregate is below the safety level.

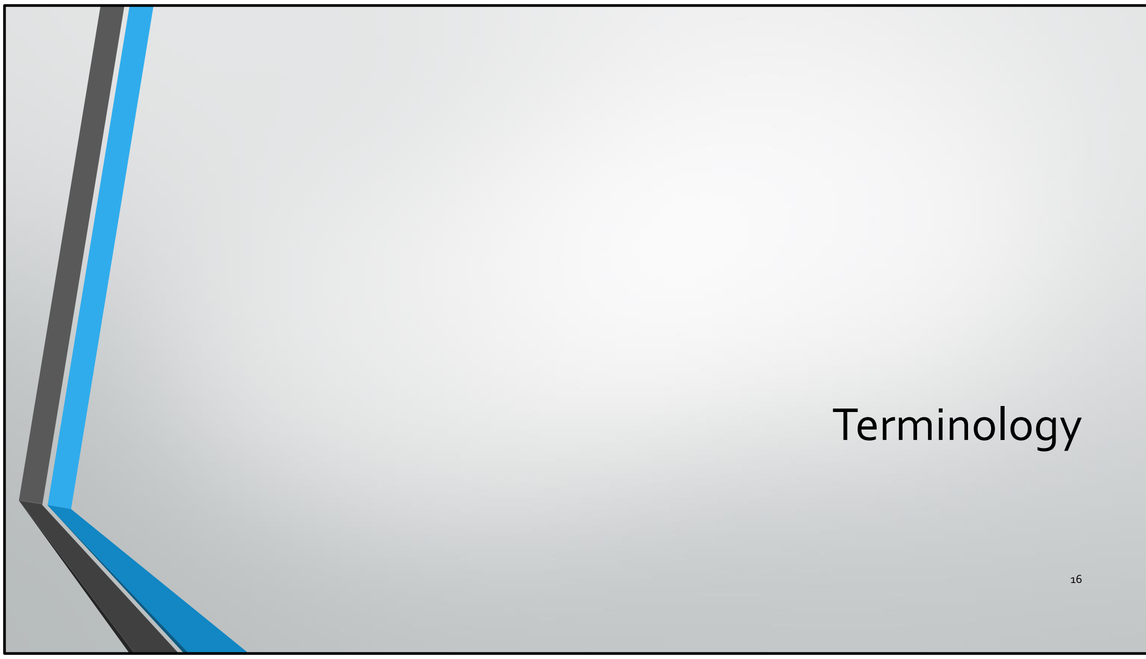


For the multi-operator-stations you need to evaluate each transmitter, associated antenna system, band of operation, power level, mode of operation and distance from the antennas.

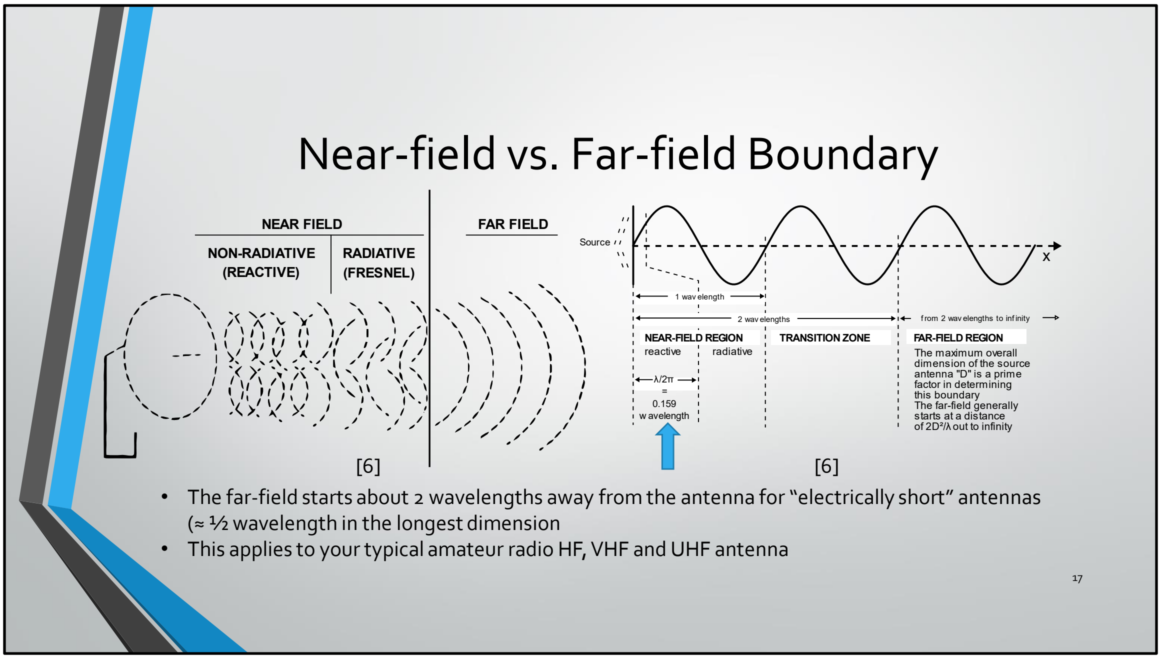
Add up the individual contributions and, so long as they are below the thresholds for the controlled or uncontrolled environments, you're in compliance.



Previously, repeaters were held to a slightly different interpretation of how to perform the calculations. Calculations were in ERP (the effective radiated power) instead of the effective isotropic radiated power. Under the new rules everything is evaluated as if it's just another amateur station. You still need to comply with the same maximum permissible exposure levels.



The new regulations have introduced a different thought process for hams compared to our previous power-level, exemption-based methods. Let's clarify some of the terminology used in the evaluation process.



There are two key terms you need to be aware of in the new calculations. One is the term near-field, and the other is the far-field. These are essentially boundary conditions that you need to take into consideration when making the assessments for both the initial and the routine power density calculations.

As the name suggests, the near-field is a region very close to the antenna. This region is evaluated separately because the antenna pattern has not fully formed and the power levels that you measure close to the antenna are not the same (or not the same level) that would be measured farther away from the antenna. This gets into antenna theory, so we're not going to go into the nuances here.

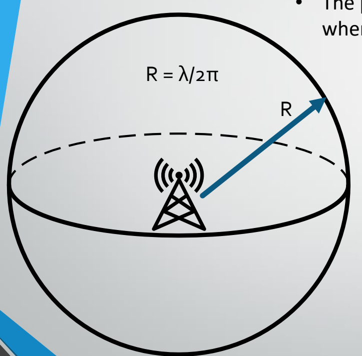
The key boundary shown with the blue arrow is the near-field region. This distance, λ/2π, corresponds to the non-radiative or reactive field where the power levels are significantly different than they would be in the far-field.

When calculating exposure levels, or making a measurement, you need to be aware if you are in the near-field or the far-field.

As you go further away from the antenna, you begin to approach the far-field condition. For most ham radio antennas, we are using what are called "electrically short antennas," meaning that they're around 1/2 wavelength long in one of their dimensions. For electrically short antennas, once you’re about two wavelengths away from the antenna, you’re into the far-field region.

Near-field Definition

- Near-field Boundary: defined by the radius R of a sphere around the antenna
- The power density in the near-field is (relatively) constant vs. in the far-field where it decreases with $1/R^2$



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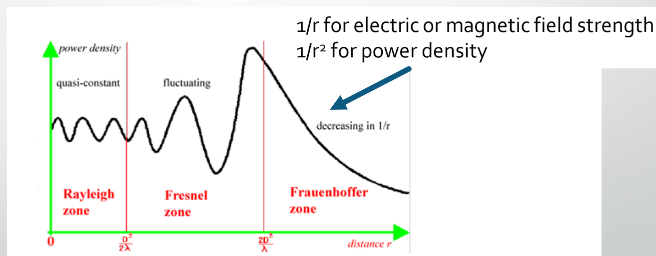

Fig. 1 : Diagram of the power density related to the distance from the antenna

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The near-field is defined by a spherical region or "bubble" around your antenna. That bubble has a radius of λ/ 2π, where λ is the wavelength. If you look at the graph on the right it describes the Rayleigh zone which corresponds to the near-field.

You'll notice that close to the antenna the power level will be lower than at points further away. When the emitted waves begin adding up in-phase (further from the antenna), the amplitude grows at one point and then they begin to fall off as you proceed into the far-field.

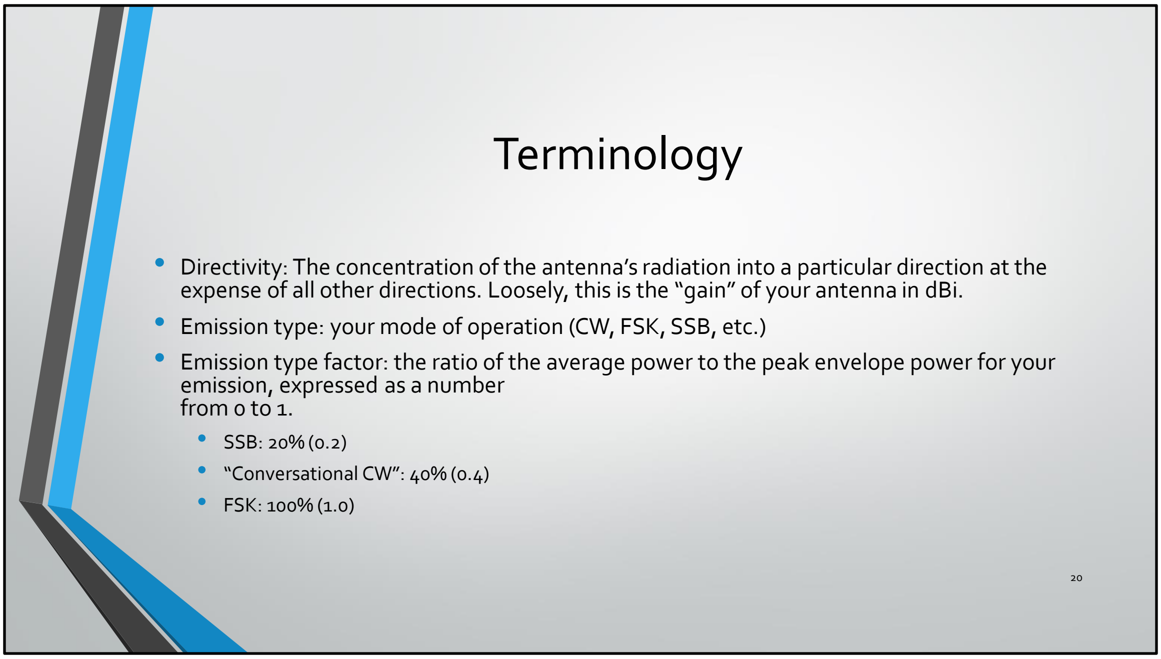
The important thing to remember, is that the near-field conditions are not the same as the far-field conditions.

Putting the Near-field in Perspective

Examples of near-field boundary conditions for $R = \lambda/2\pi$

Band (meters)	Near-field Radius (m)	Near-field Radius (ft)
160	25.46479089	83.54590456
80	12.73239545	41.77295228
40	6.366197724	20.88647614
30	4.774648293	15.6648571
20	3.183098862	10.44323807
17	2.705634033	8.876752359
15	2.387324146	7.832428552
12	1.909859317	6.265942842
10	1.591549431	5.221619035
6	0.954929659	3.132971421
2	0.318309886	1.044323807
1.25	0.198943679	0.652702379
0.7	0.11140846	0.365513332

Let’s put the near-field distances in perspective. At low frequencies such as 160 meters or 80 meters you’ll notice that the radius is quite large (83 feet and 41 feet, respectively). This probably is going to encompass a distance many hams have for their yards in typical suburban environments. At lower frequencies there is a good chance that all your calculations will be in the near-field. It's only until you get to the higher frequencies that most of your calculations will be in the far-field.



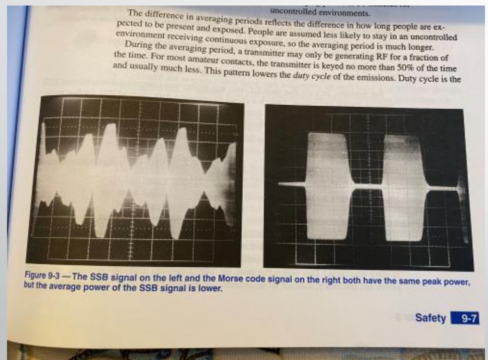
The terminology here is derived from FCC document OET65B which was release in 1997. I've developed a spreadsheet to compute MPE compliance and use the same terminology.

Directivity is a measure of how much an antenna is radiating energy in one direction and is not radiating it in another direction. The gain of our antenna is expressed in dBi or dB relative to an isotropic source. A 0dBi antenna means that you have a single point source that radiates equally in all directions.

Emission type refers to your mode of operation (CW, digital, SSB, etc.).

Emission type factor is a numerical value that expresses the ratio of the average power to the peak envelope power. The emission type factor is automatically selected in the spreadsheet when you select the emission type.

Terminology - Emission Type Factor and PEP



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- The peak power (or peak envelope power PEP) is the same in both cases
- AM and SSB peak amplitudes vary with speech, hence the average power is lower than the CW case
- SSB speech processing increases the average power
- For FM and digital modes, the average power is the same as peak power

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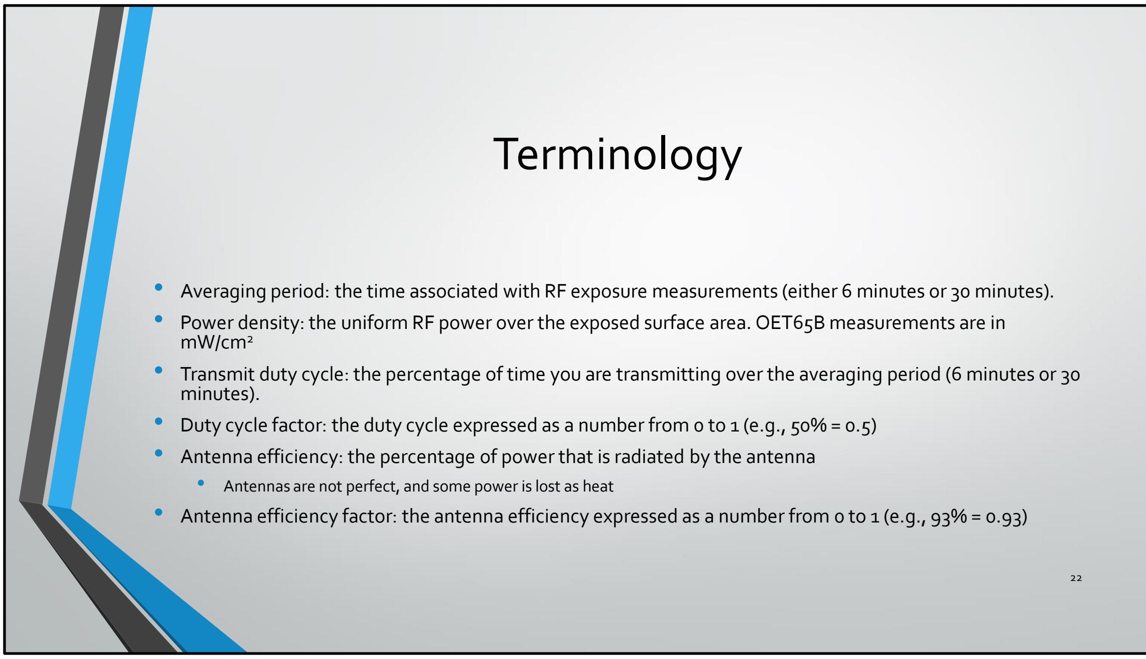
As a refresher, look at the pictures (graphs) at the left side of the slide. SSB is shown on the leftmost graph, while CW is on the rightmost graph. The peak power (peak amplitude) is the same for both modes of operation.

The SSB example has a lower average power because the peak power varies with the speech pattern. The CW example, however, has a higher average power because the signal is either off or at full peak power. In FM or digital modes such as FT8, the average power is the same as the peak power, and the emission type factor is 1.0.



In the maximum permissible exposure calculations, there are two **averaging or measurement periods** to consider. For the controlled exposure scenario, you're averaging the power over a 6-minute interval. For the uncontrolled scenario you're averaging power over a 30-minute interval.

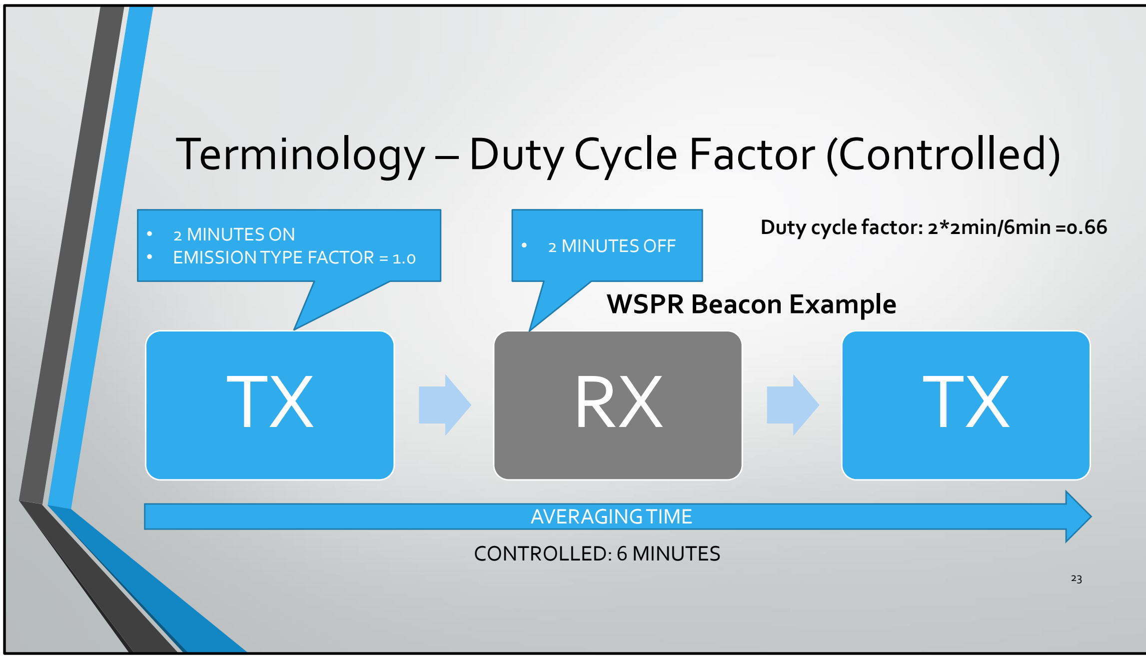
Power density refers to the RF power that's radiated toward the body of a person. The energy incident on the body is converted to heat. In the OET65B bulletin, power density is expressed as milliwatts per square centimeter.

Transmit duty cycle refers to how often you're transmitting versus how often you're listening. The duty cycle is relative to either the 6 minute or 30-minute interval under consideration. Transmit duty cycle is expressed as a percentage. In the spreadsheet (as a worst-case assessment), use the highest value of either the 6-minute or 30-minute calculations.

Duty cycle factor is a numerical value that expresses the transmit duty cycle as a number rather than a percentage.

No antenna is perfectly efficient; some of the energy is burned up as heat as opposed to being radiated. For the average amateur antenna, you're probably not going to be able to find or calculate the **efficiency** of your antenna. It's tricky to really figure out what the efficiency of an antenna is especially at the lower HF frequencies where losses in the radials or the ground play a significant part in any calculations. If you do not know the antenna efficiency, use 100%.

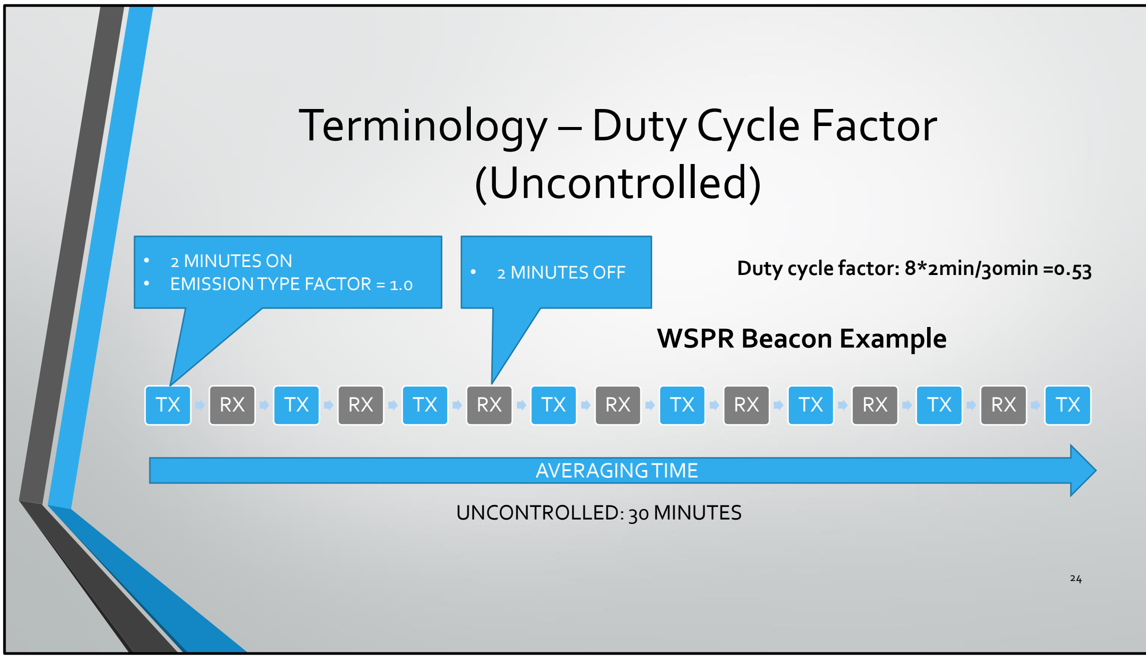
Antenna efficiency factor is a numerical value that expresses the antenna efficiency as a number rather than a percentage.



The transmit duty cycle, and the duty cycle factor are dependent on the mode of operation and the averaging period under consideration. This slide, and the next, show the differences that occur when computing the duty cycle factor for both the controlled and uncontrolled scenarios.

In these examples, a WSPR beacon is assumed only because the math is easier. A whisper beacon continuously transmits for about 2 minutes then switches over to a receive mode. Assume that operation continuously cycles between transmitting and receiving intervals.

In the above example, there are two, 2-minute transmissions over a 6-minute period. The duty cycle factor is thus 0.66.



Now, consider the uncontrolled scenario with a 30-minute average period. There are now a maximum of eight 2-minute transmissions over the 30-minute window. The duty cycle factor is 0.53.

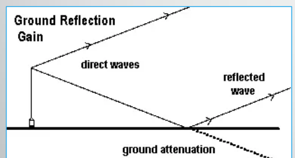
You'll notice that the duty cycle factor went down from 0.66 (for the controlled scenario) to 0.53 (for the uncontrolled scenario) due to the increased averaging time.

In the spreadsheet, it is best to select the largest duty cycle factor value to provide a worst-case evaluation.

The assumptions behind the duty cycle factor can vary significantly from one operational scenario to another. The FCC recognizes the potential for variability in number chosen in any of the calculations. Just state your assumptions and proceed with the calculations.

Terminology – Ground Reflection Gain

- In theory, you can achieve up to 6dB of gain due to ground reflections
- OET65B equation (7) uses a more realistic EPA-derived value of 4.08dB
- For worst-case MPE, use the ground reflection calculations



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> However, at distances much closer to the antenna the patterns are quite different. For example, reflected rays from trees and buildings which do not contribute to the far-field patterns are very much in evidence and must be taken into consideration when calculating near-field power density.
>
> Exposure levels which meet FCC requirements for Amateur Radio stations will translate into near-field distances for most (if not all) antenna configurations and transmitter power levels. Therefore, the contribution of ground reflection effects MUST be included in the MPE calculation in order to arrive at valid results.

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Several of the online maximum permissible exposure calculators have a check box that asks whether you want to include ground reflections in your calculation.

I wanted to explain what that means and why it's important for a typical electrically small antenna.

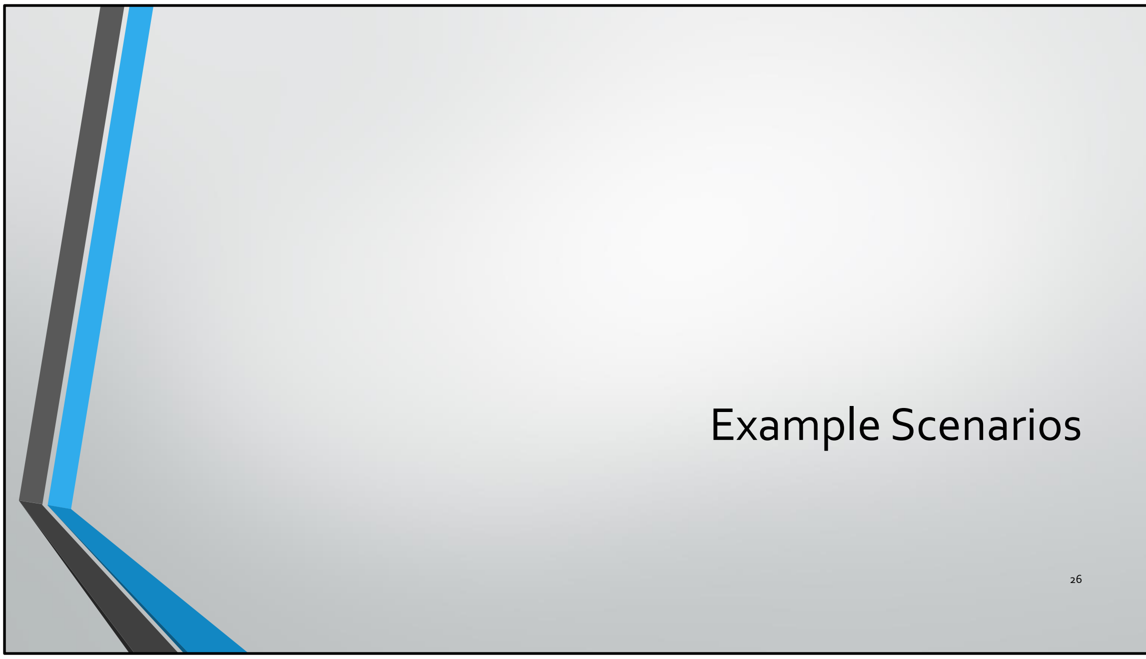
The radiated signal leaves the antenna both in a direct path and in a reflected path. The signal is reflected off the ground or off any nearby conductive surface. Some of the reflected energy combines with the direct path energy, producing an apparent gain higher than that of the antenna alone in free-space. This reflected energy is responsible for the ground reflection gain of the antenna system.

In theory, if you had a perfect ground or a perfect reflective surface, you could see an increase in gain of up to 6dB. In the OET65B bulletin, however, calculations use a more realistic value for the Earth's surface. The equations in the bulleting are derived from EPA and other documents where measured values were compared against theoretical values. In the case of the OET65B calculations, the maximum ground reflection gain is closer to 4dB.

Regardless of the ground reflection gain number used, just remember that the reflection scenario will produce a higher antenna gain than without reflections. The reflection scenario is thus the worst case.

Reflections are produced not just by the Earth's ground but by any metallic surface in the beam of the antenna. A metal roof on a building, or other metallic object near the antenna, could potentially produce a reflection gain in a specific direction.

Commercial antenna systems typically consider the antenna pattern and off-axis radiation in the uncontrolled exposure calculations. In an amateur radio antenna system, however, that information may not be readily available. For this reason, the maximum antenna gain should be used as a worst-case assessment.



Let's look at two examples showing how the considerations behind maximum permissible exposure calculations. These are examples of my HF antennas; one of them is in my backyard and the other one is at a mountain cabin.

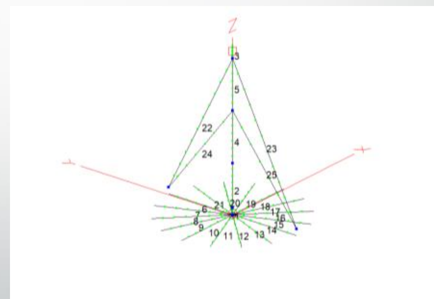
This is a Google Earth view of my house. I've indicated where my fence line is, where my deck is, and where a homebrew vertical antenna is located. The separation from my antenna to the fence line is only about 10 feet.

From the definitions of controlled versus uncontrolled environments, anything inside of my fence is considered a controlled environment and anything outside of my fence is an uncontrolled environment. The uncontrolled environment (i.e., my neighbor’s yard) is only 10 feet away from my antenna.

For the same backyard configuration, let's consider the distance from my antenna to chairs and a table located on my deck. The deck, chairs and table are on my property hence this is considered a controlled environment. I want to conduct the MPE calculations for my family's safety. My wife likes sitting outside and enjoying the sun while reading a book, so I want to make sure it's safe for her if I decide to operate in this scenario. The distance from the antenna to the nearest chair is only about 8 feet.

Backyard Antenna

- My "lousy" homebrew antenna designed to get me on the air on the lower bands.
- Construction:
  - A modified 6BTV with traps removed
  - 80-meter resonator on top retained
  - #14 wire attached to aluminum tubing
  - Feed point near the radials which are elevated by 0.1ft
    - NOT an accurate model of ground losses
    - Elevated radials used for EZNEC2 convergence



Homebrew vertical antenna

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My backyard antenna is a "lousy" vertical. It started off as a 6BTV; over time some of the traps failed. I pulled all the traps out (retaining only the 80-meter resonator on top) and basically turned the thing into an 18-foot aluminum stick. I had trouble getting my MFJ tuner (at the base of the antenna) to operate properly on 80 and 40 meters. I added some wire extensions to try and "fatten up" the antenna's surface and make it more broadband. Adding these wires helped in getting a little bit better performance on 80 and 40 meters, but by no means is this an optimal antenna. I painted the antenna tubing with flat black paint to help it blend in with trees, making it as "HOA friendly" as possible. I have very limited radial space and do not have anywhere near the ideal number of radials on the ground.

Evaluating this antenna system using a tool like EZNEC is only going to provide a coarse estimate of the antenna's actual performance. EZNEC and other tools do not model radial systems buried in the ground (unless you use the more advanced commercial versions) nor do they model radials well that are extremely close to the ground.

Backyard Antenna – EZNEC Simulation Results

Frequency (MHz)	Marker Gain (dBi)
3.5	-3.8
7.0	-2.22
10.1	-1.33
14.0	-0.63
18.1	-4.0
24.9	1.7
28.0	2.67
50.0	4.54

EZNEC simulation results showing the maximum gain value at each marker frequency

- The gain changes with frequency.
- The azimuth pattern is symmetrical up to 14MHz.
- The antenna pattern is no longer "omnidirectional" at 18.1MHz and above.

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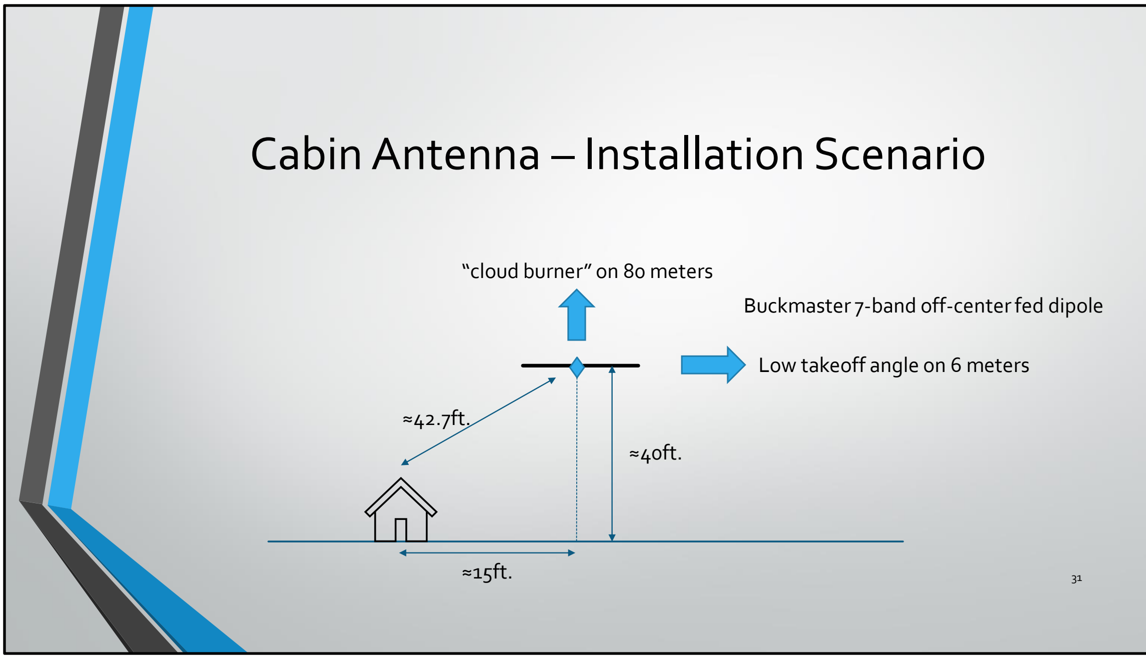
I ran the EZNEC simulation through the different bands of operation. For each plotted result, I recorded the marker value corresponding to the maximum gain.

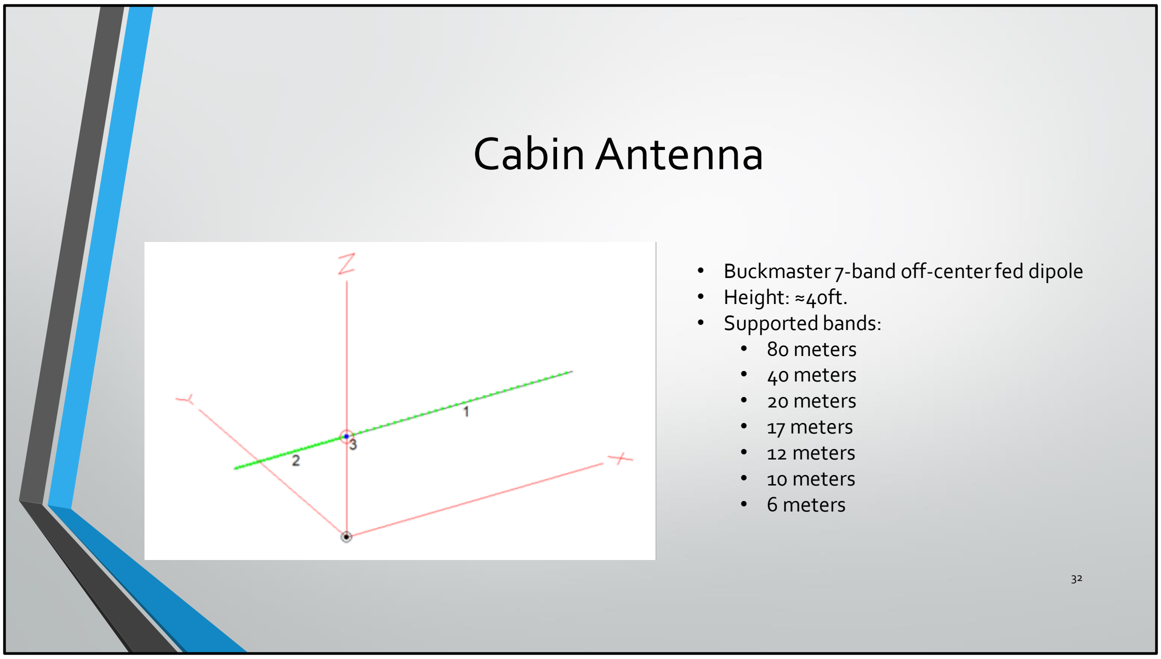
From the table, at 80 meters the antenna has a "gain" of approximately −3.8dBi. The gain increases up to 20 meters and then suddenly drops at 17 meters. Looking at the antenna simulations, the pattern stops becoming "omnidirectional" at 17 meters and above. Regardless of the antenna lobe patterns, I just recorded the maximum gain values at each band and plugged them into the table.



Now, let's look at a different antenna configuration.

I have a cabin in the mountains where I installed a Buckmaster 7-band off center fed dipole antenna strung between two trees. The antenna is located as far away from the cabin as possible at a height of approximately 40 feet. Doing the math, the straight-line distance from the antenna to the cabin is about 42 feet.

Relative to wavelength, the antenna is low to the ground on 80 meters. The antenna is essentially a “cloud burner” (or NVIS antenna) at the lower frequencies. At higher frequencies, the takeoff angle decreases, and the antenna provides more of a DX capability.



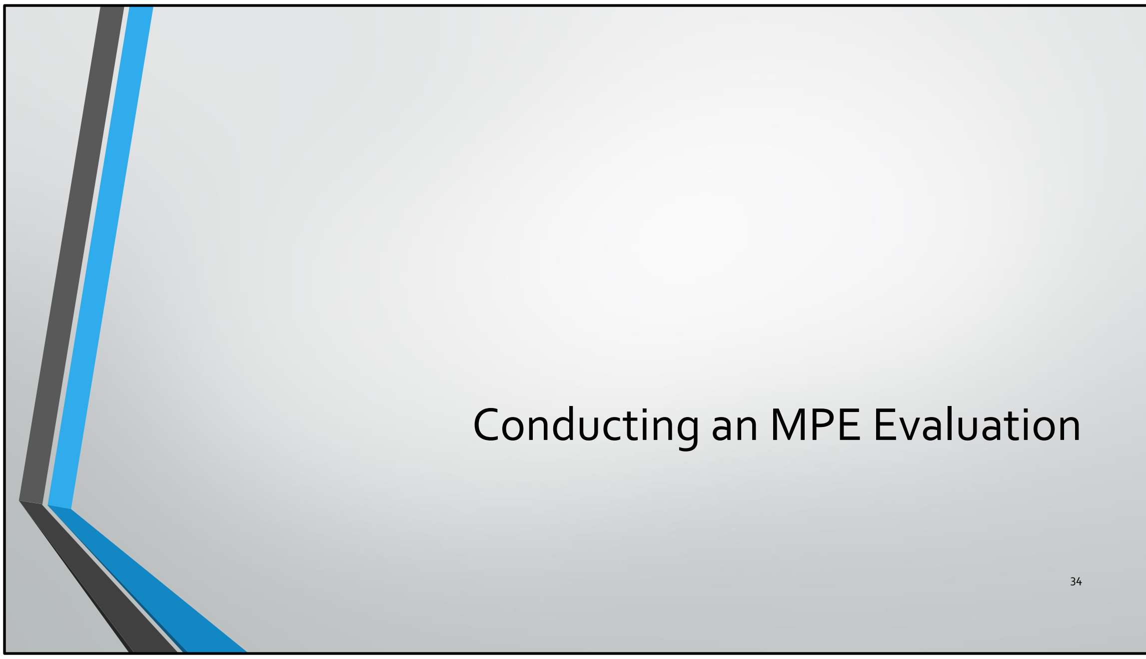
Using EZNEC, I modeled a simple off center fed dipole configuration and ran the simulations for the supported bands of operation. The marker values were then gathered up and put into a table.

Cabin Antenna – EZNEC Simulation Results

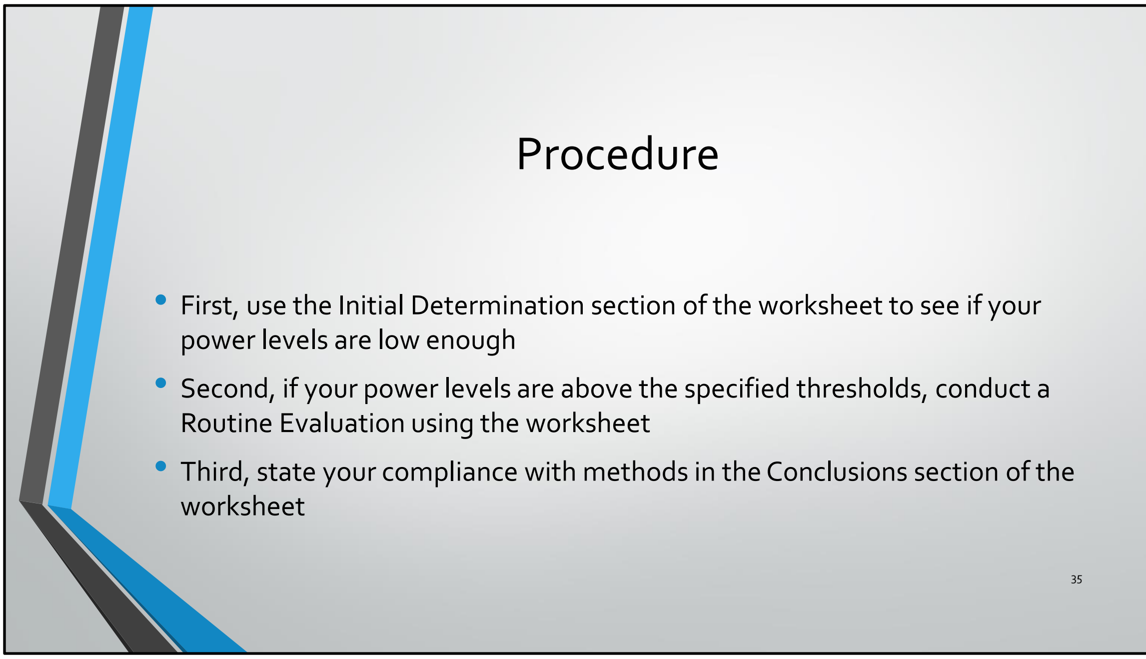
Frequency (MHz)	Marker Gain (dBi)
3.5	9.99
7.0	8.52
14.0	9.31
18.1	10.95
24.9	9.51
28.0	11.61
50.0	13.17

Supported bands:
- 80 meters
- 40 meters
- 20 meters
- 17 meters
- 12 meters
- 10 meters
- 6 meters

At 80 meters the maximum gain was about 10 dBi. The gain increases, and additional lobes are created, at higher frequencies.



Now that we have estimates for the antenna gain values, let's go ahead and conduct an MPE evaluation.

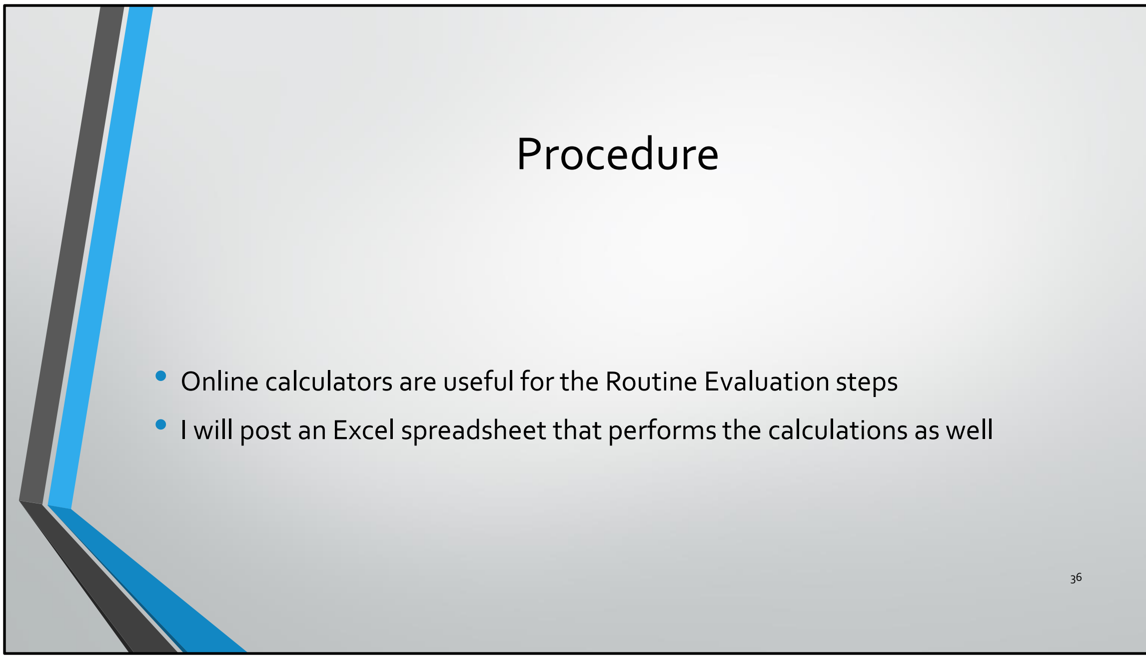


First, we’re going to conduct an initial determination to see if we need to run the routine evaluation. We need to know the peak envelop power, the distances from the antenna to the controlled and uncontrolled exposure locations, and the frequencies under consideration. Frequency and distance determine the “new” exemption values (Table 2 in FCC document 19-126). Remember, these calculations replace the previous power-only exemption values (the “old” Table 1) in OET65B. Frequency and distance also determine if we are evaluating a near-field vs. far-field scenario.

If you’re distances from the antenna falls within the near-field radius of $\lambda/2\pi$, you must conduct a routine evaluation. The initial determination exemptions do not apply in near-field scenarios.

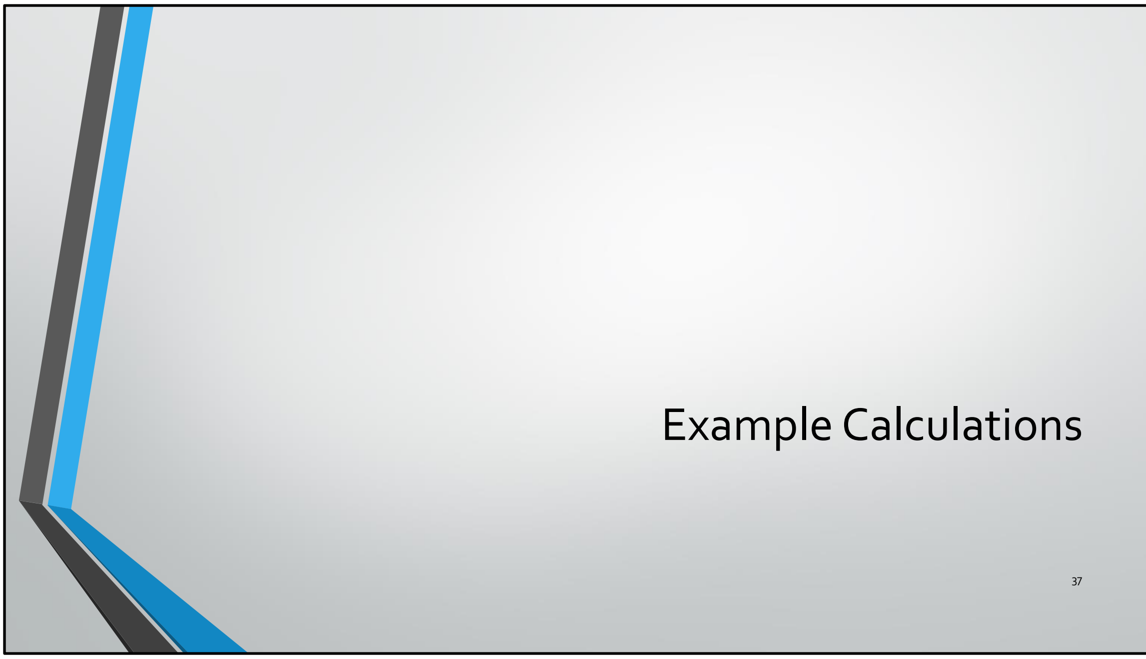
In the routine evaluation, the following parameters are used: antenna gain, emission type factor, duty cycle factor, antenna efficiency, and peak envelope power into the antenna.

At your discretion, you can complete the compliance statements. The wording from the statements was taken directly from the OET65B worksheet.

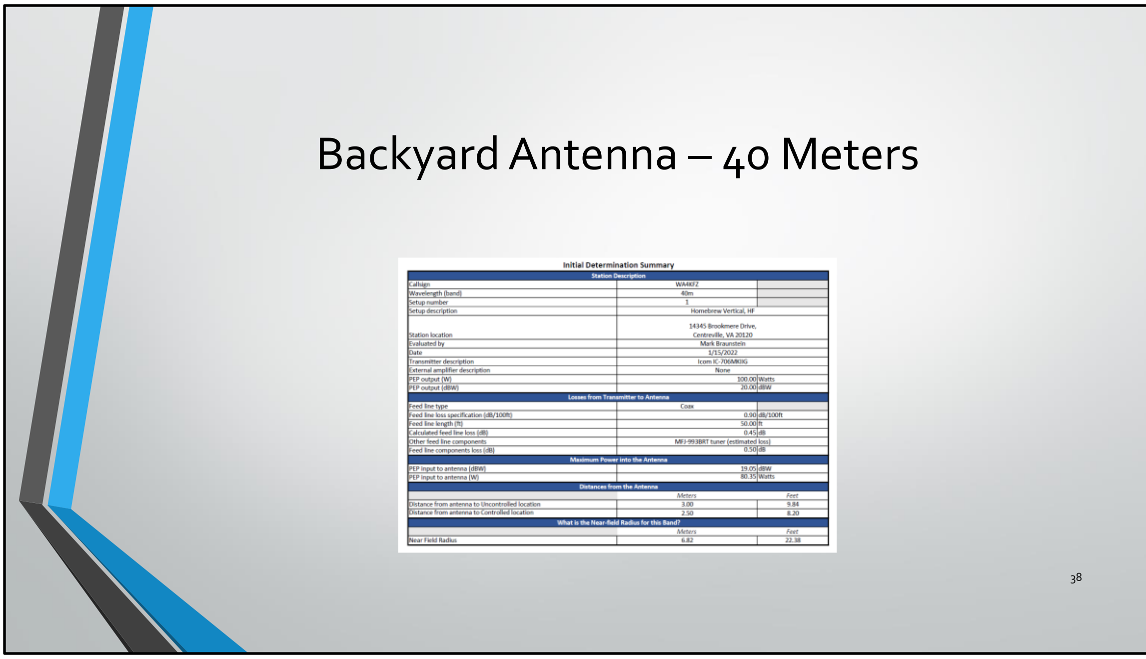


There are several online calculators available for performing the routine evaluation; a Google search yields several results. A calculator also on available at the ARRL website.

I developed an Excel spreadsheet to perform these calculations and will post this on the W4OVH website. The spreadsheet contains individual worksheets along with summary tabs formatted for printing. The goal is to use these printed results as the compliance documentation.



Let's go ahead and run the calculations using the spreadsheet I developed. For brevity, we're only going to look at the backyard antenna calculations for one band.



Initial Determination Summary

Station Description		
Callsign	WA4KFZ	
Wavelength (band)	40m	
Setup number	1	
Setup description	Homebrew Vertical, HF	
Station location	14345 Brookmere Drive, Centreville, VA 20120	
Evaluated by	Mark Braunstein	
Date	1/15/2022	
Transmitter description	Icom IC-706MKIIG	
External amplifier description	None	
PEP output (W)	100.00	Watts
PEP output (dBW)	20.00	dBW
Losses from Transmitter to Antenna		
Feed line type	Coax	
Feed line loss specification (dB/100ft)	0.90	dB/100ft
Feed line length (ft)	50.00	ft
Calculated feed line loss (dB)	0.45	dB
Other feed line components	MFJ-993BRT tuner (estimated loss)	
Feed line components loss (dB)	0.50	dB
Maximum Power into the Antenna		
PEP input to antenna (dBW)	19.05	dBW
PEP input to antenna (W)	80.35	Watts
Distances from the Antenna		
	Meters	*Feet*
Distance from antenna to Uncontrolled location	3.00	9.84
Distance from antenna to Controlled location	2.50	8.20
What is the Near-field Radius for this Band?		
	Meters	*Feet*
Near Field Radius	6.82	22.38

Station Description contains the antenna description, station location, and PEP section. Most of these field descriptions were copied over from the OET65B bulletin.

Losses from Transmitter to Antenna account for the feedline and other (e.g., tuner) losses.

Maximum Power into the Antenna defines the actual PEP power into the antenna in both Watts and dBW.

Distances from the Antenna accounts for both the controlled and uncontrolled scenarios. The results are entered in meters but displayed in both meters and feet.

What is the Near-field Radius for this Band? is used to determine the near-field/far-field boundary conditions.

Backyard Antenna – 40 Meters

Initial Determination Summary

Are You in the Far-field for this Band?	
Uncontrolled location distance > near field radius?	NO
Controlled location distance > near field radius?	NO
Compliance Statements	
Based upon the above estimates for an Uncontrolled environment, a routine evaluation is not required.	
Based upon the above estimates for a Controlled environment, a routine evaluation is not required.	

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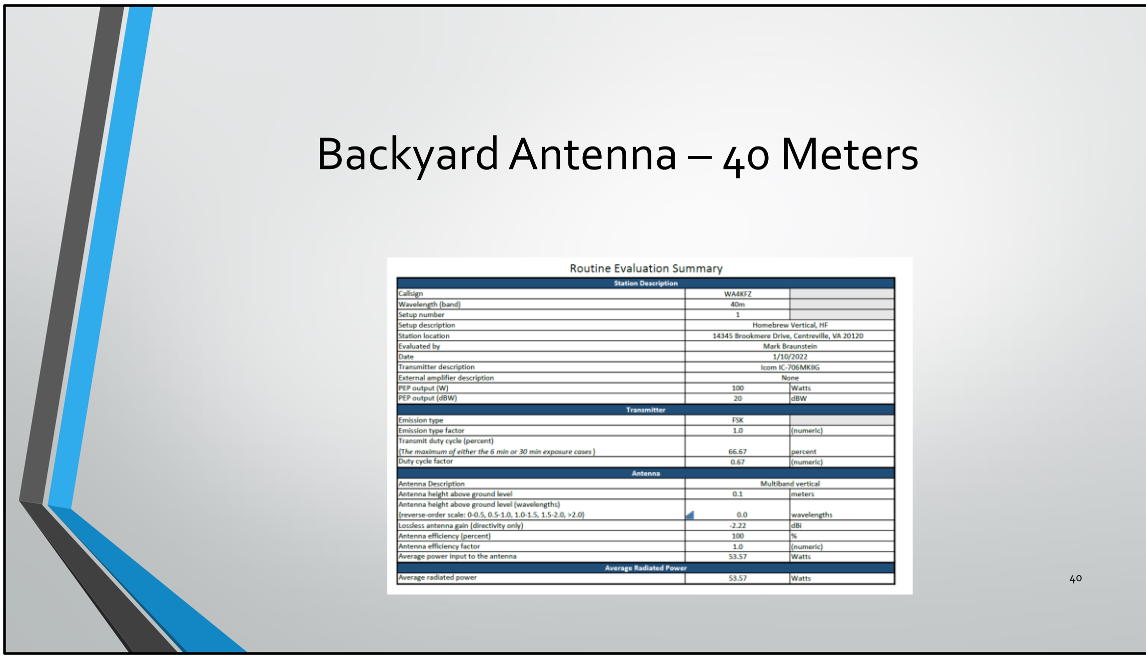
Are You in the Far-field for this Band? determines if the uncontrolled and controlled distances are far enough away from the antenna to qualify for the new exemption criteria. The fields turn red as a warning if you are in the near-field. <u>If you are in the near-field, you are required to conduct the routine evaluation.</u>

Compliance Statements are summary statements. The boxes are automatically checked if the controlled/uncontrolled distances are beyond the calculated near-field boundary value. If the distances are inside the near-field, the routine evaluation automatically needs to be performed.



Routine Evaluation Summary

Station Description		
Callsign	WA4KFZ	
Wavelength (band)	40m	
Setup number	1	
Setup description	Homebrew Vertical, HF	
Station location	14345 Brookmere Drive, Centreville, VA 20120	
Evaluated by	Mark Braunstein	
Date	1/10/2022	
Transmitter description	Icom IC-706MKIIG	
External amplifier description	None	
PEP output (W)	100	Watts
PEP output (dBW)	20	dBW
Transmitter		
Emission type	FSK	
Emission type factor	1.0	(numeric)
Transmit duty cycle (percent) *(The maximum of either the 6 min or 30 min exposure cases)*	66.67	percent
Duty cycle factor	0.67	(numeric)
Antenna		
Antenna Description	Multiband vertical	
Antenna height above ground level	0.1	meters
Antenna height above ground level (wavelengths) {reverse-order scale: 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0, >2.0}	0.0	wavelengths
Lossless antenna gain (directivity only)	-2.22	dBi
Antenna efficiency (percent)	100	%
Antenna efficiency factor	1.0	(numeric)
Average power input to the antenna	53.57	Watts
Average Radiated Power		
Average radiated power	53.57	Watts

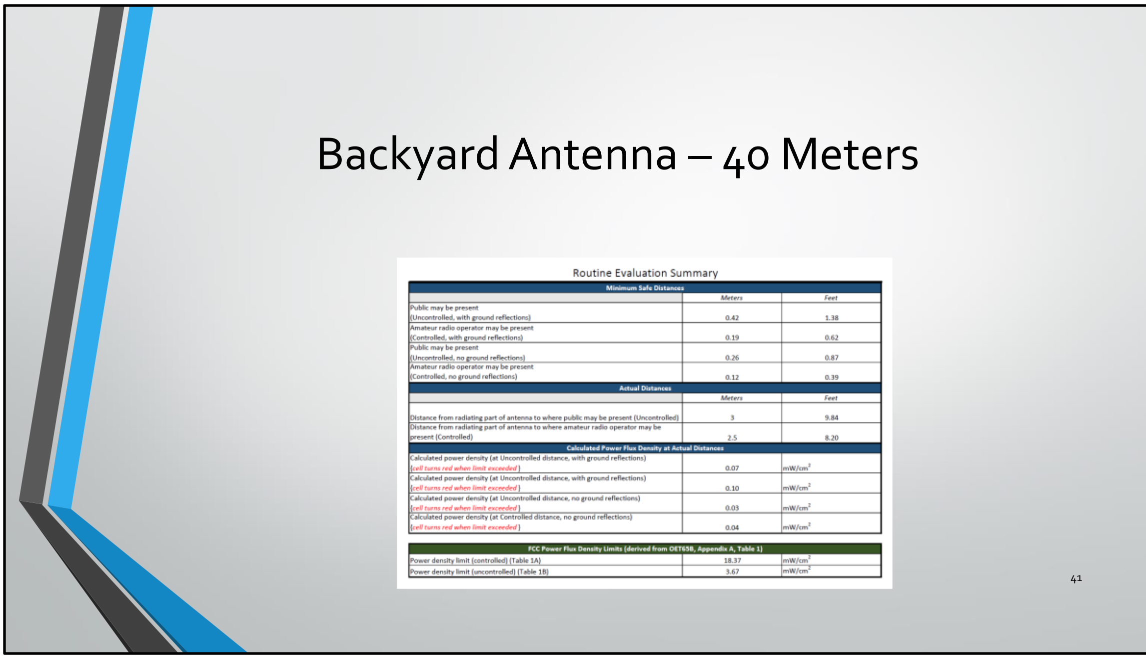
Since both the controlled and uncontrolled distances are less than the near field radius, we're required to perform the routine evaluation.

Station Description is simply repeated from the Initial Evaluation tab.

Transmitter describes the mode of operation and the duty cycle. Calculated results are provided for the emission type factor and the duty cycle factor.

Antenna uses the height in meters to calculate the height in wavelengths. Since antennas close to the ground are more heavily influenced by ground reflections, the "reverse order bar graph" provides awareness of the impact that a reflecting surface will have on the calculated results. It also serves as a recommendation when to rely on the ground reflection results that have a larger magnitude than the non-reflection results.

Average Radiated Power displays the average power, taking into consideration the transmitter parameters above.



Routine Evaluation Summary

Minimum Safe Distances		
	Meters	*Feet*
Public may be present (Uncontrolled, with ground reflections)	0.42	1.38
Amateur radio operator may be present (Controlled, with ground reflections)	0.19	0.62
Public may be present (Uncontrolled, no ground reflections)	0.26	0.87
Amateur radio operator may be present (Controlled, no ground reflections)	0.12	0.39
Actual Distances		
	Meters	*Feet*
Distance from radiating part of antenna to where public may be present (Uncontrolled)	3	9.84
Distance from radiating part of antenna to where amateur radio operator may be present (Controlled)	2.5	8.20
Calculated Power Flux Density at Actual Distances		
Calculated power density (at Uncontrolled distance, with ground reflections) {*cell turns red when limit exceeded*}	0.07	mW/cm^2
Calculated power density (at Uncontrolled distance, with ground reflections) {*cell turns red when limit exceeded*}	0.10	mW/cm^2
Calculated power density (at Uncontrolled distance, no ground reflections) {*cell turns red when limit exceeded*}	0.03	mW/cm^2
Calculated power density (at Controlled distance, no ground reflections) {*cell turns red when limit exceeded*}	0.04	mW/cm^2

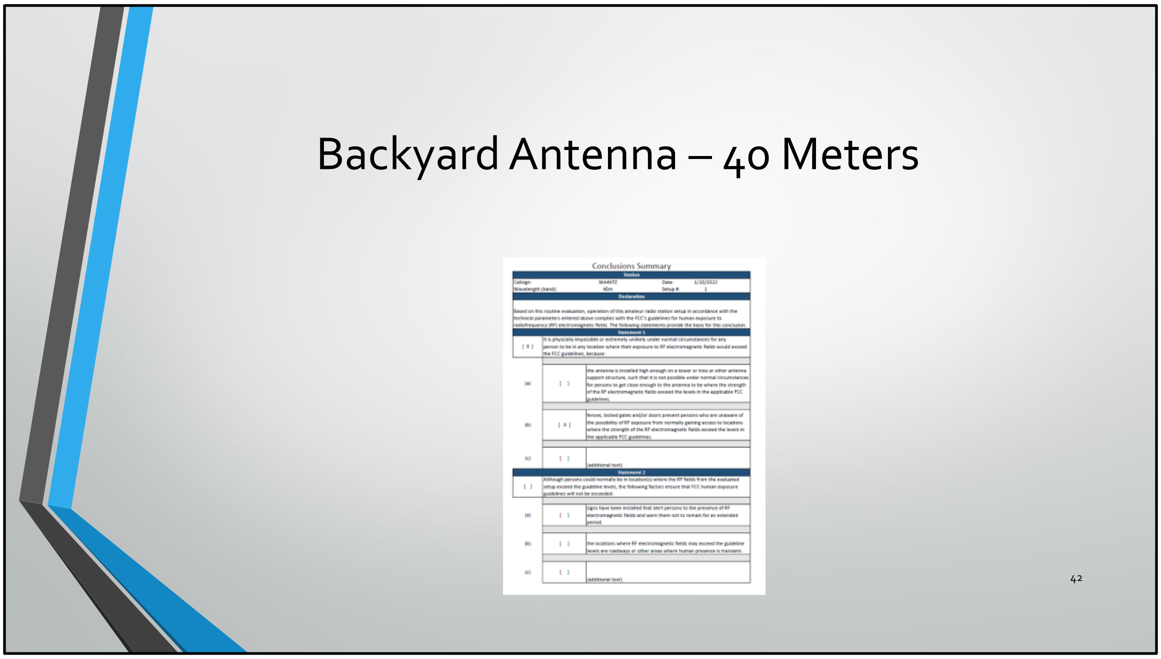
FCC Power Flux Density Limits (derived from OET65B, Appendix A, Table 1)		
Power density limit (controlled) (Table 1A)	18.37	mW/cm^2
Power density limit (uncontrolled) (Table 1B)	3.67	mW/cm^2

Minimum Safe Distances is computed from the controlled and uncontrolled power density limits in OET65B, Appendix A, Table 1. The distances, in meters and feet, show how close you can get to the antenna and still maintain compliance.

Actual Distances are the values entered for the controlled and uncontrolled scenarios under evaluation. These values come from the initial determination worksheet.

Calculated Power Flux Density at Actual Distances displays the power density values at the controlled and uncontrolled distances, both with and without ground reflections. Ground reflection results will always be larger in magnitude than non-reflection results. If the limits exceed the safe values from the FCC Power Flux Density Limits calculations (described below) the cells will turn red as a warning.

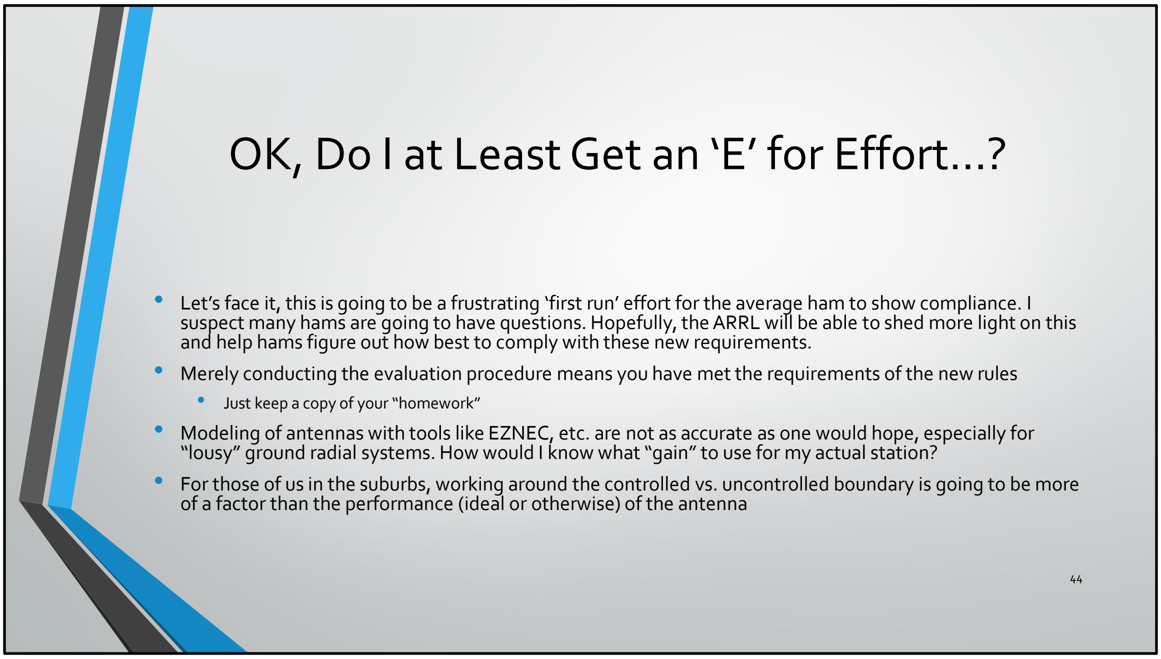
FCC Power Flux Density Limits (derived form OET65B, Appendix A, Table 1) are the computed values based on the operating frequency.



The conclusion summary is a duplicate of what appears and OET65B. Show here are the statements that would apply to the backyard antenna. The compliance statements are not required as part of the FCC evaluation but can serve to describe how compliance is achieved.

For my controlled environment, it's extremely unlikely that somebody is going to be exposed to unsafe levels because I have a fence that's prevents unauthorized people from getting too close to the antenna. I can also stop operating if someone is sitting on the deck (or “suggest” that they move inside the house…).

A few final comments.

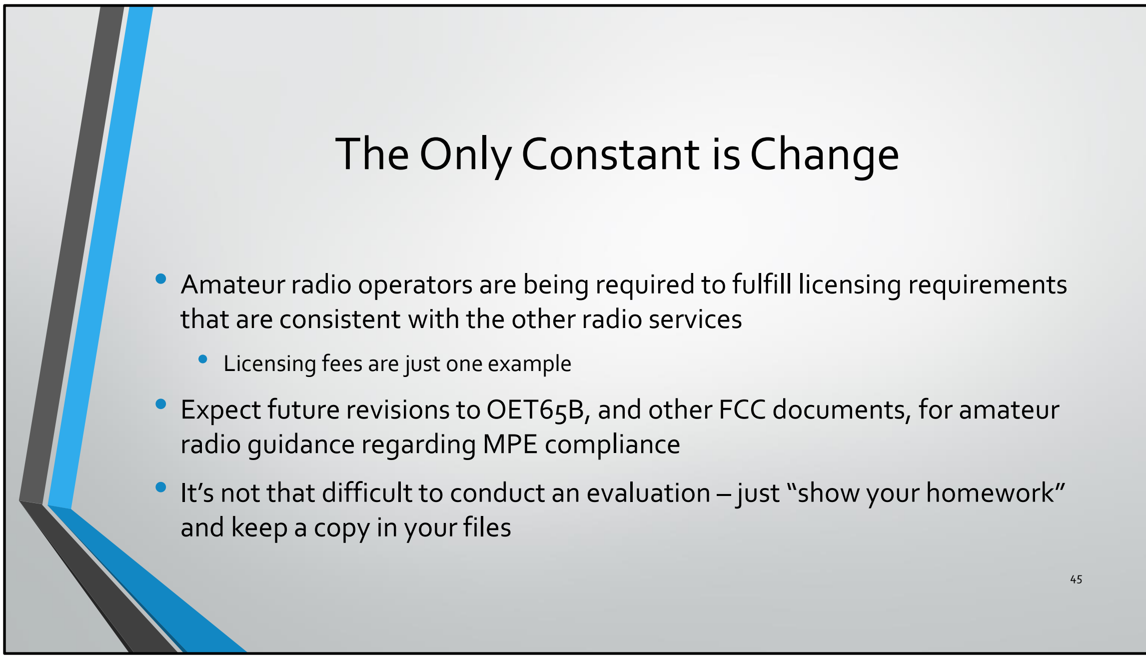


As the title of the slide asks, do I at least get an E for effort? The answer is yes. You're only required to conduct the compliance assessment. Once you've conducted your assessment you've completed what the FCC has asked you to do.

Let's face it, it's going to be frustrating for the average ham to figure this out. The spreadsheet and other online calculators help with the calculations. I think you can see that, from all the earlier slides, your assumptions going in are going to drive the calculated results that come out. My only recommendation at this point is just state your assumptions, make your calculations, and save your results . Just keep a copy of your homework.

Knowing and assessing the performance of your antenna can be a tough task unless the manufacturer can supply data. You can: use (as an estimate) the antenna gain descriptions shown in OET65B, calculate the results with a tool such as EZNEC, or rely on the manufacturer's data. Whatever you use, just note your assumptions and go forward with your calculations.

The biggest challenge for those of us that live in suburban areas is defining where the controlled and uncontrolled boundaries are located.



As the old saying goes, the only constant is change. The FCC is pushing us in the direction of having to follow the same rules as all other licensed radio services. MPE compliance assessment is no different.

There are some areas where the FCC acknowledges that, when it comes to amateur antennas, they’re going to have to provide better guidance in the future.

I would expect the FCC at some point to revisit both the handheld radio and mobile radio evaluation requirements.

Just keep a track of your assumptions, show your homework, and keep a copy of the results in your files.

References

- [1] The Ham Radio License Manual, ARRL, 2nd Edition
- [2] NCVEC Exam Pool Question – Technician Class, 2018-2022
- [3] FCC, OET Bulletin 65, Supplement B, Edition 97-01
- [4] FCC, OET Bulletin 65, Edition 97-01
- [5] http://www.arrl.org/fcc-rf-exposure-regulations-the-station-evaluation
- [6] https://en.wikipedia.org/wiki/Near_and_far_field
- [7] https://upload.wikimedia.org/wikipedia/commons/5/5b/Sphere.svg
- [8] http://www.montena.com/fileadmin/technology_tests/documents/technical_notes/TN14_Near_field.pdf
- [9] http://www.iw5edi.com/ham-radio/3233/quarter-wave-vertical-antennas
- [10] http://www.rcarc.org/presentations/RF%20Safety/MPE%20Help.pdf
- [11] https://www.hamradio.com/
- [12] https://owenduffy.net/calc/SmallLoopAF.htm
- [13] FCC 19-126, pp-18-19

Reference information.

The slides past this section are my thoughts and ruminations based on researching this topic and developing this presentation. None of these slides contain any “official” information or direction. Hopefully OET65B will be updated to reflect the latest rules changes.

Things that just make me wonder…

- Why do I suspect that handheld radios will be "revisited" at some point in the future?
- Also, just how much "shielding" does a car offer to VHF and UHF signals? Has anyone modeled or measured this? The front and rear windows are the largest apertures into the passenger compartment and are easily greater in the vertical dimension than the wavelength of 2m/70cm.

Things that just make me wonder…

- This "time averaging" stuff is wide open to interpretation. Can you really assume that you'll only transmit for up to half of the 6-minute controlled environment time limit? What happens when someone talks for 3 minutes, drops for an ID, and then starts chatting again for 3 more minutes?

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Things that just make me wonder…

"This transmit duty cycle is one of the parameters that is most easily controlled by the amateur radio station operator. As an example, with directed net or list operation, consideration should be given to whether the station is a net control station (relatively more transmit time) or a check-in (lots of listening time, relatively less transmission). When transmissions are carried through a repeater, the repeater timer may serve as a reminder to limit the length of continuous transmissions. With casual two-way conversations, the transmit duty cycle could be approximated as 50%. A more detailed discussion, with examples, is contained in Supplement B to OET Bulletin 65 under the heading of Time and Spatial Averaging".

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Excerpt from FCC OET65B

Things that just make me wonder…

- What is the “averaging period” of a repeater? What if someone keys the repeater, but it’s quiet for the next 5+ minutes in the 6-minute averaging window? Two “back-to-back” stations going through a repeater should mean that the full 6-minute averaging period needs to be applied.

Things that just make me wonder…

- Would building/buying a simple field strength meter be a better way to show compliance?
  - Need to figure out calibration method for low cost “relative measurement” meters vs. absolute field strength measurement devices
- What about building a small magnetic loop antenna and computing the antenna factor?

https://www.hamradio.com/

https://owenduffy.net/calc/SmallLoopAF.htm

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FCC Comments about Amateur Radio Antennas

- "If the antenna performance characteristics are known, then the process of determining whether the facility is exempt from routine RF exposure evaluation would be as simple as accounting for distance separation to accessible areas in conjunction with the known ERP and operating frequency.[99] For situations where antenna performance characteristics may not be well understood for a particular amateur radio installation, the most feasible option of demonstrating compliance remains to be evaluated, and various resources exist to alleviate any burdens that may exist.[100] In addition, for low-frequency, low-efficiency antennas such as those used by many amateur radio licensees, evaluation generally was already required and will continue to be required under the new rules." [5][101]

FCC 19-126, pp-18-19

FCC Comments about Amateur Radio Antennas

- "100 When evaluation is required, additional guidance is available in tabulated generic analyses of compliance for broad classes of antennas and installations from the Commission and third parties. See FCC Office of Engineering at Technology, Additional Information for Amateur Radio Stations, OET Bulletin 65, Supplement B, (1997); Ed Hare, RF Exposure and You, The Amateur Radio Relay League (1998). This guidance has been available for years and is an acceptable method to determine compliance. These resources were developed by the Commission and private amateur groups, including the ARRL, to aid in determining compliance with the exposure limits." [5]

FCC 19-126, pp-18-19

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FCC Comments about Amateur Radio Antennas

- The FCC acknowledges there may be some level of ambiguity regarding the performance of antennas used by radio amateurs
- The tabulated antennas only address monoband scenarios, but "real" ham antennas are generally not as idealized in their response
- Antenna modeling can be useful, but there are always going to be discrepancies between modeled results and actual results

FCC Comments about Amateur Radio Antennas

TABLE 4a. (MF/HF Bands)
(Developed by Fred Maia, W5YI Group, working in cooperation with the ARRL.)

Estimated distances in meters from transmitting antennas necessary to meet FCC power density limits for Maximum Permissible Exposure (MPE) for either occupational/ controlled exposures ("Con") or general population/uncontrolled exposures ("Unc") using typical antenna gains for the amateur service and assuming 100% duty cycle and maximum surface reflection. Chart represents worst case scenario.

Freq. (MF/HF) (MHz/Band)	Antenna Gain (dBi)	Peak Envelope Power (watts) 100 watts Con.	100 watts Unc.	500 watts Con.	500 watts Unc.	1000 watts Con.	1000 watts Unc.	1500 watts Con.	1500 watts Unc.
2.0 (160m)	0	0.1	0.2	0.3	0.5	0.5	0.7	0.6	0.8
2.0 (160m)	3	0.2	0.3	0.5	0.7	0.6	1.06	0.8	1.2
4.0 (75/80m)	0	0.2	0.4	0.4	1.0	0.6	1.3	0.7	1.6
4.0 (75/80m)	3	0.3	0.6	0.6	1.3	0.9	1.9	1.0	2.3
7.3 (40m)	0	0.3	0.8	0.8	1.7	1.1	2.5	1.3	3.0
7.3 (40m)	3	0.5	1.1	1.1	2.5	1.6	3.5	1.9	4.2
7.3 (40m)	6	0.7	1.5	1.5	3.5	2.2	4.9	2.7	6.0
10.15 (30m)	0	0.5	1.1	1.1	2.4	1.5	3.4	1.9	4.2
10.15 (30m)	3	0.7	1.5	1.5	3.4	2.2	4.8	2.6	5.9
10.15 (30m)	6	1.0	2.2	2.2	4.8	3.1	6.8	3.7	8.3
14.35 (20m)	0	0.7	1.5	1.5	3.4	2.2	4.8	2.6	5.9
14.35 (20m)	3	1.0	2.2	2.2	4.8	3.1	6.8	3.7	8.4
14.35 (20m)	6	1.4	3.1	3.1	6.8	4.3	9.6	5.3	11.8
14.35 (20m)	9	1.9	4.3	4.3	9.6	6.1	13.6	7.5	16.7
18.168 (17m)	0	0.9	1.9	1.9	4.3	2.7	6.1	3.3	7.5
18.168 (17m)	3	1.2	2.7	2.7	6.1	3.8	8.6	4.7	10.6
18.168 (17m)	6	1.7	3.9	3.9	8.6	5.5	12.2	6.7	14.9
18.168 (17m)	9	2.4	5.4	5.4	12.2	7.7	17.2	9.4	21.1
21.145 (15m)	0	1.0	2.3	2.3	5.1	3.2	7.2	4.0	8.8
21.145 (15m)	3	1.4	3.2	3.2	7.2	4.6	10.2	5.6	12.5
21.145 (15m)	6	2.0	4.6	4.6	10.2	6.4	14.4	7.9	17.6
21.145 (15m)	9	2.9	6.4	6.4	14.4	9.1	20.3	11.1	24.9
24.99 (12m)	0	1.2	2.7	2.7	5.9	3.8	8.4	4.6	10.3
24.99 (12m)	3	1.7	3.8	3.8	8.4	5.3	11.9	6.5	14.5
24.99 (12m)	6	2.4	5.3	5.3	11.9	7.5	16.8	9.2	20.5
24.99 (12m)	9	3.4	7.5	7.5	16.8	10.6	23.7	13.0	29.0
29.7 (10m)	0	1.4	3.2	3.2	7.1	4.5	10.0	5.5	12.2
29.7 (10m)	3	2.0	4.5	4.5	10.0	6.3	14.1	7.7	17.3
29.7 (10m)	6	2.8	6.3	6.3	14.1	8.9	19.9	10.9	24.4
29.7 (10m)	9	4.0	8.9	8.9	19.9	12.6	28.2	15.4	34.5

Note: Multiply above distances by 0.707 if duty cycle is 50% - such as during a typical back and forth communications exchange. To convert from meters to feet multiply meters by 3.28. Distance indicated is shortest line-of-sight distance to point where MPE limit for appropriate exposure tier is predicted to occur.

Excerpt from OET65B

FCC Comments about Amateur Radio Antennas

TABLE 6. Omnidirectional HF quarter-wave vertical or ground plane antenna (estimated gain 1 dBi) assumes surface (ground) reflection

Distance (meters) from any part of the antenna for compliance with either occupational/controlled or general population/uncontrolled exposure limits										
	3.5 MHz		7 MHz		14 MHz		21 MHz		28 MHz	
Transmitter power (watts)	con.	unc.	con.	unc.	con.	unc.	con.	unc.	con.	unc.
100	0.2	0.4	0.4	0.8	0.8	1.7	1.1	2.5	1.5	3.3
500	0.4	0.9	0.8	1.9	1.7	3.7	2.5	5.6	3.3	7.5
1000	0.6	1.3	1.2	2.7	2.4	5.3	3.5	7.9	4.7	10.6
1500	0.7	1.6	1.4	3.2	2.9	6.5	4.3	9.7	5.8	12.9

Excerpt from OET65B