

Changes to FCC RF Exposure Rules 2021

How Radio Amateurs Must Evaluate Human Exposure
from their Stations Differently Beginning May 3, 2021



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FCC Human Exposure Rules

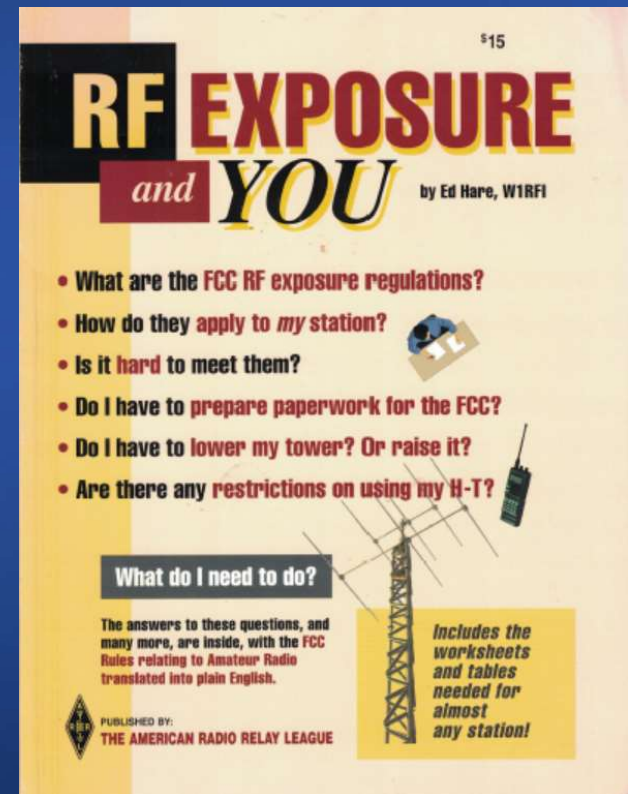
- Became effective for hams in 1998
 - Radio amateurs were introduced to human exposure limits for the first time.
 - ARRL published *RF Exposure and You*
 - No longer in print but PDF is available:
[www.arrl.org/files/file/Technology/RFsafetyCommittee/RF Exposure and You.pdf](http://www.arrl.org/files/file/Technology/RFsafetyCommittee/RF%20Exposure%20and%20You.pdf)
- Minor rule changes were made in 2013
 - No changes for Radio Amateurs.



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FCC Human Exposure Rules Updates

- New rule changes were published in the April 1, 2020 Federal Register
 - New rules were to take effect June 1, 2020.
 - Changes were delayed to May 3, 2021.
 - Existing stations have until May 3, 2023 to comply.
 - New or changed stations after May 3, 2021 must comply immediately.
- Rule changes to 47 CFR Parts 1, 2, 15, 18, 22, 24, 25, 27, 73, 90, 95, 97 and 101.
 - Amateur Radio Service is affected by Parts 1, 2, and 97.



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What Has Changed

- Amateurs No Longer Have **Categorical Exclusions** to Evaluation
 - Stations with power at the antenna input below certain limits did not have to perform routine evaluations.
 - No mobile transmitters had to perform routine evaluations.
- New **Exemptions** to Routine Evaluation are based on frequency, power and distance.
- All transmitters that are within 20 cm of the body must be evaluated with SAR.
- SAR modeling is accepted in addition to SAR testing.



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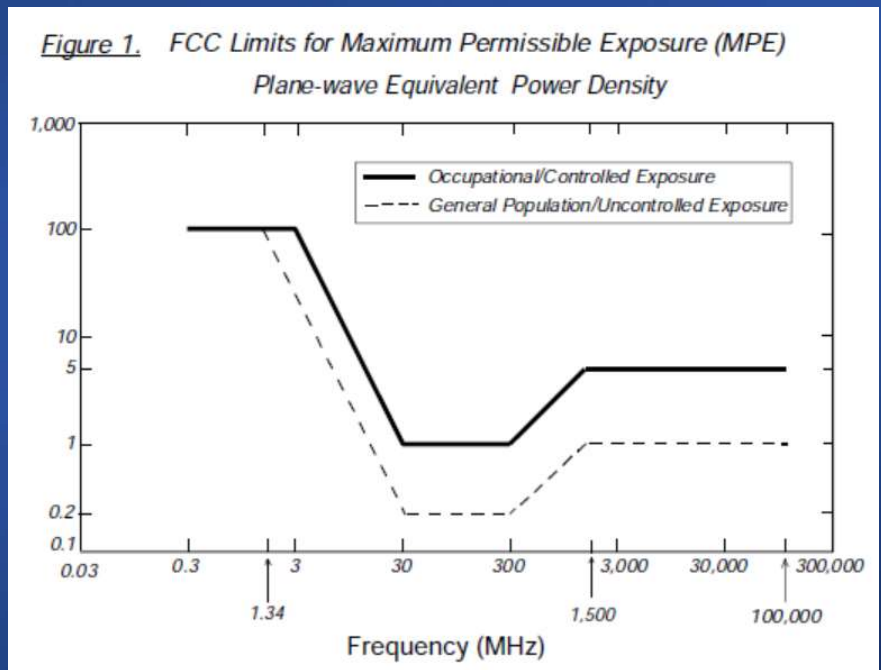
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What Has Not Changed

- MPE limits are the same – see graph
- SAR limits are the same:
 - 0.4 W/Kg averaged over the whole body.
 - 8 W/Kg averaged over any 1 gram of tissue.
 - 20 W/Kg averaged over 10 grams of tissue in the hands, wrists, feet and ankles.
- Hams and their families are still considered to be in the Occupational / Controlled Exposure category (including 6 min averaging rather than 30 min).
- Hams are expected to perform their own exposure analyses and **do not have to submit results to the FCC unless asked** (but count on being asked if anyone complains about your station to the FCC).



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Previous Categorical Exclusions in § 97.13(c)

The licensee must perform the routine RF environmental evaluation prescribed by § 1.1307(b) of this chapter, if the power of the licensee's station (in watts at the input to the antenna) exceeds the limits given in the following table:

160 m	500	VHF (all bands)	50
80 m	500	70 cm	70
75 m	500	33 cm	150
40 m	500	23 cm	200
30 m	425	13 cm	250
20 m	225	SHF (all bands)	250
17 m	125	EHF (all bands)	250
15 m	100		
12 m	75		
10 m	50		

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



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Previous Categorical Exclusions in § 1.1307(b)

- In addition to the exclusions based on frequency band and power:
 - All other mobile, portable, and unlicensed transmitting devices were categorically excluded from routine environmental evaluation for RF exposure.
 - This means that most likely no one measured the SAR of your HT or mobile rig.



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FCC Caveat to Categorical Exclusions

- Categorical Exclusions were meant to simplify the lives of ham radio operators by identifying situations where overexposure is unlikely.
- It should be obvious that it is still possible to have an overexposure situation on a categorially excluded system.
- The FCC has an overriding requirement:

No station is exempt from *compliance* with the FCC's rules and with the MPE limits.



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What the Change Means for Hams

- If you performed an environmental assessment on your station in the past, it still applies and you're done.
- If a **Categorical Exclusion** applied to you and you didn't perform an environmental assessment, you may now need to do so.
 - Categorical Exclusion was based on power entering the antenna for each band.
- **Categorical Exclusions** for hams have been replaced by **Exemptions** for every service.



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What the Change Means for Hams

- All mobile radios were previously Categorized Excluded for hams.
 - That includes handheld radio that are held next to the head.
- The new Exemptions are based on distance from the antenna to the body.
 - Anything less than 20 cm must be measured or modeled with SAR.
 - SAR is very complicated to either measure or model.
 - The SAR Exemptions are only valid for frequencies above 300 MHz.



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Requirements for Hams

- All amateur radio stations must be evaluated for human exposure
 - For existing stations prior to May 3, 2021, the deadline for an exposure analysis is May 3, 2023
 - For stations that were built or materially changed after May 3, 2021, the analysis must be performed before the station is put on the air
- There are several acceptable methods of evaluation



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How to Start

- Every method of analysis needs to know the same thing:
 - For each antenna:
 - What is the shortest distance between a person and any part of the antenna?
 - Determine the gain of the antenna
 - An analysis must be performed for each type of operation:
 - Frequency band
 - Modulation type
 - Power level
 - Operating type



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About Different Exposure Populations

- The General (Uncontrolled) Population:
 - Everyone who doesn't know they are being exposed
 - People that don't have the knowledge to control their exposure
 - Subject to lower exposure limits (about 1/5th as high) and 30-min averaging time
- The Occupational (Controlled) Population:
 - People who are exposed as part of their job
 - All licensed hams and the people in their houses are in this group
 - Must be trained about how to control their exposure
 - Subject to higher exposure limits and 6-min averaging time



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Averaging

- Exposure is considered as an average of instantaneous exposures over a given time period
- The duty cycles allow the maximum instantaneous exposure to be reduced
 - Modulation has a duty cycle - some types of modulation do not transmit for the entire time
 - There is a transmit/receive duty cycle - exposure only happens while you are transmitting
- The combination of both duty cycles reduces the average exposure during the time period



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Types of Analysis - FCC Exemption

■ Pros

- Simplest calculation

■ Cons

- Cannot be used in the reactive near-field ($\lambda/2\pi$)
- Does not distinguish between Occupational and General Populations
- Does not account for modulation duty cycle
- Does not account for transmit/receive duty cycle
- Treats antenna gain as being in all directions



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Reactive Near-Field Distances

Frequency Band	$\lambda/2\pi$ Dist in m (ft)	Frequency Band	$\lambda/2\pi$ Dist in m (ft)
2200 m (135.7-137.8 kHz)	351.5 (1153.2)	20 m (14.0-14.35 MHz)	3.4 (11.2)
630 m (472-479 kHz)	101.1 (331.6)	17 m (18.068-18.168 MHz)	2.6 (8.7)
160 m (1.8-2.0 MHz)	26.5 (86.9)	15 m (21.0-21.45 MHz)	2.3 (7.5)
80 m (3.5-3.75 MHz)	13.6 (44.7)	12 m (24.89-24.99 MHz)	1.9 (6.3)
75 m (3.75-4.0 MHz)	12.7 (41.7)	10 m (28.0-29.7 MHz)	1.7 (5.6)
60 m (5.33-5.40 MHz)	9.0 (29.4)	6 m (50-54 MHz)	95 cm (3.1)
40 m (7.0-7.3 MHz)	6.8 (22.4)	2 m (144-148 MHz)	33 cm (13 in)
30 m (10.1-10.15 MHz)	4.7 (15.5)	1.25 m (222-225 MHz)	21 cm (8 in)

For amateur frequencies higher than the 1.25 m band, $\lambda/2\pi$ is less than 20 cm. SAR analysis required if closer.



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Transmitter Frequency	Threshold ERP
0.3 – 1.34	1,920 R ²
1.34 – 30	3,450 R ² /f
30 – 300	3.83 R ²
300 – 1,500	0.0128 R ² f
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.

FCC Exemption Formulae

You must determine your own ERP to use to these equations. To get ERP, calculate transmitter output power minus feedline loss times antenna gain with respect to a dipole.



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Calculations you need to perform

- Be careful of all the unit conversions:
 - If antenna gain (G_A) is specified in dBi, FCC uses dBd ($\text{dBi} - 2.14$)
 - Feedline loss (F_L) is usually specified in dB/100 meters
 - Transmitter power (P_T) is in watts, convert to dBW ($10 \log_{10} (P_T)$)
 - To get ERP in dBW = $P_T \text{ (dBW)} - F_L \text{ (dB)} + G_A \text{ (dBd)}$
- Convert result back to Watts = $10^{(\text{ERP(dBW)}/10)}$
- Compare this to the appropriate FCC Exemption Formula
- If you don't meet the Exemption, you have three choices:
 - Decrease your power
 - Keep people farther away from your antenna
 - Recalculate with a more accurate method



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New Exemptions

- The new **Exemptions** are based on three things:
 - Frequency
 - Maximum ERP (taking into account feedline loss and antenna gain)
 - Distance between a person and any part of the antenna
 - **Exemptions** do not apply to distances less than $\lambda/2\pi$ (reactive near-field)
- **Exemptions** require less calculation than a full exposure analysis.
- If you don't qualify for an exemption, you can still perform the full analysis, which takes into account T/R duty cycle.



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An Example Calculation

- I have a multiband (20, 17, 15, 12 & 10M) vertical in my yard.
- There is a sidewalk 15' (5 meters) away from my antenna.
- I have a 100W transmitter that uses 50' of RG-58 to feed the antenna.
- To check if I qualify for an Exemption, I use the table from the last slide. The same equation applies to all bands on my vertical:

$$\text{Maximum ERP} = 3450 R^2 / f^2$$

- To simplify, I notice that the allowed ERP decreases most for higher frequencies. I only need to calculate for the top of the 10M band:



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An Example Calculation

- First determine my maximum ERP allowed at the top of 10M:
 $3450 \times (5 \text{ meters})^2 / (29.7 \text{ MHz})^2 = 97.8 \text{ watts ERP}$
- Next determine my ERP:
 $\text{ERP}_{\text{dBW}} = \text{Transmitter Power (dBW)} - \text{Feedline Loss (dB)} + \text{Ant Gain (dBd)}$
 - Transmitter output of 100W = 20 dBW
 - 50' of RG-58 at 29.7 MHz has 1 db of loss (from manufacturer datasheet)
 - A ground-plane vertical has 0 dBd of gain (same gain as a half wave dipole) $\text{ERP}_{\text{dBW}} = 20 \text{ dBW} - 1 \text{ dB} + 0 \text{ dBd} = 19 \text{ dBW}$ $\text{ERP} = 10^{(\text{ERP}_{\text{dBW}} / 10)} = 79.4\text{W}$
- The allowed radiated power is 97.8W and my ERP is 79.4W.
- This antenna is Exempt from performing a full analysis!



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An Example Calculation

- If I change anything (antenna position closer to the sidewalk, increased transmitter power, install better coax) I have to recalculate.
- So now, let's try to determine how close I can put the antenna to the sidewalk and still retain my Exemption:

- Rearrange my equation:

$$R = \sqrt{(ERP * f^2 / 3450)} = \sqrt{(79.4 * (29.7)^2 / 3450)} = 4.5 \text{ meter}$$

- So, I could move the antenna half a meter closer to the sidewalk and still be able to claim the Exemption.



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An Example Calculation

- What if I can't claim the Exemption?
- There are several possibilities:
 - I never use 10M above 28.6 MHz, so recalculate at that frequency.
 - Move the antenna farther away from the sidewalk.
- Or, perform a more complicated evaluation...
 - The Exemption is very conservative.
 - If I calculate the actual exposure of people on the sidewalk I will find that it is less than the Exemption allows for.
 - One large difference is averaging time. If I talk the same amount of time that I listen, then exposure is halved.



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Types of Analysis - "Far-Field" Calculator

$$P(r) = [P_0 \cdot G_A / (4 \pi r^2)] \cdot R$$

$P(r)$ is the power density at distance r , in W/m^2

P_0 is the power fed into the antenna, in W (power from transmitter minus feedline losses)

G_A is the gain of the antenna with respect to an isotropic antenna

r is the distance from the center point of the antenna, in meters

R is the ground reflection factor. 1.0 for "Free Space", 1.6 for "Perfect Ground"

■ Pros

- Basis of most online tools
- Can be used in the near-field for full size wire antennas

■ Cons

- Cannot be used in the reactive near-field ($\lambda/2\pi$) for all antenna types
- Treats antenna gain as being the same in all directions



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www.arrl.org/rf-exposure-calculator



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RF Exposure Calculator

FCC RF-Exposure Regulations -- the Station Evaluation
ARRL RF Safety Committee
RF Exposure Calculator
RF Exposure Calc Instructions
Changes in the FCC RF Exposure Regulations

The FCC has changed its RF-exposure rules, eliminating service-specific exemptions from the need to do a routine RF-safety evaluation and replacing those exemptions with a formula that applies to all radio services. See the FAQ on the ARRL RF-Exposure page for more information. The rules did not change the exposure limits nor the two-tiered exposure environments for controlled and uncontrolled exposure. The controlled limits generally apply to amateurs and members of their household if those people have been given instructions by the amateur about RF safety. The uncontrolled limits apply in all other circumstances, such as exposure to the general public.

To use the RF Exposure Calculator, fill-in the form below with your operating power, antenna gain, and the operating frequency. Depending on how far above ground the RF source is located, you might want to consider ground reflections — and then click "Calculate".

You may need to run the calculator multiple times to get a complete picture of your situation, i.e. take into account the antenna's lobes and directionality.

View detailed instructions for each parameter. (opens in new tab/window)

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

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):

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Types of Analysis - Modeling

■ Pros

- Most exact
- Can be customized to the type of ground in an area
- Can account for signal loss in structures, if they are modeled
- EZNEC is now free - www.eznec.com

■ Cons

- More difficult and time consuming to use



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Types of Analysis - Measurement

■ Pros

- Very exacting
- Accounts for things that are missed by modeling, like reflections with other objects
- Usually more accurate determination of signal attenuation

■ Cons

- Expensive calibrated equipment
- Difficult to use properly
- Many measurements must be made to average out variations in time, space, and polarity



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How Exact do Evaluations have to be?

- Usually, not exact at all
- Simplifications that overestimate exposure are fine as long as the thresholds are not exceeded
- If the calculations say that the thresholds are exceeded, then more exact data can be used
- For example, I usually calculate exposures without considering feedline losses. They usually are not needed to get a passing result



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What about multiple transmitters?

- We have calculated the exposure levels from a person standing closest to each antenna
- Can someone standing in the middle of two antennas that are operating at the same time be overexposed?
 - It is possible, but only if the exposure levels are near the limit
 - Although we didn't calculate the exact combinations, there is little chance that this will occur at a typical amateur station
- Combining two power densities is not a simple sum
 - Square root of the sum of the squares of all signals
- This could be an interesting exercise to confirm



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Some things to keep in mind

- If you fail to meet exposure limits with a simple method, recalculating with a more accurate method may help
- If that doesn't work, some simple changes might help:
 - Raise your antenna higher above the ground
 - Put up a fence to keep people away from the antenna
 - Don't operate when someone is near the antenna
- The FCC doesn't want your evaluation
 - But keep it handy in case they ever ask for it
- Keep your evaluations up to date if parameters change



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Positive Access Control

- The FCC requires any regions that exceed exposure limits to be made inaccessible to people who may be overexposed
 - Regulations refer to fencing and locked doors leading to roofs
 - Warning signs are also required
- We are not big fans of this type of mitigation for hams
 - One suggestion that we have made to the FCC is that hams be permitted to either stop operating or lower their power levels if they see people wandering into their high exposure areas
 - The FCC tentatively replied that would be acceptable if the ham can see those areas at all times



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What About the 2M HT?

- The 2M HT is not covered under the new Exemptions:
 - Its antenna is within 20 cm of the head
 - Its frequency is < 300 MHz
- No known SAR tests have been performed with Amateur HTs
 - SAR testing is too complex for most hams to perform.
 - SAR modeling is also too complex for most hams to perform.
- Newly produced amateur HTs will have to be characterized by their manufacturers for SAR.
- Amateur HTs manufactured before the rule change on May 3, 2021 are grandfathered-in.



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How Will Hams Follow the Rules Going Forward?

- The new rules have been released with a 2-year transition period for existing stations.
- The FCC's aids for following human exposure rules: *OET Bulletin 65* and *OET Bulletin 65 Supplement B for Radio Amateurs* are being revised.
- The ARRL RF Safety Committee is working with the FCC personnel to revise these documents.
- ARRL is working on finding or developing tools that all hams can use to perform exposure assessments.



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Modeling

- Three main types of modeling used to predict human exposure.
 - Method of Moments (NEC)
 - Finite Difference Time Domain (FDTD)
 - Finite Element Analysis (FEM)
- Modeling must take into account patterns in:
 - Near Field
 - Far Field
- SAR Modeling must account for energy absorption in tissue.
 - The model must include realistic absorption in the body.



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Evaluating Exposure

- The key indicator of exposure is Specific Absorption Rate (SAR)
 - Defined as the rate at which energy is absorbed by tissue.
 - Amount of tissue can be 1 gram, 10 grams, or whole body depending on the type of exposure.
 - Typically measured in W/Kg.
 - Complicated (and expensive) to measure or model.
- Maximum Permissible Exposure (MPE) can estimate SAR
 - Assumption of plane wave exposure.
 - E-field typically measured in V/m.
 - H-field typically measured in A/m.
 - EM power density typically measured in mW/cm^2



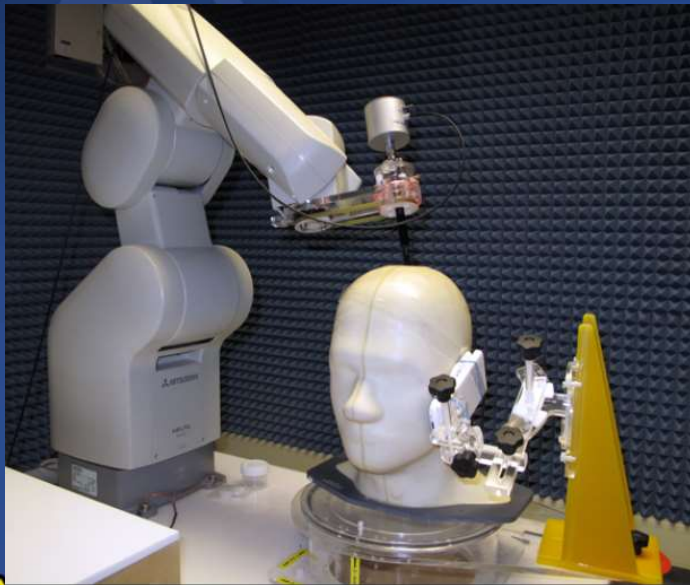
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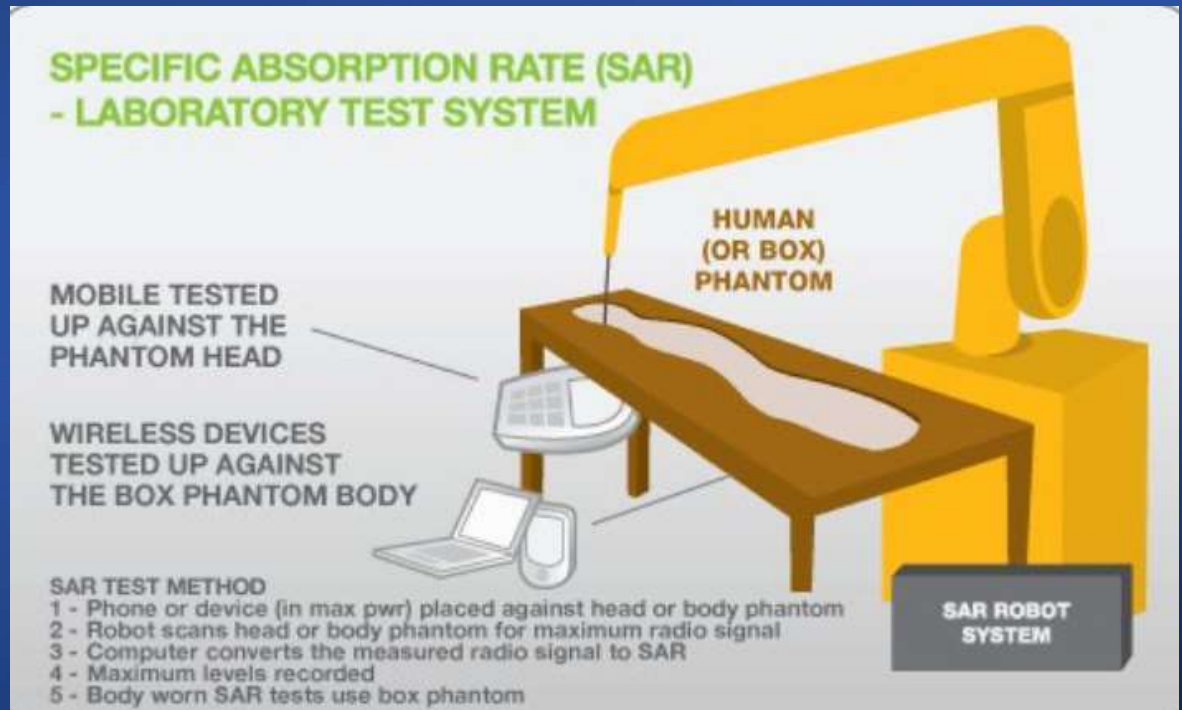
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SAR Testing for Mobile Devices



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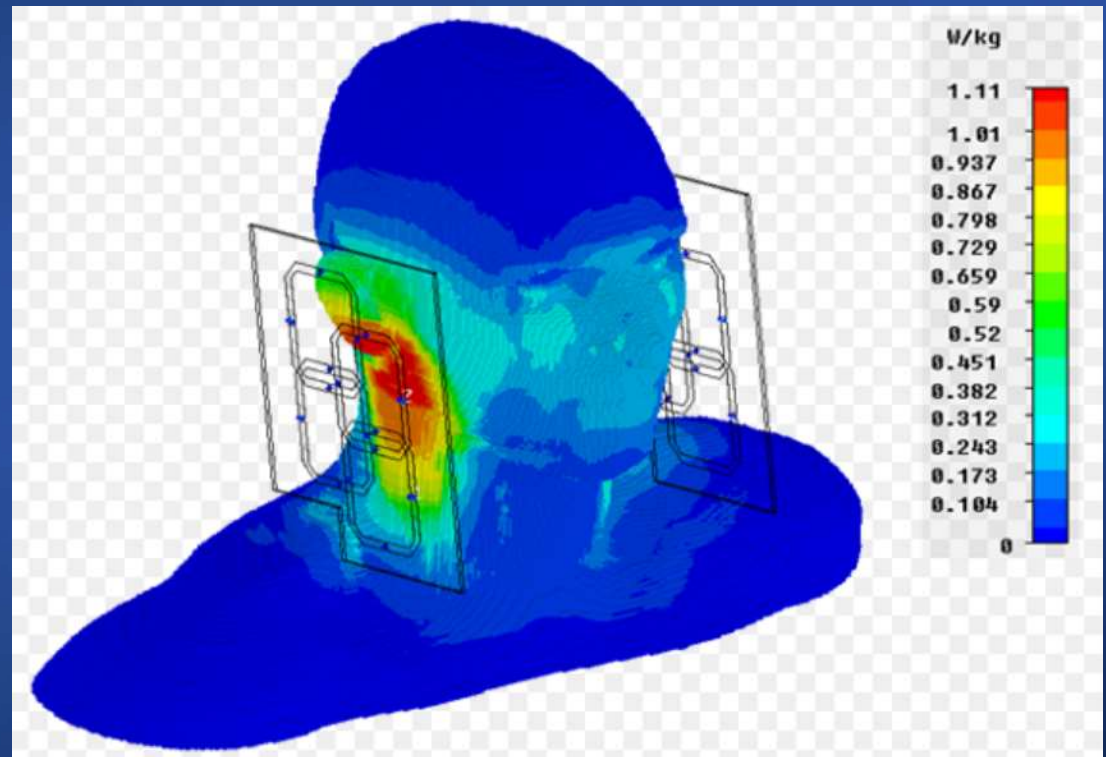


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SAR Modeling for Mobile Devices

- FDTD or FEM modeling
- Requires exact antenna configurations.
- Must be repeated for all orientations.



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Some issues with SAR

- If a manufacturer goes to the added expense of testing its HTs for SAR, will they pass that cost on to the consumer?
- SAR tests are specific for a particular antenna.
 - A manufacturer can perform SAR testing with different antennas.
 - If a ham changes the HT antenna to one that was not tested, the SAR results may no longer be valid.
- The RFSC is studying whether existing SAR testing on commercial HTs can be extended to cover HTs in the nearby ham bands.



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Possible Future Changes

- The FCC issued an NPRM last year that is examining other possible changes to the exposure regulations:
 - Addition of Electrostimulation effects at frequencies below 10 MHz as instantaneous values rather than averages over time.
 - Extension of the high exposure limits from 100 GHz to 3 THz.
 - New localized MPE limits above 6 GHz.
- Electrostimulation limits would have the greatest effect on ham radio operations.



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Misconceptions

- From what I've been seeing online, there are a several of misconceptions about the FCC Exposure Rules making the rounds
- The FCC is not trying to stop you from operating.
 - The Amateur Radio Service is a valued FCC Service and they go out of their way to make it possible for us operate.
 - They have classified us as being part of the occupational group, which gives us higher thresholds.
 - They have provided the Exemptions table to allow us to avoid the more detailed assessments for many stations.



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Misconceptions

- Equipment (except HTs) does not have to be certified.
 - Every ham is responsible for confirming that his or her operating does not cause people to be exposed to RF over the FCC thresholds.
 - There are many options for controlling this. To name a few:
 - mounting your antennas higher,
 - keeping people away from your antenna with ropes or signs,
 - talking for shorter periods of time,
 - lowering your power,
 - pausing your operating when people are known to be near your antennas.



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Misconceptions

- You don't need any special test equipment to meet the exposure requirements.
 - The only thing that is difficult to measure or model is the antenna that is less than 20 cm from a human.
 - We are working with the FCC to make sure hams do not have to perform SAR tests.
 - If the simple calculations say there is too much exposure, you can perform a full analysis using an available modeling tool, such as EZNEC, to get a more exact solution. Often you will find that no one is exposed above the FCC thresholds when you calculate more exactly.



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References to read more about it

- ARRL RF Exposure and You - PDF at:
[www.arrl.org/files/file/Technology/RFsafetyCommittee/RF Exposure and You.pdf](http://www.arrl.org/files/file/Technology/RFsafetyCommittee/RF%20Exposure%20and%20You.pdf)
- FCC OET 65 Supplement B (new version is being written):
transition.fcc.gov/oet/info/documents/bulletins/oet65/oet65b.pdf



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Summary

- Be prepared to perform environmental analyses on your station.
- Nothing about the evaluation has changed, so if you did it before you already comply under the new regulations.
- You don't need to worry about the SAR limits for handhelds, the manufacturers will perform the testing when required.
- As always, whether you are required to perform an environmental analysis or not, **you must comply with the FCC's exposure limits.**
- Operate safely. Common sense should tell you what to do.



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