MPE Calculator

1. **FCC Compliance Guidelines:**

In 1996, the FCC published new guidelines and procedures for evaluating human exposure to environmental radiofrequency (RF) electromagnetic fields from FCC-regulated transmitters. These guidelines set new limits on maximum permissible exposure (MPE) levels that apply to all transmitters and licensees regulated by the FCC.

Amateur radio installations are subject to routine evaluation for compliance with the FCC's RF exposure guidelines effective January 1, 1998. As is the case with all other FCC rules, an amateur station licensee or grantee is responsible for compliance with the FCC's rules for RF exposure. The licensee must perform the routine evaluation if the transmitter power of the station exceeds the levels specified in 47 CFR § 97.13(c)(1)(see Power Thresholds for Routine Evaluation of Amateur Radio Stations).

Amateur stations using mobile and portable (hand-held) transmitters are categorically excluded from this routine evaluation requirement. Such mobile and portable stations are presumed to be used only for very infrequent intermittent two-way operation. They are, however, required to comply with the exposure guidelines. It is advisable that mobile stations be considered for potential exposure before an amateur automatically applies the categorical exemption. In particular, mobile stations utilizing high power with a vehicle mounted antenna would certainly merit evaluation. Such stations may represent a potential hazard to occupants of the vehicle depending on the location of the antenna and shielding inherent in the construction of the vehicle.

Even if the regulations do not require an evaluation, there could be a number of reasons to conduct one anyway. At a minimum, performing such an evaluation now would be good practice for when you are required to do an evaluation because of a change to your station. In addition, the results of an evaluation will certainly demonstrate to the amateur and his or her neighbors that the station's operation is well within the guidelines and is not a cause for concern. Regardless of categorical exemption, the FCC's rules require compliance with the MPE limits. In the case of unusual circumstances, the FCC may ask that an evaluation be performed on any transmitter regulated by the FCC.

2. Exposure Limits:

An important point to remember concerning the FCC's exposure guidelines is that they constitute exposure limits (not emission limits) and they are relevant only to locations that are accessible to people. There are several important

features of the FCC's exposure limits that determine how exposure is measured and evaluated:

A. The exposure limits apply to power densities that are spatially averaged over the body dimensions and are expressed as milliwatts per centimeter squared of body surface.

B. The exposure limits vary with the frequency of the transmitted RF - as the frequency increases, the exposure limits become more strict.

C. The exposure limits may be averaged over certain periods of time with the average not to exceed the limit for continuous exposure. This 'time-averaging' method measures transmitter on and off times within the time limits for controlled and uncontrolled environments (see below).

In addition to averaging power over time, the exposure is affected by the duty cycle used by the amateur. Various modes of operation have their own duty factor that is representative of the ratio between average and peak power. The program multiplies the transmitter peak envelope power by the appropriate duty factor from the following table to calculate MPE for each duty cycle:

Operating Mode	Duty Factor
SSB, without speech processor	0.2
Conversational CW	0.4
SSB with speech processor	0.5
FM/FSK/PSK/AFSK/RTTY/SSTV/Carrier	1.0

The FCC guidelines incorporate two separate tiers of exposure limits that are dependent on the situation in which the exposure takes place and/or the status of the individuals who are subject to exposure:

A. CONTROLLED/OCCUPATIONAL exposure limits apply to situations in which persons are exposed as a consequence of their employment and in which those persons who are exposed have been made fully aware of the potential for exposure and can exercise control over their exposure. Controlled exposure limits also apply where exposure is of a transient nature as a result of incidental passage through a location where exposure levels may be above the general population/uncontrolled limits, as long as the exposed person has been made fully aware of the potential for exposure and can exercise control over his or her exposure by leaving the area or by some other appropriate means.

   Controlled exposure limits apply to amateur licensees and members of their immediate household who have been provided educational instruction in RF safety and occasional visitors on your property who

have been provided educational instruction in RF safety if transmitters are in operation.

Awareness of the potential for RF exposure in a controlled environment can be provided through specific training. Warning signs and labels can also be used to establish such awareness as long as they provide information on risk of potential exposure and instructions on methods to minimize such exposure risk. A 6 minute time period is used when applying time-averaging to controlled exposure.

B. UNCONTROLLED/GENERAL POPULATION exposure limits apply to situations in which the general public may be exposed or in which persons who are exposed as a consequence of their employment may not be made fully aware of the potential for exposure or cannot exercise control over their exposure. Your neighbors, unwarned individuals passing through your property, and other non-household members would normally be subject to the uncontrolled exposure limits. Uncontrolled exposure limits are necessarily more strict than controlled exposure limits.

3. Power Thresholds for Routine Evaluation of Amateur Radio Stations:

No station is exempt from compliance with the FCC's rules and with the MPE limits. However, many amateur stations are categorically exempt from the requirement to perform a routine station evaluation for compliance. Stations operating at or below the power levels shown in the following table are not required by the FCC to perform a routine evaluation for compliance:

Wavelength/ Amateur Band	Evaluation Required if Input Power to the Antenna Exceeds:
160 meter	500 watts
80	500 watts
75	500 watts
40	500 watts
30	425 watts
20	225 watts
17	125 watts
15	100 watts
12	75 watts
10	50 watts
6	50 watts
2	50 watts
1.25	50 watts
70 cm	70 watts

33	150 watts
23	200 watts
13 cm and above	250 watts

Repeater Stations (all bands):

Non-building-mounted antennas: if the distance between ground level and the lowest point of the antenna is less than 10 meters and the Effective Radiated Power (ERP) is greater than 500 watts.

Building-mounted antennas: if the power exceeds 500 watts ERP.

4. Multi-Transmitter Operations:

Multiple transmitter sites represent a special challenge in meeting the FCC's exposure limits. At multiple transmitter sites, two or more transmitters could be in operation at the same time, each adding to the RF exposure level. Such multiple transmitter conditions might exist at a home station at which both HF and VHF transmitters are in use by family members at the same time.

Multiple transmitter operations frequently occur at a field day site or during a multi-op or club contest activity. Additionally, transmitters for other radio services might be located at a repeater site. Whenever multiple transmitters are in operation, regardless of the frequencies in use, the RF fields of all transmitters (and antennas) must be totaled to determine whether the FCC exposure limits are being exceeded at any given location where individuals could be exposed. Such an evaluation is very important in the safe operation of multiple transmitter sites.

A. To calculate total RF exposure at any given location, it is necessary to determine what percentage of the maximum permissible exposure is being contributed by each transmitter. These percentages are then added together to determine if the total exposure exceeds 100%.

B. For example, consider a multiple transmitter field day site set up in a public park. When evaluating each transmitter setup, the MPE Calculator POWER DENSITY option can be used to calculate the percent of MPE contributed by that transmitter at the location used by the operators (and possibly visited by the public).

C. The combined RF exposure for the operators (and visitors) can then be determined by totaling these percentages for all transmitters. If the combined exposure is less than 100% of the maximum permissible exposure, the operator location is within the FCC guidelines for safe operation.

5. Controlling Exposure to RF Fields:

After a station evaluation is performed, if a determination is made that a potential problem exists, several methods may be used for reducing or controlling exposure:
Restricting access to high RF-field areas: Limiting access may be the easiest method to reduce exposure. If the antenna is in an area where access is generally restricted (such as a fenced-in yard), it may be sufficient to simply control access to the yard when transmitting. An antenna may also be placed high enough on a tower or mast so that access to high RF levels is generally impossible.

A. Operating at reduced power when people are present in high RF-field areas: Reducing transmitting power can also significantly reduce exposure levels. If power output at the transmitter is reduced by 50%, then RF power density at a given location in the field of the antenna will also be reduced by 50%.

B. Transmitting at times when people are not present in high RF-fields areas.

C. Considering time-averaging exposure or mode of operation: If time-averaging has not been considered in calculating exposure levels, doing so may result in more acceptable results. Likewise, changing to a lower duty cycle mode or reducing the 'transmitter on' durations may result in acceptable exposure levels.

D. Relocating antennas or raising antenna height.

E. Incorporating shielding techniques: Placing a mobile antenna in the center of a metal vehicle roof may provide more adequate shielding for the occupants of the vehicle.

F. Using monitoring or protective devices.

G. Erecting warning/notification signage.

6. Entering Antenna and Operating Information:

In order to calculate the Maximum Permissible Exposure for an antenna, the required data must be entered into the data boxes on the screen. The following are required:

antenna type	antenna gain
transmission line (type and length)	transmitter power
operating frequency	ground reflection effects.

When the program begins, you must enter the data into the respective data boxes to describe your antenna and operating conditions. The MPE calculator software cannot generate results until ALL required information is entered. Once all data boxes are filled, the program will display the RF power delivered to the antenna (based on transmission line type and length) and a complete MPE results table (safe distances from the antenna in feet) according to operating mode for both controlled and uncontrolled environments. Antenna gain is the only data box that can be set to zero. The transmitter power, transmission line, and frequency data boxes must contain values greater than zero.

Once the initial data has been entered and the first calculated results are displayed, any of the data values can be changed to cause a recalculation of the results. Simply click on the data box to be changed and enter a new value - the software will recalculate and display the new results. In this manner, different station and antenna configurations can be modeled to determine the effects of changes on the MPE results.

A. Antenna Types: The selection of antenna type serves to both record the antenna used for the printed station evaluation report and allow an initial identification of antenna gain for the purpose of making the MPE calculation.

You may choose from among the following list of common antenna types: quarter-wave vertical, half-wave dipole, a series of yagi-type beams having from 2 to 17 elements, and 'other antenna type'. Selecting 'other antenna type' allows you to enter a textual antenna description.

Following antenna selection (or description), you are shown the typical antenna gain value (or asked to enter a gain value for an antenna described under 'other antenna type'). If the typical gain value offered is not correct for your antenna, enter the correct gain value.

When describing antennas under the 'other antenna type' option, it must be recognized that the gain of the antenna is important for the MPE calculation, not the actual identifying description. The program will accommodate virtually any type of antenna, even the most exotic types, as long as the antenna gain is known or can be estimated.

B. Antenna Gain:

The antenna gain must be entered in order for the MPE calculation to be performed. The antenna gain is measured as dBi (decibels gain in relation to an isotropic radiator). For the purposes of this calculation, only the antenna gain resulting from the directivity of the antenna is considered.

The typical gain values offered for the selection of antennas listed in the program are dBi values. Most antenna manufacturers provide gain values in dBi as part of their product documentation. If antenna gain values are given as dBd (decibels in relation to a dipole), conversion to dBi is accomplished by adding 2.15 (the gain of a dipole antenna) to the dBd value. An antenna gain of zero (0) is permitted.

C. Transmission Line Type and Length:

Both the type of transmission line and length of the transmission line must be known to allow the calculation of transmitter power losses due to transmission line attenuation.

The transmission line choices you are offered represent a selection of transmission lines commonly used in amateur radio:

- RG-58 (A, B, or C)Coax, 52 ohm, 0.195" dia., polyethylene dielectric
- RG-59 Coax, 73 ohm, 0.242" dia., polyethylene dielectric
- RG-8X Coax (mini-8), 52 ohm, 0.242" dia., foam polyethylene dielectric
- RG-8 (solid) Coax, 52 ohm, 0.405" dia., polyethylene dielectric
- RG-8 (foam) Coax, 50 ohm, 0.405" dia., foam polyethylene dielectric
- RG-213 Coax, 50 ohm, 0.405" dia., polyethylene dielectric
- 9913 Coax, 50 ohm, 0.405" dia., air space polyethylene dielectric
- LMR-400 Coax, 50 ohm, 0.405" dia., 100 percent foil and 88 percent braided shield, foam polyethylene dielectric
- 1/2 inch Hardline, 50 ohm, 0.5" dia., foam polyethylene dielectric
- 7/8 inch Hardline, 50 ohm, 0.5" dia., foam polyethylene dielectric
- Open-Wire, 450 ohm, insulated 'ladder line' with parallel conductors

If the transmission line in actual use is not found in the choices offered, select the transmission line that represents the closest possible match. A transmission line length of zero (0) is not permitted. Even when using a long wire antenna, a short length of coax must be used to connect the transmitter to the matching system.

Note: the WORST CASE result does not take transmission line losses into account.

D. Transmitter Power:

Transmitter power (Average Power or Peak Envelope Power (PEP)) must be entered to allow the calculation of power density in the antenna field. Enter the actual transmitter power value at the transmitter (or amplifier, if one is used). DO NOT adjust for transmission line losses as the

transmitter power value will be reduced by transmission line losses (if applicable) by the software as part of the MPE calculation.

A Note about Time Averaging: the FCC regulations on permissible RF exposure are not based on peak envelope power (PEP), but on average power over a 30-minute time period for uncontrolled environments, or a 6-minute time period for controlled environments. This can lead to some confusion about the correct transmitter power value to enter into the MPE Calculator software. Most amateurs do not operate their transmitter continuously over the 6 minute controlled environment or 30 minute uncontrolled environment time periods used by the FCC for MPE calculations.

Typically, an amateur SSB conversation will actually result in about 2 minutes "on" followed by about 2 minutes "off" – repeated over the span of the SSB conversation. For typical CW conversations this "on-off" ratio is probably similar.

- If transmitting 100 watts, such a SSB or CW conversation measured over a 6 minute period (controlled environment) would result in an average transmitter power over that time period of about 40 watts (2 minutes at 100 watts, 2 minutes at 0 watts, and 2 minutes at 100 watts (2/3 X 100 = 40).
- Similarly, if transmitting 100 watts, such a SSB or CW conversation measured over a 30 minute period (uncontrolled environment) would also result in an average transmitter power over that time period of about 40 watts (20 minutes "on" over the 30 minutes (2/3 X 100 = 40).
- Similar calculations can be made for other operating practices using measured "on/off" ratios over both 6 minute and 30 minute operating periods. For example, stations operating RTTY, PSK, or other digital modes or a contest station operating in a heavy pileup could spend considerably more time transmitting than usual during a 6 minute controlled environment or 30 minute uncontrolled environment time period used by the FCC for MPE calculations. Such a station might actually calculate a time averaged transmitter power of 80 watts when using a 100 watt PEP transmitter (or 800 watts when using a 1000 watt PEP amplifier).

This 'time averaging' does not take into consideration duty cycle which is calculated separately by the MPE Calculator program.

Thus, when entering Transmitter Power into the software, you may choose to enter your actual PEP transmitter power or a calculated average transmitter power. The software will then calculate the MPE

results for each of the transmission modes as well as the worst case for both controlled and uncontrolled environments.

The power at the antenna is displayed after all of the operating data has been entered and the calculation results are displayed. This value represents the transmitter power (PEP or average) minus transmission line losses. Whenever the transmitter power value or the transmission line type and/or length is changed, the power at the antenna value will be updated.

E. Mode of Operation:

In addition to Time Averaging discussed above, mode of operation also affects average transmitter power (average or PEP) based on the operating characteristics of the different modes. By using single sideband (SSB) without speech processing or Conversational CW, the average PEP is reduced to just 20% or 40% respectively of the amount of power produced by a full carrier or by such modes as RTTY and FSK (see Exposure Limits). For SSB with speech processing, the average PEP is reduced to 50% of the full carrier power.

DO NOT adjust the transmitter power (average or PEP) value according to the mode of operation. RF exposure resulting from the duty cycle factor representative for each mode of operation is automatically calculated by the software for each transmitter and antenna configuration entered. The MPE results displayed (and printed) include the distance from the antenna required to meet FCC exposure guidelines at each of the operating modes commonly used by amateurs.

G. Operating Frequency:

Calculation of RF power density (MPE) is dependant on frequency of operation. Enter each frequency as megahertz (MHz)(for example, 7258 kHz should be entered as 7.258 MHz). A frequency greater than 99,999 MHz cannot be entered because the FCC does not have exposure limits for frequencies greater than 100,000 MHz (100 GHz).

Because the power density of the RF field increases with increased frequency, it is suggested that the upper limit of each amateur band be entered for the antenna being evaluated. If an antenna is used for more than one band, the MPE results should be calculated (and printed) for each band separately. Example: a triband antenna designed for the 10-15-20 meter bands would require a separate MPE evaluation for 29.7 MHz, 21.45 MHz and 14.35 MHz.

H. Ground Reflection Effects:

The typical antenna radiation patterns with which we are all familiar are the result of a combination of direct RF energy from the antenna and indirect RF energy which is reflected from the ground out in front of the antenna. These two sources of RF energy combine at some distant point to form the familiar antenna RF patterns and are called far-field radiation patterns.

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.

The program offers you two choices: calculation of MPE results with the inclusion of ground reflection effects, and calculation without the inclusion of ground reflection
effects.

WORST CASE MPE results always include ground reflection effects regardless of your choice for the other MPE calculations.

7. Power Density Calculator

The MPE Calculator program provides a Power Density option for use in estimating the RF power density and percent of MPE at any given distance for any station and antenna configuration you describe. The power density calculator is a menu option located on the menu bar at the top of the main screen.

This option is enabled after you have entered all of the necessary data to complete the MPE calculations for a station configuration. After clicking on the POWER DENSITY menu option, you will be prompted to enter the distance (in feet) from the point of interest to the antenna. The point of interest is the location where you wish to measure the RF power density produced by the antenna at the frequency and power levels you have entered on the main screen.

The screen will display the FCC's Maximum Permissible Exposure limits for both controlled and uncontrolled environments at the selected frequency. The screen will also display the percentages of the MPE produced at that location for controlled and uncontrolled environments in each operating mode. Entering a new distance value will cause these results to be recalculated. These results can then be saved as a text file for this station and antenna configuration by clicking on the 'Save Results' button. By clicking on the 'QUIT' button, you can return to the main screen to enter new station and antenna configurations.

When the power densities at the point of interest (as MPE percentages) have been calculated (and saved) for each transmitting configuration in use at a multi-transmitter site, these percentages can be totaled to determine if the location in question is within the FCC guidelines for total RF exposure. If the total of the individual percentages (total RF exposure due to all antennas) at the point of interest exceeds 100%, the multiple transmitter site exceeds the FCC Maximum Permissible Exposure limits at that location.

8. Interpretation of Results:

The calculated results shown on the screen (and in the printout) represent the distance (in feet) that must be maintained from the antenna in order to meet the FCC power density limits in both controlled/occupational and uncontrolled/general public environments under the operating conditions you entered into the program.

The results show safe distances from the antenna for controlled and uncontrolled environments under three operating modes: SSB without speech processing - 20% duty cycle, conversational CW – 40% duty cycle, SSB with speech processing - 50% duty cycle; and all 100% duty cycle modes. In calculating these results, the program utilized your average transmitter power (transmitter PEP multiplied by each duty cycle factor), transmission line losses, antenna gain, operating frequency, and ground effects (if selected).

The WORST CASE result is a calculation which is based on 100% duty cycle and utilized full transmitter power (PEP), antenna gain, operating frequency, and ground effect (whether selected or not). Transmission line losses are NOT considered in the WORST CASE result.

After calculating the safe distances for each antenna under both controlled and uncontrolled conditions, you must verify that it is physically impossible or extremely unlikely under normal circumstances for any person to be closer to your antennas than is safe. To do so, measure the actual distances from the antennas to all locations where individuals might be located. You may find it necessary to relocate or reconfigure antennas or make other changes to your station operating environment in order to insure that the FCC Maximum

Permissible Exposure limits are observed at all times (see Controlling Exposure to RF Fields).

9. Saving and Printing Results:

You must keep a record of your complete station evaluation results. This can be accomplished by clicking on the 'Save Results' menu option at the top of the screen after entering each antenna configuration. This option is enabled after you have entered all of the necessary data to complete the MPE calculations for each station configuration. Whenever you change the station configuration, the option is disabled until you recalculate for the new configuration. The report will saved to a text file that is stored in the C:\MPE directory. The file is named according to the antenna and date. When you change the station configuration for that antenna, a new report is appended to the original report file stored in the C:\MPE directory. If a different antenna is selected, a new report file will be opened in C:\MPE named after the new antenna. A printed report can then be produced from each saved file by either directly printing that text file to your printer or copying the text from the file into a word processor and printing from that software.

The first time 'Save Results' is selected, you will be prompted to enter identifying information (name, amateur callsign, address, city, state, and zipcode) to be printed at the top of each report. It is not necessary to enter your amateur callsign or zip code, but all other identifying information must be entered before a report will be saved. This identifying information is only entered once, it is then used for all subsequent reports saved.

As you change your station configuration (antenna, frequency, transmission line type and/or length, power), you should save a report for that configuration. For example, if your station setup uses dipole antennas for 160-meters, 80-meters, and 40-meters; a triband beam for 20-15-10 meters and a 5-band vertical, you should produce separate reports for each dipole, three separate reports for the triband beam (one each for 20 meters, 15 meters, and 10 meters), and another set of reports for the multiband vertical (one for each band). Finally, if the 80-meter dipole is also used for 10 meters, a separate report should be produced for both the 80-meter band and 10-meter band for that antenna.

If you also perform power density analysis of your station operating and antenna configuration, you may save that analysis for printing as well. When that analysis is saved, a separate report is opened according to the antenna and date. Subsequent power density calculations for different station operating characteristics using that same antenna will be appended to the original file. Selecting another antenna for analysis will result in a new report file being opened according to the new antenna and date.

You should also print out and sign a conclusions page to be attached to each report based on those results. A separate Conclusions text file is provided which can be printed for use with each report. Check the appropriate statements providing the basis for your conclusions, filling in additional comments as needed. Sign and date each report and conclusions and keep them for future reference. DO NOT send your reports to the FCC, they are for your use only as needed.