

# RF MPE CALCULATOR



Version 1.00

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## 1.0 Purpose of the RF MPE Calculator

In August 1996, the FCC announced a new set of regulations regarding exposure to RF fields. These rules are intended to limit human exposure to RF energy through correct station design and operation. As of January 1998, any amateur licensee filing a form 610 with the FCC (such as renewal or change of station location) will have to be in compliance with *Bulletin 65*<sup>1</sup> when the the form is signed. These rules state the *maximum permissible exposure*, or “MPE” for various conditions of operation.

### *What is Required for Compliance?*

Each amateur station is required to perform a *station evaluation* to determine that its operation is within the bounds of the safety rules. The evaluation can utilize one or more of the following methods:

- Direct RF field-strength measurements.
- RF field-strength estimation by table (the method proposed for amateurs by the FCC.)<sup>2</sup>
- Raw RF field-strength calculations.

Most amateurs don't possess the equipment to make direct RF field measurements; it is quite expensive, and requires specialized training in order to obtain reasonable results. This method would probably be a last-resort to prove compliance.

Many amateurs will use the lookup tables provided by the FCC as part of Bulletin 65. This is not an exceeding difficult method, but is definitely time-consuming and leaves plenty of room for operator error. The station operator will need to provide documentation that the evaluation was completed if the station is inspected by the FCC.

Raw calculation of RF field strengths is not unduly complicated, and probably the most flexible of the above approaches; but due to the large variety of antennas, feedlines, and transmitter power levels, there are a lot of

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<sup>1</sup> “The FCC's New RF-Exposure Regulations” , Ed Hare, QST January 1997

<sup>2</sup> “What's New About the FCC's New RF-Exposure Regulations?” , Ed Hare, QST October 1997

opportunities for mistakes! **RF MPE Calculator** is designed to not only automatically perform these calculations (eliminating most of the possibility of error), but also to compile the results of these calculations into a complete, easily-readable report that can be filed in a station's permanent record.

### *Why is it Important to Perform a Station Evaluation?*

Radio waves emanating from an amateur radio station are a form of electromagnetic energy. In recent years, authorities have begun to question whether or not the various forms of EM energy (not limited to RF) could be harmful to humans. As of this writing, there is no conclusive evidence that the RF fields surrounding us everyday are dangerous; however, because the potential hazard is not completely understood, a proper individual attitude is “prudent avoidance” as discussed in several ARRL publications.

As amateur operators, we have the right to use radio transmitters. Along with the right comes the responsibility for their safe operation; others besides ourselves will be exposed to the radiation fields they emit. **RF MPE Calculator** is a quick way to determine rules compliance without expensive instruments or cumbersome look-up tables.

It is also quite instructive to use **RF MPE Calculator** to help plan a new station, or to “tweak” an existing one for better performance. The program contains built-in data on the most commonly-used transmission lines (completely frequency-compensated) and antennas, and it’s very easy to simply “point and click” a potential station configuration (with results instantly available on screen).

### *Are any Stations Exempted from Performing the Evaluation?*

As of January 2021, the FCC has unified MPE rules across the services. There are no longer specific exemptions for any individual service.

Refer to FCC rules for specifics on this topic.

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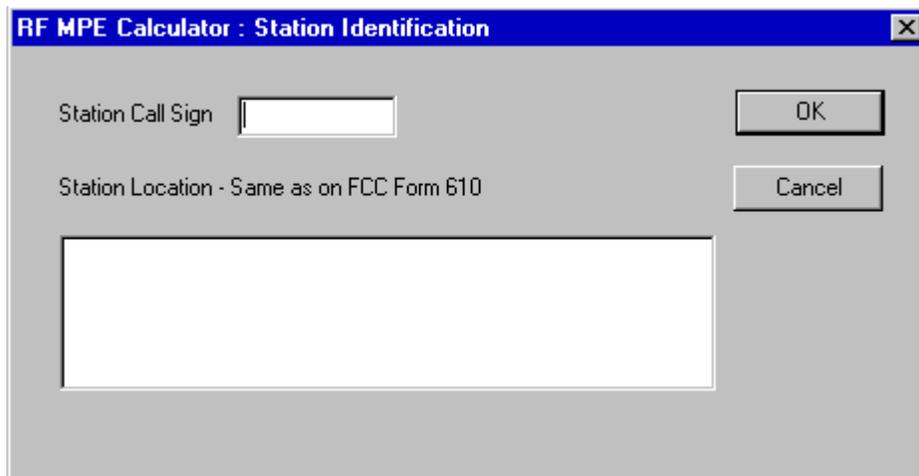
## 2.0 How to Use the Calculator – Step by Step

### *Installing the Program*

Download the supplied ZIP file, and unpack it onto the desktop of your computer. This ZIP contains the RFMPE.EXE executable and the RFMPE help file. *NOTE: Windows HELP is not supported by Microsoft after Windows 8.*

### *Starting an RF MPE Calculator Session*

Double-click the RF MPE icon on the desktop to start the program. The following dialog box will appear:



The image shows a Windows-style dialog box titled "RF MPE Calculator : Station Identification". The dialog has a blue title bar with a close button (X) in the top right corner. The main area is light gray and contains the following elements:

- A text label "Station Call Sign" followed by a small, empty text input field.
- A text label "Station Location - Same as on FCC Form 610" followed by a larger, empty text input field.
- Two buttons on the right side: "OK" (top) and "Cancel" (bottom).

At this point, you can either type in your station call and location, or press CANCEL. The program collects this information to add to the finished report, but it is not required. Once this has been completed, the main program box will appear as shown on the next page.

## Main Program Dialog Box Parts

The screenshot shows the 'RF MPE CALCULATOR V1.0' dialog box. It is divided into three main sections:

- Radiation Characteristics:** Contains input fields for Power Level (100 Watts), Duty Cycle (100 %), Frequency (30.00 MHz), Feedline Type (Generic), Feedline Loss (0 dB), Antenna Gain (0 dBi), and Effective AVERAGE Radiated Power (100.00 Watts). There are 'Calculate...' buttons for Feedline Loss and Antenna Gain. A 'QUIT' button is also present.
- Maximum Permissible Exposure Limits:** Contains input fields for Controlled (1.00 mW/cm<sup>2</sup>) and Uncontrolled (0.20 mW/cm<sup>2</sup>) limits, and their respective distances (4.7 Feet and 10.5 Feet). It also has radio buttons for 'English' (selected) and 'Metric'.
- Report Generation:** Contains a text area with the text 'RFMPE Version 1.00 (c) 1998 Tom A. Wheeler NOGSG (UNREGISTERED Evaluation Copy)' and 'Callsign:' and 'Station Location:'. There are 'Add to Report' and 'Save Report' buttons.

Red numbered callouts (1-5) point to specific elements: 1 points to the Power Level field, 2 points to the Feedline Type dropdown, 3 points to the 'Calculate...' button for Antenna Gain, 4 points to the Controlled exposure limit field, and 5 points to the 'Add to Report' button.

The controls in the **RF MPE Calculator** are quite straightforward:

**1** This area holds the power level, duty cycle, and frequency of your station. You simply type in the desired values. “Duty Cycle” is the percentage of time that your station actually transmits; for worst-case estimates, it can be left at 100%. For most amateur operation (such as SSB, CW, and packet), the actual duty cycle is lower than 50%.

**2** Your feedline or transmission line information is entered here. The box above that states “Generic” will give the actual type of transmission line that is being used (once a selection is made). **The “Generic” label really means that RF MPE Calculator will not make any adjustments to feedline loss with frequency changes – it has merely accepted the figure that you have typed into the “Feedline Loss” box.**

**3** The two **Calculate** buttons are used to ask **RF MPE Calculator** to assess feedline and antenna gain for you. Alternately, you can simply fill in the blanks if you already know the correct figures.

**4** The two **Distance** readouts give the *minimum* distance from the transmitting antenna in order to be within the **Exposure Limits** (gray boxes) shown. The exposure limits are based on FCC rules and are automatically recalculated whenever the frequency is changed. **Some distance readouts will be less than 2 wavelengths from the antenna and will therefore be in a region of combined near and far-field radiation. The exposure limits prescribed by the rules do not take this into account; for the purpose of rules compliance, this is not a problem.**

**5** The **Report Generation** controls allow you to add the current screenful of data into the **report window**. You can freely scroll through and edit the **report window** contents; you can even cut, copy and paste the contents to and from the Windows clipboard by using **^X**, **^C**, and **^V**, just like any other Windows application. The **Save Report** button saves the **report window** contents to a standard text file, which can then be opened and printed with either the **Notepad** tool or some other text editor.

### *Calculating the MPE Limit for a 10 Meter Station*

Let's assume that the following station needs to be evaluated:

- Frequency = 30.0 MHz (10 meter voice operation)
- Power = 100 Watts
- Feedline is type RG-8 Coaxial, 150 feet in length.
- Antenna is a half-wave dipole 30 feet above ground.

**RF MPE Calculator** always starts with a frequency of 30 MHz and a power of 100 Watts, so all that needs to be done is to enter in the particulars of the antenna and feedline installation for this case.

Press the **Calculate** button for **Feedline Loss** and the following **Feedline Loss Calculator** will open to help you calculate the feedline loss.

**Feedline Loss Calculator** [X]

Frequency  MHz (Frequency is same value as selected within main program.)

Feedline Type **1**

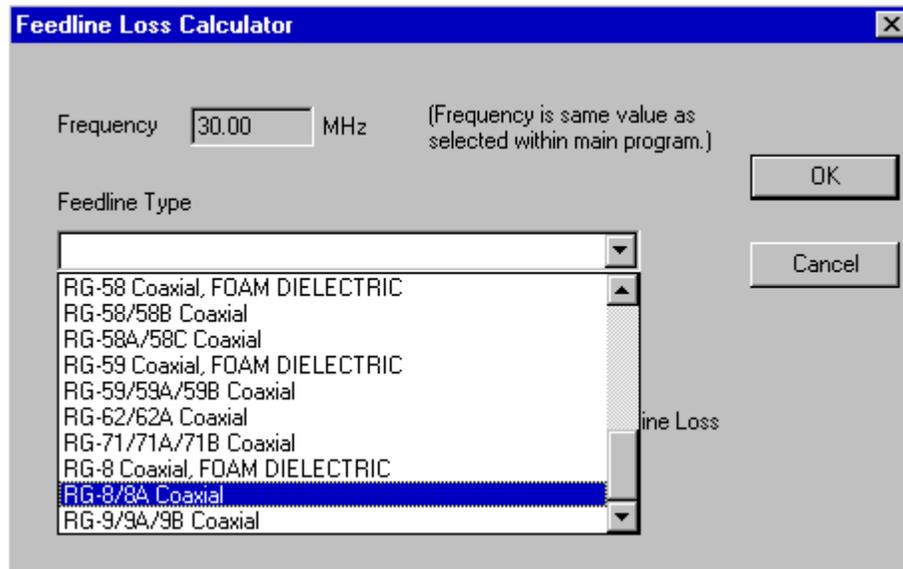
Specific Loss  dB / 100 Feet **2**

**3** Feedline Length    Computed TOTAL Feedline Loss  dB **4**

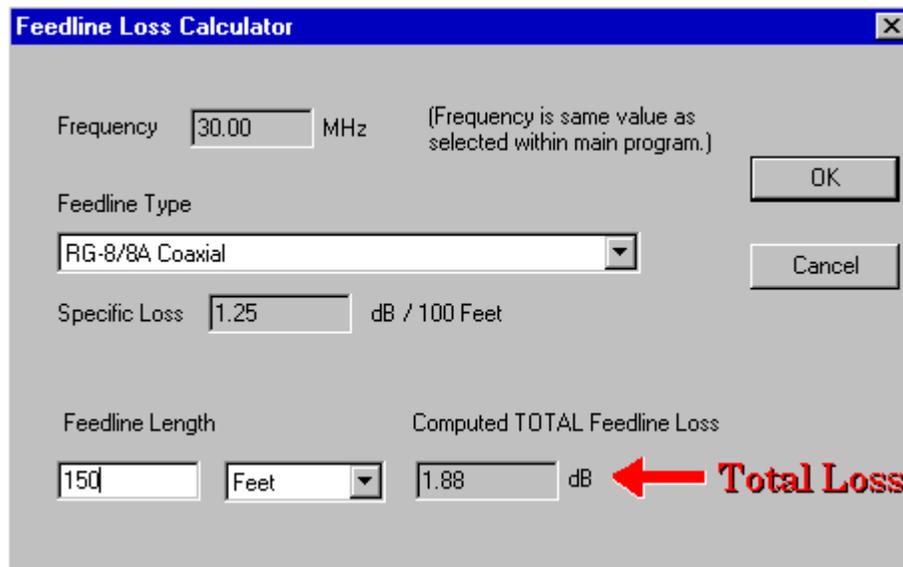
OK

Cancel

In the **Feedline Loss Calculator**, the type of feedline is chosen by selecting from the choices available at control **1**:



At **2** the **specific loss** (Loss per unit length) of the transmission media is reported. After typing the length into the **Feedline Length** box at 3, the **Total Feedline Loss** will be displayed.

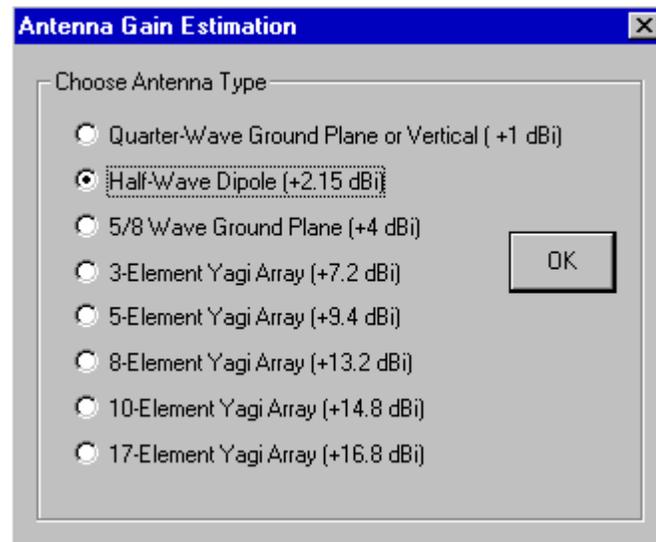


These inputs can be supplied in any desired order. Note that the **Feedline Loss Calculator** uses the frequency selected by the main program to determine feedline loss.

In general:

- Feedline loss will increase with increasing frequency. If you're planning a station, you can see the effect of different types of feedline by re-selecting the **Feedline Loss Calculator**.
- The **Feedline Loss Calculator** continues to calculate feedline loss, even after you've pressed **OK** to close it. *This means that the feedline loss will automatically be adjusted if the operating frequency is changed at a later time.*

After pressing **OK**, the program again displays the screen of data collected so far. To continue our analysis, we now need to enter our antenna information, so we'll press the **Calculate** button to the right of the **Antenna Gain** control:



The **Antenna Gain Estimator** allows the choice of several “canned” antennas. Most transmitting antennas will closely match at least one of these.

- If your antenna doesn't match any in the estimator, you might be able to pick one that is close. For example, a half-wave vertical antenna is almost identical in gain to a half-wave dipole, so for the purposes of analysis, a dipole could be used.
- If there is no antenna that closely matches your antenna, use the manufacturer's specification for gain. **RF MPE Calculator** assumes that antenna gain is in **dBi** (dB with respect to a theoretical Isotropic source). If the manufacturer gives the antenna gain in **dBd** (dB gain with respect

to a halfwave dipole), **add 2.15 dB** to this figure to convert it into **dB*i*** units.

After entering in the antenna data as shown, the program will now display the results:

RF MPE CALCULATOR V1.0

Radiation Characteristics

Feedline Type: RG-8/8A Coaxial

Power Level: 100 Watts

Duty Cycle: 100 %

Frequency: 30.00 MHz

Feedline Loss: 1.87 dB

Antenna Gain: 2.15 dBi

Effective AVERAGE Radiated Power: 106.66 Watts ← *Calculated EIRP*

Maximum Permissible Exposure Limits

Controlled: 1.00 mW/cm<sup>2</sup> @ Distance of 4.8 Feet (6 Minute Average)

Uncontrolled: 0.20 mW/cm<sup>2</sup> @ Distance of 10.8 Feet (30 Minute Average) ← *Calculated Safety Distances*

Report Generation

CONTROLLED Limit = 1.00 mw/cm-cm @ 4.8 Feet

UNCONTROLLED Limit = 0.20 mw/cm-cm @ 10.8 Feet

Buttons: QUIT, About..., Add to Report, Save Report

Under the conditions we gave, the program has determined the following:

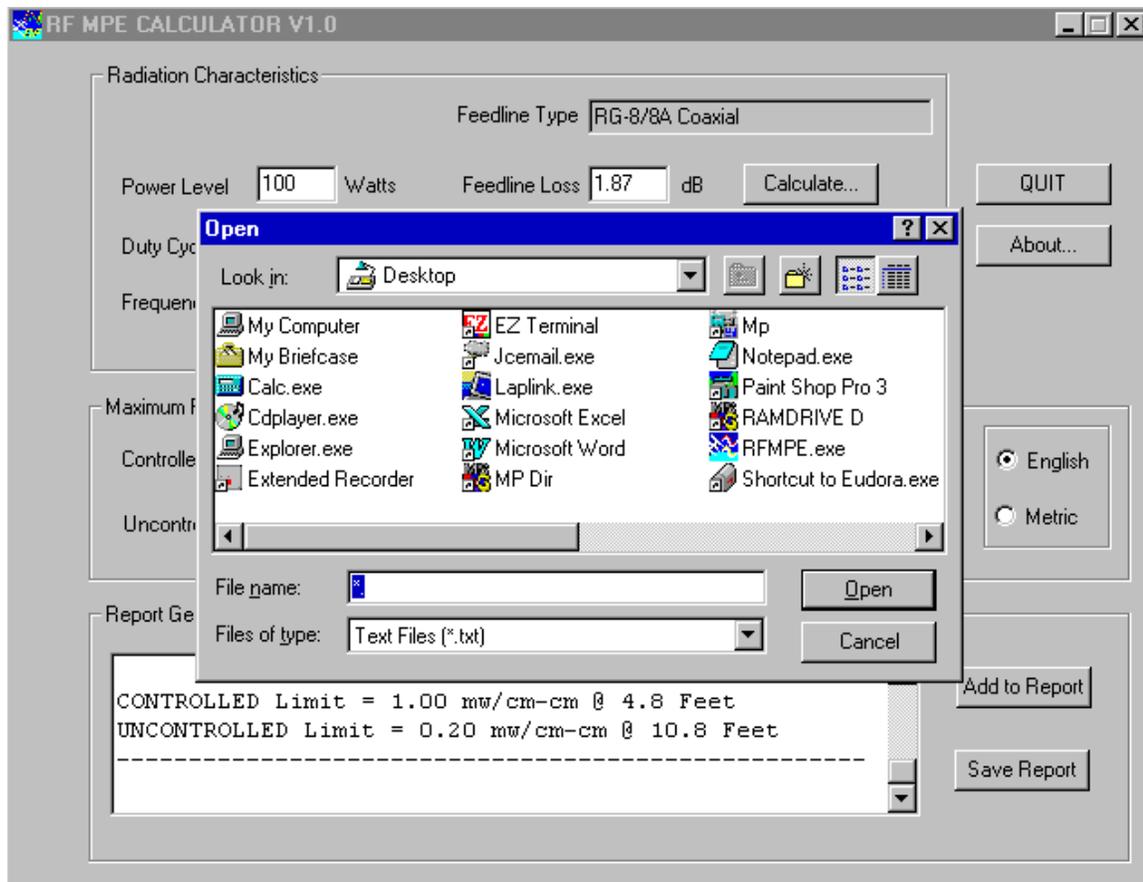
- The equivalent isotropic (point-source) transmitted power is 106.66 Watts. This figure is valid only at the axis of the major lobe of the antenna pattern.
- For the general population (those unaware or unable to protect themselves from the RF radiation), your antenna needs to be at least 10.8 Feet away. This is the meaning of the **Uncontrolled** figure. This figure is averaged over a 30-minute period.
- For the **Controlled** environment, the distance from the antenna must be at least 4.8 Feet.

Obviously, since the antenna is 30 feet up in the air, there's no immediate problem below; as long as the distances are at least as large as those given in the results box.

### *Creating the Final Report*

To document the characteristics calculated thus far, press the **Add to Report** button. This will add the results to the report box.

Tip: Remember that the results box is actually a “mini text editor.” You can freely edit its contents at any time – for example, you can add descriptive comments about the data you've entered.



To create a permanent copy of the report, press the **Save Report** button, which will bring allow you to choose a filename and path for the resulting text file. Type the desired file name (for example, “MyCall.txt”) and press **Open**.

*Congratulations, You're finished!*

That's all there is to performing a basic analysis of your station. Naturally, you'll want to repeat the analysis for each antenna and power level in your station, pressing **Add to Report** after each one. The result will be a text document with a concise summary of all the information you've entered.

**TIP:** You can read the resulting text file into any word processor or text editor and make additional comments, additions, or deletions. Make sure to keep a hardcopy of this file in your station records.

### 3.0 What If? . . .

You may find that one or more of your station configurations appears to be out of compliance with the FCC rules, and wonder what you can do about it.

The *first* thing that you can do is to adjust the duty cycle of the emissions from your station. Most likely, you are not transmitting 100% of the time; therefore, it would make sense to try adjusting the **Duty Cycle** figure to something more reasonable. *Most amateur communications use less than a 50% duty cycle, and in many cases it is much less than 50%!*

Adjusting duty cycle is not a trick just to make the numbers look right! The exposure regulations cite an *average* power density of exposure over a specified period of time (6 or 30 minutes). Thus, making this adjustment actually can make the computed RF exposure levels much closer to those which will actually occur.

If you're still out of compliance, then you have several options:

- Reduce power. How low should you go? Type the distance to the occupied area into the **Distance** box. **RF MPE Calculator** will automatically compute the maximum power level that you can use and display it. Remember that FCC rules require amateur stations to use the minimum power to complete communications.
- Refine your calculation. For example, a horizontally-mounted Yagi antenna mounted 60 feet above ground may produce ground fields near a dwelling significantly smaller than those 60 feet away in its major lobe of radiation. (Use antenna table data or manufacturer's data sheet information to calculate this information and use it to adjust the effective **Antenna Gain** in the direction of the occupied area).
- Move the antenna away from the occupied areas; for example, raise an outdoor antenna further. Or in the case of a directional antenna, don't point it in the offending direction without first reducing your power level appropriately.
- Reduce your duty cycle further. For example, the FCC has no problems with you taking a two-minute break out of a 30-minute on-air session.

## 4.0 Common Questions

The following are commonly-asked questions about RF Safety and **RF MPE Calculator**:

### What is “Power Density?”

When RF energy leaves a transmitting antenna, it does so in three-dimensional waves. These waves are spherical in shape and move outward from the source, much like the ripples in a pond would move away from the point where a stone is dropped. A theoretical antenna called an “Isotropic” antenna radiates equally well in all three directions; the expanding wave pattern from such an antenna would look like the inflation of a balloon. The RF energy from the transmitter is distributed upon the surface of this “balloon,” and naturally gets considerably smaller as distance grows from the transmitter. Power density is the amount of RF energy (in Watts) that would be available to a certain square area on the surface of the “balloon” (RF wavefront) at a given distance from the transmitter. At large distances from the antenna, there is very little power per unit area and the “balloon” is so large that at any point, its surface appears approximately flat, much like the earth. “Gain” antennas concentrate the RF energy in one or more directions; a crude analogy would be distorting the shape of a water-filled balloon by squeezing it. The total RF power has not changed; only its distribution in space.

### How are the EPA power densities calculated?

The EPA power densities are calculated with acknowledgment that people live on or near the ground. A *ground reflection factor* of about 2.56 is used for power density calculations. This factor takes into account (at least approximately) the “double whammy” effect of being exposed not only to an incident wave from an antenna, but also to its reflected “brother” coming out of the ground. Those of us that have spent a day at the lake already know how easy it is to be sunburned (exposed to excessive ultraviolet radiation) on the water; this too is due to reflection. In reality, power densities at earth level are very hard to predict and in most cases will be less than this factor predicts.

*How does feedline radiation affect these results?*

**RF MPE Calculator** assumes that your feedline is doing exactly what it's supposed to be doing – and that means *not* radiating a signal! Severe impedance mismatch, or load imbalance can cause a feedline to become part of your antenna system. This means that parts of your radio system are emitting RF energy that shouldn't; and that these parts may be very close to **you** or **other people**, causing your station to be **out of compliance** with FCC rules (and at high power levels, possibly presenting a hazard.)

*What should be done in a radio station to keep RF power levels at their minimum?*

The following would be good ways to keep stray RF to a minimum:

- Use a good station ground. Plumbing is not generally a good RF ground. Many articles have been written on this subject.
- Make sure that feedlines are terminated in proper loads, and matched and balanced as required to prevent feedline radiation.
- Don't operate transmitters with covers removed, especially at VHF and UHF.
- Use the minimum power needed to complete communications.

*How can I put RF MPE Calculator on my Web site?*

This version of **RF MPE Calculator** has been licensed to you as a single end user, so it is not appropriate to copy it onto a web site. You are welcome to provide a link to our website.

*I have questions or comments about the program, where do I send them?*

Questions, comments, bug reports (please tell us what data causes the problem), and suggestions are always welcome; many will be implemented in the next version of the program. Send them to:

tom.n0gsg@gmail.com  
http://n0gsg.com  
73,  
Tom N0GSG