RFExposure report generator

version 0.25A

U.S. Amateur Radio RF Exposure Report Generator

PC Information Group, Inc.

AMATEUR RADIO PRESS

visit pcig.net amd amateurradiopress.com

RFExposure

By PC Information Group, Inc.

Published by PC Information Group, Inc., 1031 Riverchase North Drive, Brandon, MS

For permission requests, write to the publisher at the address below:

PC Information Group, Inc.

1031 Riverchase North Drive, Brandon, MS

Published in United States of America

First Edition

Alpha (0.25A)

Disclaimer

The information and calculations provided in this document are intended for general informational purposes only. While we strive to ensure the accuracy and reliability of the content, we make no representations or warranties of any kind, express or implied, about the completeness, accuracy, reliability, suitability, or availability with respect to the report or the information, calculations, or related graphics contained in the document for any purpose. Any reliance you place on such information is therefore strictly at your own risk.

By using this document, you agree that:

1. Use at Your Own Risk: The calculations and information provided by this document are to be used at your own risk. The results and outputs generated are for informational purposes only and should not be used as a sole source of guidance for any decisions or actions related to RF exposure or any other matters.

2. No Liability: The publishers of this document are not liable for any loss or damage, including without limitation, indirect or consequential loss or damage, or any loss or damage whatsoever arising from loss of data or profits arising out of, or in connection with, the use of this report.

3. Professional Advice: This document does not replace professional advice. Users are encouraged to consult with a qualified professional for specific advice tailored to their situation. By using this document, you acknowledge that you have read, understood, and agree to be bound by this disclaimer. If you do not agree with any part of this disclaimer, please do not use this document.

Table of Contents

Section 1.0 – Introduction

Welcome to RFExposure

Are you a dedicated ham radio operator committed to both top-notch performance and compliance with RF safety standards? **RFExposure** is here to empower you with the tools you need to assess your station's **RF exposure limits**, ensuring it aligns seamlessly with the latest **FCC guidelines**.

Why does this matter? Radio frequency energy is integral to modern communication, but excessive exposure can pose risks to both operators and the general public. With RFExposure, you can effortlessly calculate the **safe operating distances** for your station and ensure it meets the **Federal Communications Commission's (FCC)** safety requirements for **electromagnetic field (EMF) exposure**.

This comprehensive tool takes the guesswork out of compliance. By simply entering your station's parameters—such as transmitter power, antenna gain, and operating environment—RFExposure provides precise, actionable insights in the form of a detailed safety report. The result? You can operate confidently, knowing your setup is both safe and compliant.

What Makes RFExposure Indispensable?

RFExposure is not just a calculator—it's your gateway to safer and smarter amateur radio operations. Radio frequency (RF) energy, while invaluable for communication, must be carefully managed to prevent unwanted health effects, particularly **RF-induced heating** in human tissue.

Without proper precautions, RF exposure can exceed acceptable limits. That's where RFExposure comes in: it helps you navigate the complexities of safety compliance with precision and ease.

Key Features and Capabilities:

RFExposure performs advanced calculations by analyzing critical factors that define your station's RF exposure profile:

1. **Transmitter Power and Duty Cycle**:
   Accurately factor in the **average power output** of your transmitter and the **duty cycle** for different operating modes (e.g., CW, SSB, FM, digital modes).
2. **Antenna Gain and Radiation Patterns**:
   Assess how your antenna's gain and radiation patterns affect exposure levels. RFExposure accounts for vertical and horizontal radiation components for better accuracy.
3. **Operating Frequencies and Band-Specific Analysis**:
   Get detailed insights across all amateur bands, from **MF/HF** frequencies for long-distance communication to **VHF/UHF** for local operations.

4. **Environment Classification**:
   Define whether your station is in a **controlled environment** (e.g., private property with restricted access) or an **uncontrolled environment** (e.g., areas accessible to the general public).
5. **Real-World Conditions**:
   RFExposure accounts for **ground reflection factors**, environmental multipliers, and **field strength variations** to reflect real-world conditions accurately.

By simplifying these advanced calculations, RFExposure makes safety compliance accessible to operators of all experience levels, from beginners to seasoned experts.

Understanding Your Results

RFExposure provides two essential safety metrics to guide your station's operations:

1. Controlled Environment Distance

This is the minimum safe distance required for operators and other informed individuals who are aware of RF exposure risks and understand how to minimize them. This group typically includes operators, technicians, and family members familiar with your station's setup.

2. Uncontrolled Environment Distance

This is the greater safety margin required to protect members of the public who may unknowingly enter the RF field. This distance ensures compliance even in areas where awareness of RF risks is low.

A Commitment to Accuracy

RFExposure's calculations are grounded in the **FCC's OET Bulletin 65, Supplement B**, ensuring alignment with the most recent and rigorous regulatory guidelines. The tool integrates:

- **Time-Averaged Power Density Calculations**: Ensures compliance over typical duty cycles.
- **Ground Reflection Multipliers**: Models real-world conditions for more accurate results.
- **Multi-Frequency Operations**: Simultaneously evaluates RF exposure across multiple operating frequencies to ensure full-spectrum safety.

These reports are not only a valuable safety tool but also provide **critical documentation** for inspections or audits, demonstrating your commitment to FCC compliance.

Why RFExposure Is Essential for Every Operator

Staying compliant is no longer optional. Recent updates to FCC regulations have made RF exposure evaluations mandatory for all amateur radio operators. Failure to comply can result in fines, station shutdowns, or even equipment confiscation.

Whether you're a casual operator or a high-power enthusiast, RFExposure equips you to handle compliance with confidence. It's indispensable if you're:

- **Setting Up a New Station**: Avoid surprises by designing your station for compliance from day one.
- **Modifying an Existing Setup**: Ensure new equipment or configurations meet updated safety standards.
- **Operating Portable or Mobile**: Evaluate exposure risks for temporary setups, including field day operations and contesting.
- **Running Multi-Band or Multi-Mode Configurations**: Account for the complexity of simultaneous operations across multiple frequencies.
- **Teaching New Operators**: Help newcomers understand the importance of RF safety as part of their licensing journey.

What Sets RFExposure Apart?

RFExposure is designed with **ham operators in mind**, combining advanced algorithms with a user-friendly interface. Unlike generic RF calculators, it:

- **Adapts to Your Station**: Tailor calculations to your unique setup and operating environment.
- **Saves Time**: Automate complex compliance calculations, eliminating manual effort.
- **Provides Professional Reports**: Generate detailed, PDF-based safety reports suitable for record-keeping and inspections.

These features make RFExposure not only a compliance tool but also an invaluable resource for building a safer, more efficient station.

Ready to Get Started?

Don’t leave RF safety to chance. With RFExposure, you’ll have everything you need to evaluate, document, and maintain compliance with FCC **Maximum Permissible Exposure (MPE)** limits.

Here’s how to begin:

1. Gather basic details about your station setup (power, duty cycle, antenna configurations, etc.).
2. Follow the tool’s simple, step-by-step data entry process.
3. Generate your RF exposure safety report in minutes.

Whether you’re a seasoned ham or just starting, RFExposure ensures that your station is safe, compliant, and optimized for operation. Start today, and join the thousands of operators prioritizing safety in the amateur radio community!

Section 2.0 – RF Exposure Report Calculation Worksheet

The RF Exposure Calculation Worksheet Form

The primary purpose of the **RF Exposure** report generation tool is to assist in assessing potential exposure to radio frequency (RF) energy for a given station and antenna system. The RF Exposure Report Calculation Worksheet serves as the mechanism for entering required parameters such as antenna characteristics, transmission power, operating frequency, and other key data necessary to ensure compliance with regulatory exposure limits, protecting you and others from excessive RF exposure.

Summary of Panels

The **RF Exposure Report Calculation Worksheet** consists of 15 data entry fields, grouped by functionality across five separate data entry panels. These panels include:

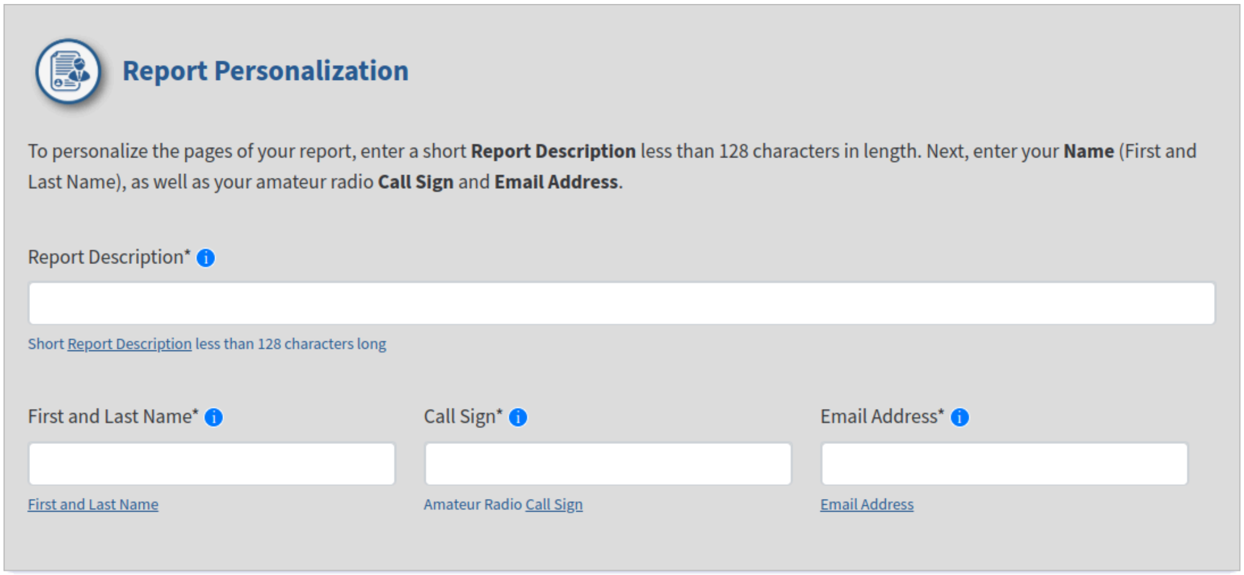
1. **Report Personalization:** Provide essential details to personalize your report, such as a brief **description** of the report, your **full name**, amateur radio **call sign**, and **email address**.
2. **Single or Multi-Band Exposure Analysis:** Select the **multi-band group** (e.g., MF/HF or VHF/UHF) and **frequency** position within a given band for analysis. You also have the option to perform a simple **single frequency** analysis if your setup requires it.
3. **Antenna Specifications:** Enter detailed information about your antenna, including its **description**, **gain**, and whether to account for **ground reflection effects** for a worst-case exposure analysis.
4. **Transmission Specifications:** Specify the transmitter **power**, mode **duty factor**, and **transmit** and **receive times**.
5. **Generate RF Exposure Report:** Decide whether to **include detailed calculation pages** in your report. After reviewing all form entries, generate your RF exposure report, customized based on the data provided.

By carefully entering your operating data, the generated RF exposure report will accurately reflect your station's operating conditions, ensuring safe and compliant operations.

This revision preserves your content's intent while improving clarity and precision. Let me know if you need further refinements!

Report Personalization

The **Report Personalization** panel allows you to tailor your RF exposure report by providing essential information that will be reflected throughout the document. The form collects basic details, including a description of the report, your full name, amateur radio call sign, and email address. This information personalizes the generated report, making it specific to your unique radio/antenna configuration and preferences.



Data Entry Fields

1. ### Report Description

   - **Purpose:** This field is for entering a short description of the report. The description should summarize the content or purpose of the report.
   - **Character Limit:** 128 characters.
   - **Mandatory:** Yes.
   - **Guidance:** The description should be concise yet informative enough to identify the report easily. For example, "Field Day Event Exposure Report" or "Home Station Compliance Check for G5RV."

2. ### First and Last Name

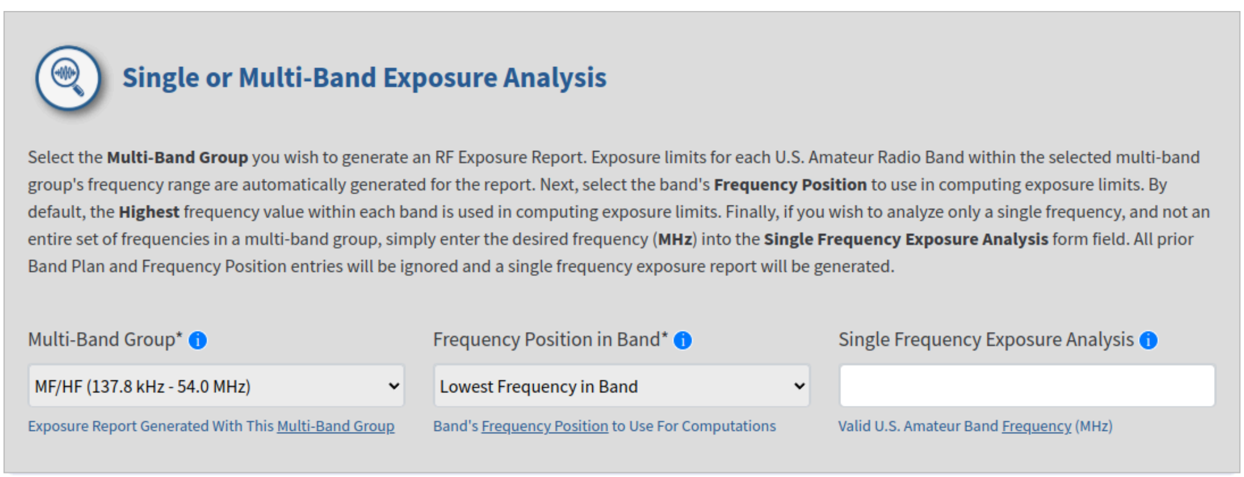
   - **Purpose:** This field captures the user's full name, which will be displayed on the report.
   - **Mandatory:** Yes.
   - **Guidance:** Enter your first and last name as you would like them to appear on the report. This ensures the report is personalized and identifiable.

3. **Call Sign**
    - **Purpose:** The call sign uniquely identifies the amateur radio operator. It is an essential part of the report, linking the report to the operator's licensed identity.
    - **Mandatory:** Yes.
    - **Guidance:** Enter your U.S. amateur radio call sign. This call sign will appear prominently in the report.

4. **Email Address**
    - **Purpose:** The email address allows for optional contact or follow-up regarding the report.
    - **Mandatory:** No.
    - **Guidance:** Please provide a valid email address. This will be included in the report for identification or contact purposes.

Single or Multi-Frequency Analysis Panel

The **Single or Multi-Band Exposure Analysis** panel enables users to select the **Multi-Band Group** you wish to generate an RF exposure report. Exposure limits for each U.S. Amateur Radio Band within the selected multi-band group's frequency range are automatically generated for the report. Next, select the band's **Frequency Position** to use in computing exposure limits. By default, the **Highest** frequency value within each band is used in computing exposure limits. Finally, if you wish to analyze only a single frequency, and not an entire set of frequencies in a multi-band group, simply enter the desired frequency (**MHz**) into the **Single Frequency Exposure Analysis** form field. All prior Band Plan and Frequency Position entries will be ignored and a single frequency exposure report will be generated.



Data Entry Fields

1. ### Multi-Band Group to Generate Exposure Report

   - **Purpose:** This field allows you to select the **Multi-Band Group** (e.g., MF/HF or VHF/UHF) for which you wish to generate an RF exposure report. The chosen multi-band group plan determines the frequency ranges to be analyzed.
   - **Options**:
     - MF/HF (137.8 kHz - 54.0 MHz)
     - MF/HF (54.0 MHz - 1,300.0 MHz)
   - **Mandatory:** Yes.
   - **Guidance:** Select the Multi-Band Group corresponding to the frequencies you are interested in analyzing. The RF exposure limits for each band within the selected group will be automatically generated in the report.

2. ### Frequency Position in Band

3. - **Purpose:** This field specifies which frequency position within the selected band will be used for computing RF exposure limits. The default setting uses the highest frequency value in the band, but users can choose other positions as needed.
   - **Options**:
     - Highest Frequency in Band
     - Center Frequency in Band
     - Lowest Frequency in Band
   - **Mandatory:** Yes.
   - **Guidance:** To analyze exposure based on a specific and consistent frequency position within the band, select the appropriate option. This allows for more targeted analysis based on the characteristics of your radio and antenna setup.

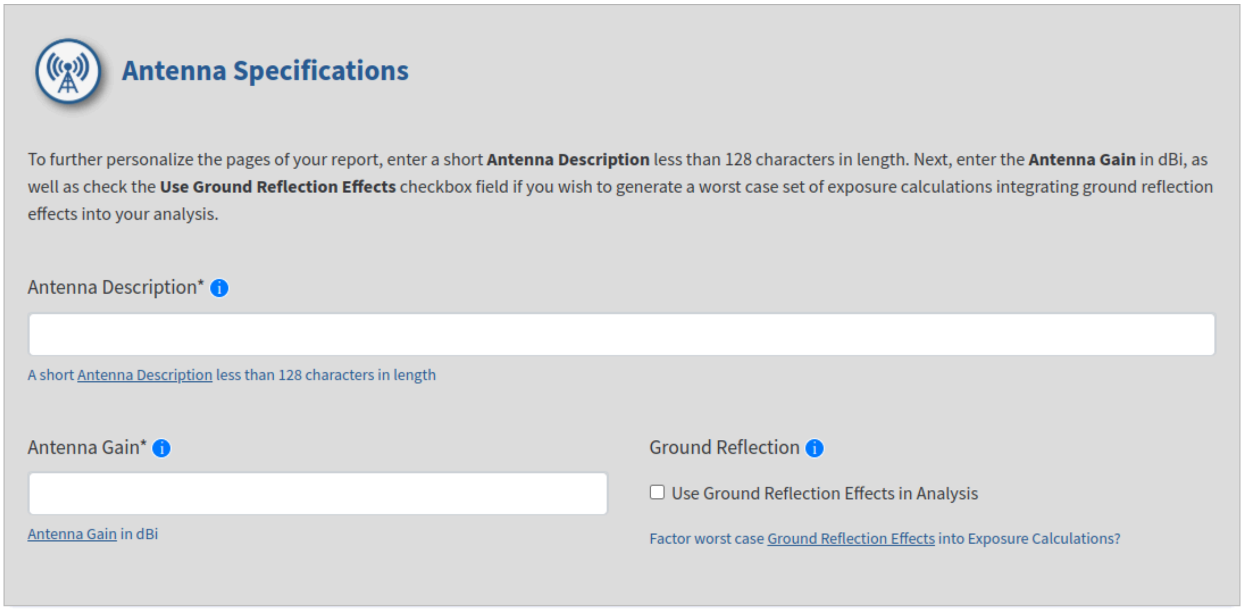
---

1. ### Single Frequency Analysis

   - **Purpose:** This optional field allows users to specify a single frequency for analysis. When a frequency is entered in this field, the system will ignore the selected Multi-Band Group and Frequency Position and will analyze only the entered frequency.
   - **Mandatory:** No.
   - **Guidance:** If you wish to analyze exposure limits for a specific frequency only, enter a valid U.S. Amateur Band Frequency (in MHz) here. This feature is particularly useful if your setup operates predominantly on a single frequency rather than across a range.

Antenna Specifications Panel

The **Antenna Specifications** panel is designed to capture details about the antenna used in your RF exposure analysis. This section allows you to further personalize your report by entering a short **Antenna Description** (less than 128 characters in length). Next, specify the **Antenna Gain** in dBi, and check the **Use Ground Reflection Effects** check-box if you wish to generate a worst-case set of exposure calculations that integrate ground reflection effects into your analysis.



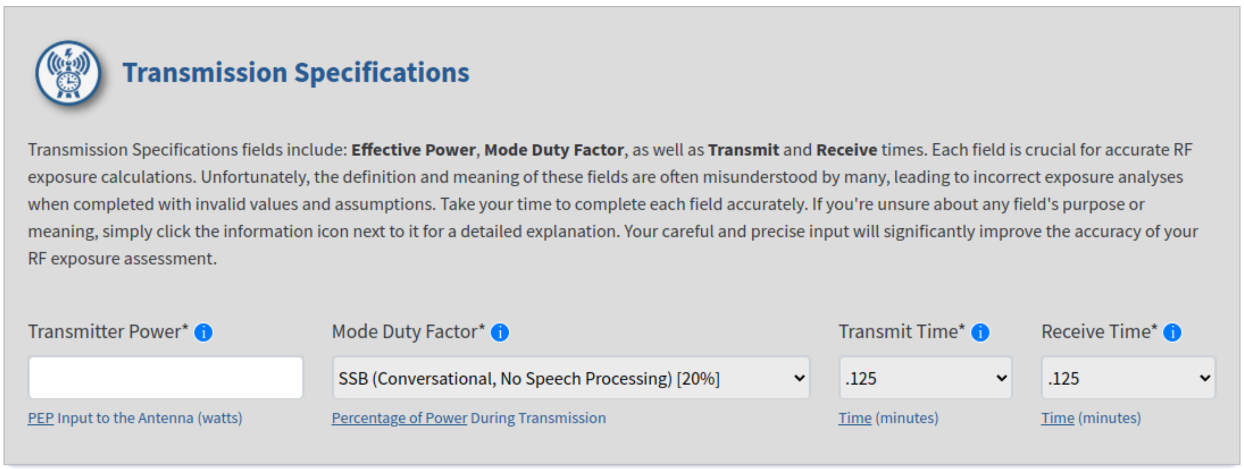
Data Entry Fields

1. **Antenna Description**
   - **Purpose:** This field is for entering a short description of the antenna being analyzed. The description will appear throughout the report to identify the specific antenna setup under review.
   - **Character Limit:** 128 characters.
   - **Mandatory:** Yes.
   - **Guidance:** Provide a concise description of your antenna, including relevant details such as the model, type, and installation specifics. Examples include "20-Meter Dipole Mounted at 30 feet" or "Yagi 3-Element at 40 Feet."
2. **Antenna Gain**
   - **Purpose:** This field requires you to input the gain of the antenna in decibels relative to an isotropic radiator (dBi). Antenna gain is crucial for calculating RF exposure levels, as it indicates how much power is directed in a specific direction.
   - **Mandatory:** Yes.
   - **Guidance:** Enter the gain value in dBi as specified by the antenna manufacturer or determined through measurement. This value is essential for accurate RF exposure calculations.
3. **Ground Reflection Effects**

- **Purpose:** This checkbox option allows users to include ground reflection effects in the RF exposure analysis. Ground reflections can increase power density at certain locations, leading to a more conservative (worst-case) exposure scenario.
- **Mandatory:** No (Optional).
- **Guidance:** Check the "Use Ground Reflection Effects" box if you want to factor in ground reflections for a worst-case scenario analysis. This option is recommended if your antenna is installed at a height where ground reflections might significantly affect exposure levels.

Transmission Specifications Panel

The **Transmission Specifications** panel is critical for defining the parameters that directly affect the RF exposure calculations. This section gathers key information about the transmitter power, mode duty factor, and the duration of transmit and receive times. Correctly inputting these values is essential for producing an accurate RF exposure assessment.



Data Entry Fields

1. Transmitter Power

- **Purpose:** This field captures the Peak Envelope Power (PEP) that is fed into the antenna during transmission. This value is one of the primary factors in determining RF exposure levels.
- **Mandatory:** Yes.
- **Guidance:** Enter the PEP value in watts as used during your transmissions. Ensure that this value reflects the actual power being used for accurate calculations.

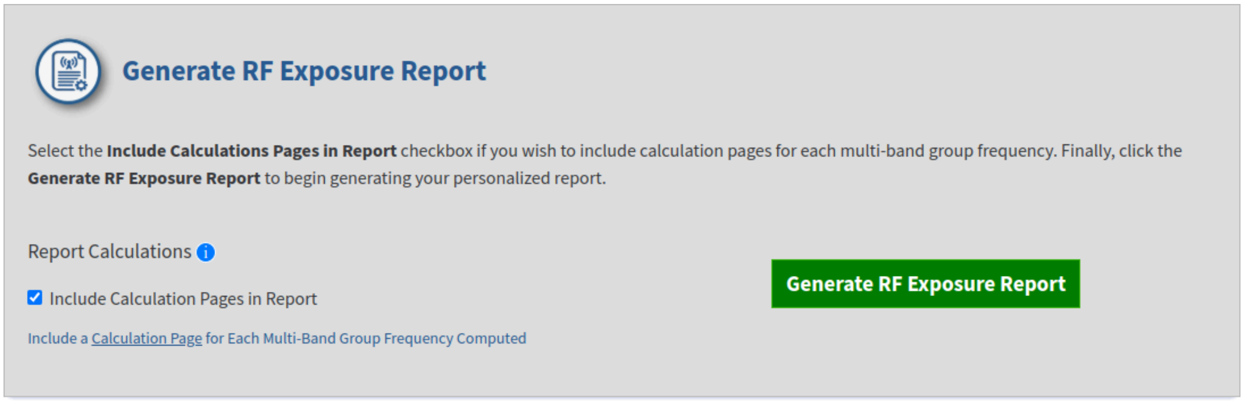
2. **Mode Duty Factor**
    - **Purpose:** The Mode Duty Factor represents the percentage of time the transmitter is actually producing RF energy during a transmission cycle. Different transmission modes (e.g., SSB, CW, FM, etc.) have varying duty factors.
    - **Options:** A drop-down menu offers various mode settings, such as:
        - SSB (Conversational, No Speech Processing) [20%]
        - SSB (Conversational, Speech Processing) [50%]
        - CW [40%]
        - FM [100%]
        - AM [100%]
        - AFSK (e.g., RTTY, etc.) [100%]
        - FT4 [100%]
        - FT8 [100%]
        - Carrier for Tuning [100%]
        - Unknown Mode (Assume Worst Case) [100%]
    - **Mandatory:** Yes.
    - **Guidance:** Select the duty factor that corresponds to your mode of operation. This value accounts for the nature of the transmission mode and significantly impacts the exposure calculation.

3. **Transmit Time**
    - **Purpose:** This field specifies the duration of time (in minutes) that the transmitter is active during the exposure calculation period.
    - **Mandatory:** Yes.
    - **Guidance:** Select the transmit time in minutes (e.g., 0.125 for 7.5 seconds). This should reflect the average duration of your transmissions during a typical operating period.

4. **Receive Time**
    - **Purpose:** This field captures the duration of time (in minutes) that the station is in receive mode during the exposure calculation period.
    - **Mandatory:** Yes.
    - **Guidance:** Select the receive time in minutes. Typically, this value complements the transmit time, ensuring the total time represents a full operating cycle.

Generate RF Exposure Report Panel

The **Generate RF Exposure Report** panel is the final step in creating your personalized RF exposure report. This section allows you to choose whether to include detailed calculation pages for each frequency in the selected multi-band group (e.g., MF/HF or VHF/UHF bands). After making your selection, you can generate the report, which will incorporate all the field values entered in the previous panels.



Data Entry Fields and Options

1. **Include Calculation Pages in Report**
   - **Purpose:** This check-box allows users to include detailed calculation pages in the final report. These pages provide an in-depth view of the calculations performed for each frequency within the selected band plan.
   - **Mandatory:** No (Optional).
   - **Guidance:** To review detailed exposure calculations for each analyzed frequency, check this box. This option is useful for users who need a comprehensive understanding of exposure levels across all frequencies. If left unchecked, the report will be more concise and omit detailed calculation breakdowns.
2. **Generate RF Exposure Report**
   - **Purpose:** This button initiates the generation of your RF exposure report based on the data and selections made in the preceding panels.
   - **Mandatory:** Yes.
   - **Guidance:** After verifying your inputs and deciding whether to include calculation pages, click the **Generate RF Exposure Report** button. The system will compile your data into a personalized report that can be downloaded, reviewed, saved, or printed.

Next Steps

Once the report is generated, download and review the PDF output to ensure the analysis meets your requirements. If adjustments are needed, return to the **RF Exposure Report Calculation Worksheet** to modify your inputs and regenerate the report.

Additional guidance on interpreting the report will be provided in subsequent sections, including the **RF Exposure Report Summary**.

Section 3.0 – RF Exposure Report Summary

Overview

The output of the RF exposure report is designed in a manner that allows you to effortlessly determine the safety and compliance of your amateur radio operations. By understanding the data presented in the report, you can make informed decisions about antenna placement, transmission power, and operating conditions. This section delves deeply into the report's structure, providing a detailed explanation of each component and practical guidance on interpreting the results. Whether you're a beginner or an experienced operator, this guide will enhance your understanding of RF exposure analysis and help you optimize your station's setup.

U.S. Amateur Radio RF Exposure Report - Version 0.25A

1 **G5RV Exposure Report**

G5RV positioned on East side of home and oriented North-to-South 2

3 Transmission Watts: **100.0**

Band Plan: **MF/HF**

Gain (dBi): **2.2**

Transmit Time (min.): **7.000**

Mode Duty Factor (%): **20.0**

Band Frequency Position: **Highest**

Ground Reflection: **True**

Receive Time (min.): **7.000**

4

U.S. Amateur Radio Band (meters)	Band Transmission Frequency (MHz)	Controlled Maximum Power Density (mW/cm²)	Controlled Compliance Distance (feet)	Uncontrolled Maximum Power Density (mW/cm²)	Uncontrolled Compliance Distance (feet)
160	2.000	100.00	0.27	45.00	0.29
80	4.000	56.25	0.36	11.25	0.59
60	5.500	29.75	0.50	5.95	0.81
40	7.300	16.89	0.66	3.38	1.07
30	10.200	8.65	0.92	1.73	1.50
20	14.300	4.40	1.29	0.88	2.10
17	18.200	2.72	1.64	0.54	2.67
15	21.500	1.95	1.93	0.39	3.16
12	25.000	1.44	2.25	0.29	3.67
10	29.700	1.02	2.67	0.20	4.36
6	54.000	1.00	2.70	0.20	4.41

Page 2 of 13

Sections of the Report

On the RF Exposure Report Summary displayed above, red, numbered circles have been placed to denote the major sections of the report. Each of these report sections are defined below.

1. Report Title

The header at the top of the report is a report title, or a personalized **description** of your operating setup. Information such as the antenna name and power used for this calculation.

2. Antenna Title/Description

The next title displayed is the antenna title. A proper definition of the antenna title might include the type of antenna, it's location, orientation, and any special configurations.

3. RF Exposure Calculation Worksheet Input Values

A list of the values you entered on the **RF Exposure Calculation Worksheet Form** are displayed below the titles. These values define the scope of the RF exposure analysis calculated and displayed on this summary report:

1. **Transmission Watts:** Indicates the transmitter's Peak Envelope Power (PEP), representing the maximum power used during transmission.
2. **Multi-Band Group:** Specifies the group of bands analyzed (e.g., MF/HF or VHF/UHF).
3. **Gain (dBi):** Represents the antenna's directional gain, influencing how RF energy is distributed.
4. **Transmit Time (minutes):** Reflects the average time the transmitter is transmitting during an operating period.
5. **Mode Duty Factor (%):** Represents the percentage of time the transmitter is actually producing RF energy during a transmission cycle.
6. **Band Frequency Position:** Refers to the selected frequency within each band (e.g., **Highest**, **Center**, or **Lowest** frequency).
7. **Ground Reflection:** Indicates whether ground reflections were considered in the analysis, accounting for worst-case exposure scenarios.
8. **Receive Time (minutes):** Specifies the time the station is in receive mode during the operating period.

These parameters collectively define the scope and precision of the RF exposure analysis. Accurate inputs are critical to ensure meaningful results.

4. Calculated Compliance Table

The RF exposure report includes a comprehensive table summarizing exposure metrics across various amateur radio bands. Each column is carefully designed to provide key insights into RF exposure characteristics.

Column 1: U.S. Amateur Radio Band (meters)

This column identifies the wavelength bands analyzed in the report, ranging from low-frequency bands like **160 meters** to higher-frequency bands like **6 meters**. Each band represents a specific frequency range allocated for amateur radio use. Understanding the characteristics of each band helps operators plan safe and effective station configurations.

Column 2: Band Transmission Frequency (MHz)

This column lists the specific frequencies analyzed within each band. These frequencies are selected based on the **Band Frequency Position** parameter:

- **Highest Frequency in Band:** Captures worst-case exposure scenarios due to shorter wavelengths (for MF/HF bands only).
- **Center Frequency in Band:** Provides a balanced representation of exposure characteristics for the band.
- **Lowest Frequency in Band:** Accounts for longer wavelengths and their propagation effects.

Column 3: Controlled Maximum Power Density (mW/cm^2)

This column indicates the maximum permissible power density for controlled environments, where individuals are informed about RF exposure risks. The values are calculated using FCC guidelines and vary by frequency:

- **Lower frequencies:** Tend to have higher maximum power density limits due to their lower energy absorption rates.
- **Higher frequencies:** Have stricter limits due to increased energy absorption potential.

Column 4: Controlled Compliance Distance (feet)

This column provides the minimum safe distance required to comply with controlled power density limits. These distances ensure safety for operators and others familiar with RF exposure risks. ***The compliance distance increases with power levels and typically decreases at higher frequencies due to shorter wavelengths.***

Column 5: Uncontrolled Maximum Power Density (mW/cm^2)

This column lists the maximum permissible power density for uncontrolled environments, such as areas accessible to the public. These limits are more conservative to account for uninformed individuals.

Column 6: Uncontrolled Compliance Distance (feet)

This column specifies the minimum safe distance for individuals in uncontrolled environments. These distances are typically larger than those in controlled environments to provide an additional safety margin. ***As frequency increases, these distances generally decrease due to the shorter wavelength and reduced propagation effects.***

Key Insights for Interpretation

Ground Reflection Considerations

Including ground reflections in the analysis provides a worst-case scenario estimate, especially for antennas mounted near reflective surfaces. Ground reflections can amplify RF power density, increasing the need for larger compliance distances.

Practical Implications

Operators can use the report to make critical decisions, such as:

- Adjusting transmission power to reduce compliance distances in constrained spaces.
- Reorienting antennas to minimize exposure in high-traffic areas.
- Selecting operating frequencies that balance communication effectiveness and safety.

Summary

The RF Exposure Report is a powerful tool for ensuring the safety and compliance of amateur radio operations. By analyzing parameters such as transmission power, antenna gain, and operating frequency, the report provides actionable insights for optimizing your station setup. Understanding the details of the table columns and the relationships between frequency, power density, and compliance distances will enable you to operate responsibly and confidently.

Take the time to thoroughly review your report and apply its recommendations to protect yourself and others from potential RF hazards while maintaining effective communication capabilities.

Section 4.0 – Analysis of RF Exposure Calculations

At the bottom of the **RF Exposure Report Calculation Worksheet** form is a panel named **Generate RF Exposure Report**. Located in this panel is a check mark field labeled **Include Calculation Pages in Report**. If you "check" this field before generating an exposure report, a page of calculations, like that display in figure 4-1 below, will be generated for **each** frequency evaluated.

U.S. Amateur Radio RF Exposure Report - Version 0.25A

RF Exposure Computation Report

A frequency from each band of the U.S. Amateur Radio Band Plan selected has been computed. Each frequency and the computations associated with that particular frequency are displayed on individual pages in this report. For more information regarding these calculations and how to interpret them, please refer to the following web page:
https://www.rfassure.com/computations

U.S. Amateur Band (meters): 160

FREQUENCY
* Frequency (MHz): **1.8000**

POWER
* Power-PEP (W): **100**
* Power (mW): **100,000**
* Duty Factor: **1.00**
* Transmit Time Ratio: **0.5**

(P) Power (Effective) (mW): Power x Duty Factor x Transmit Time Ratio = 100,000 * 1.00 * 0.5 = **50,000**

ANTENNA GAIN
(G) Antenna Gain (Numeric): 10^(2.2 dBi/10) = **1.6596**

GROUND REFLECTION
(GRM) Ground Reflection Multiplier: **0.64**

REFACTORED BASE EQUATION FOR MINIMUM DISTANCE
(R) Radius (cm) = **sqrt((GRM x P x G) / (S* PI))**

CONTROLLED
Control Mode: **ControlMode.CONTROLLED**
(S) Controlled Maximum Density (mW/cm2): **100.00** (Lookup Table)
(R) Radius (cm): sqrt((GRM x P x G) / (S* PI)) = sqrt((0.64 x 50,000 x 1.6596) / (100.00 * 3.14159)) = **13.0017**
Min Distance (cm): **13.0017** Min Distance (feet): **0.4266** Min Distance (meter): **0.1300**

UNCONTROLLED
Control Mode: **ControlMode.UNCONTROLLED**
(S) Uncontrolled Maximum Density (mW/cm2): **55.5560** (Lookup Table)
(R) Radius (cm): sqrt((GRM x P x G) / (S* PI)) = sqrt((0.64 x 50,000 x 1.6596) / (55.56 * 3.14159)) = **17.4436**
Min Distance (cm): **17.4436** Min Distance (feet): **0.5723** Min Distance (meter): **0.1744**

Page 3 of 13

Figure 4-1 RF Exposure Report Computation Report Page

The remainder of this section of the documentation details the equations and exposure calculations performed, as well as the meaning and purpose of each variable used in these calculations.

Important Tip

Anyone with a basic high school algebra background (even if it was completed 50 years ago) should be capable of understanding the equations, the meanings and use of the equation variables, as well as derivations of these equations to calculate the minimum distance required to meet MPE limits. We suggest you concentrate on the meaning and purpose of each variable in the equations, as well as the units (e.g., cm, mW, dBi, etc.) associated with each variable. By taking this approach, your understanding of the meaning and utility of each equation will be enhanced.

4.1.0 Power Density Equation: The Cornerstone of the RF Exposure Calculation Set

We will now explore each equation and calculation used to predict potential RF exposure and the minimum safe distance we can safely operate near amateur radio antenna RF emissions.

For non-directional antennas, power density in the far-field can be estimated using specific equations like the **Power Density Equation** displayed below. While equations like these are accurate in the far-field, they may overestimate power density in the near field, making them ideal for computing conservative, "worst-case" predictions for an antenna. The base **Power Density Equation** we will use for predicting RF exposure is:

$$\mathrm{S} = \frac{\mathrm{PG}}{4\pi\mathrm{R}^2}$$

where:

S = Power Density (**mW/cm²**)
P = Total Effective Power Radiated from the Antenna (**mW**)
G = Antenna Power Gain in the Direction of Interest Relative to an Isotropic Radiator (**dBi**)
R = Distance to the Antenna's Center of Radiation (**cm**)

If you look closely at the Power Density Equation you will notice that Power Density (S) is expressed as "units of power divided by units of area." In other words, Power Density equals some measure of power flowing into and subsequently being radiated from our antenna (in our calculations that's power in milliwatts) divided by some fixed area of exposure (e.g., centimeters squared). So, the variables in the equation's numerator collectively represent the **power component** and the variables in the equation's denominator represent the **fixed area component** of the equation.

> **Important Note!**
>
> When employing these and other formulas, it's crucial to ensure that the units of all variables must be consistent. For instance, if you aim to calculate power density in units of mW/cm², the power should be in milliwatts and the distance in centimeters. Although different units can be employed, one must apply the correct conversion factors where needed.

4.2.0 Effective Isotropically Radiated Power (EIRP)

In the FCC literature, particularly *FCC OET Bulletin 65 Supplement B (Edition 97-01)*, you might observe that the previous **Power Density Equation** is alternatively written as:

$$\mathrm{S} = \frac{\mathrm{EIRP}}{4\pi \mathrm{R}^2}$$

where:

S = Power Density (**mW/cm²**)
EIRP = Effective Isotropically Radiated Power: Power (**P**) times a Power Gain Factor (**G**) (**mW**)
R = Distance to the Antenna's Center of Radiation (**cm**)

Unfortunately, the numerator, or the "power component" in the equation above doesn't represent the entire "power profile" required to determine the true MPE limits we desire. Because FCC exposure guidelines allow power density to be time averaged, factors such as transmission "Duty Factor" and "On/Off Ratios" must also be factored into the "power component" portion of the equation to accurately reflect the **average exposure power**, pr **effective power** radiated.

Therefore, we will explore each of the variables required to compute a **effective power** component for the equation. Once we have established these variables and how they affect the results, we will compute the final power value called Effective Power, defined as:

$$\mathrm{Power}_{effective} = \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR}$$

where:

P (pep) = PEP Power Transmitted from Transmitter (**mW**)
DF = Duty Factor: Percent of Time Power is Being Sent to the Antenna During Transmit (**dimensionless number**)
TR = On/Off Transmit Time Ratio (**dimensionless number**)

4.2.1 Peak Envelope Power (PEP)

The first variable used to calculate Effective Power is **Peak Envelope Power (PEP)**. For our calculations, we will ignore "**coax line loss**" and use **PEP**, or the actual output power of the transmitter, which is standard for amateur radio compliance calculations. If you wish, you can (1) physically measure, using a watt meter, and use this power value, or (2) mathematically calculate the theoretical line loss and subtract this value from the PEP value.

Therefore, for our RF exposure calculations, we convert Power at the antenna feed point, defined in watts, to milliwatts for further RF exposure calculations.

$$\mathrm{Power}_{pep} = \mathrm{Power}_{feed\ point}\ \mathrm{W} \times 1,000\frac{\mathrm{mW}}{\mathrm{W}}$$

where:

P (pep) = PEP Power Transmitted from Transmitter (**mW**)
P (feed point) = Theoretically Calculated Power to the Antenna Feed Point (**W**)

4.2.2 Duty Factor (DF)

The **duty factor** in RF exposure calculations refers to the proportion of time that a transmitter is actively radiating RF energy during a specific period. It's an essential factor in evaluating RF exposure because it accounts for the actual time RF energy is transmitted, as opposed to assuming continuous operation for modes such as SSB or CW, which are intermittent rather than continuous.

RF exposure limits are typically based on **average power**, not peak power. The duty factor reduces the peak power value to an equivalent average power based on how often the transmitter is active. For modes like CW (Morse code), SSB (Single Sideband), and digital modes, the duty factor varies based on the operator's activity and the characteristics of the mode.

Duty factor is estimated using the following equation:

$$\text{Duty Factor} = \frac{\text{Time Transmitting (min.)}}{\text{Total Transmission Time (min.)}}$$

Typical Duty Factors for Amateur Radio Modes

Mode	Duty Factor
SSB (Conversational, No Speech Processing)	20%
SSB (Conversational, Speech Processing)	50%
CW (Conversational)	40%

Mode	Duty Factor
FM	100%
AM	100%
AFSK (e.g., RTTY, etc.)	100%
FT4	100%
FT8	100%
Carrier For Tuning	100%
Unknown Mode (Assume Worst Case)	100%

> **Important Note!**
>
> The main takeaway from this calculation is to know that **lower duty factors** reduce the calculated exposure, potentially allowing higher transmit power or closer proximity to antennas while remaining within safety limits.

4.2.3 Transmit Time Ratio (TR)

Time and spatial averaging are methods used to determine if exposure to radio frequency (RF) fields is within safe limits. These guidelines consider both the time over which exposure occurs and the area of the body exposed.

For example, imagine RF exposure as sunlight on your body. Instead of focusing on a single spot that might feel extra hot (like your hand under a magnifying glass), spatial averaging looks at the sunlight's effect on your entire body. Even if one area is exposed to more RF energy, it's acceptable if the overall exposure averaged across the body stays within safe limits.

Time averaging considers how exposure varies over time. It has been determined that the "averaging time for occupational or controlled exposures is 6 minutes," while the "averaging time for general population or uncontrolled exposures is 30 minutes."

Consider the following theoretical examples:

- If the safety limit is 1 unit of RF energy, exposure at **2 units for 3 minutes** followed by **0 units for 3 minutes** averages out to the safe limit over a 6-minute period.
- Similarly, exposure at **3 units for 2 minutes** would need **0 units for 4 minutes** to stay within limits.

This ensures brief higher exposures are acceptable if balanced by low or no exposure periods.

$$\text{Transmit Time Ratio} = \frac{\text{Time Transmitting (min.)}}{[6 \text{ or } 30] \text{ (min.)}}$$

4.2.4 Effective Power

Unfortunately, determining the value of the numerator or power component of the base equation is simply not the result of multiplying two numbers that returns a value for power being fed to the antenna. This resulting value of variables "P x G" in the numerator is actually derived from the product of five operating values and/or multipliers that ultimately create what is often referred to as **Effective Isotropically Radiated Power (EIRP)**.

$$\text{Power}_{effective} = \text{P}_{pep} \times \text{DF} \times \text{TR}$$

where:

EIRP = Effective isotropically radiated power (**mW**)
P (pep) = PEP Power Transmitted from Transmitter (**mW**)
DF = Duty Factor: Percent of Time Power is Being Sent to the Antenna During Transmit (**dimensionless number**)
TR = On/Off Transmit Time Ratio (**dimensionless number**)
GR = Ground Reflection (**dimensionless number**)
G = Power Gain Factor (**dimensionless number**)

For our first set of calculations we will concentrate on each of the variables and multipliers required for computing EIRP.

4.3.0 Ground Reflection (GR)

Because we are creating a truly "worst case" calculation of power density near surfaces, such as ground-level areas or rooftops, 100% reflection of incoming radiation represents can be assumed. To assist in this assumption, the U.S. Environmental Protection Agency (EPA), as outlined in Bulletin 65 mentioned, has developed models that account for ground reflection and suggest that ground reflections can increase field strength by up to 1.6 times, resulting in a 2.56-fold increase in power density. This approach offers a balanced prediction between extreme worst-case assumptions and practical real-world conditions.

Assuming we wish to **implement these ground reflection assumptions** in our calculations, we now have an equation that looks as follows:

$$S = \frac{2.56 \times P_{pep} \times DF \times TR \times G}{4 \times \pi \times R^2} = \frac{0.64 \times P_{pep} \times DF \times TR \times G}{\pi \times R^2}$$

If we opt to **not to use these ground reflections assumptions** in our calculations, the formula remains the same and be re-factored as follows:

$$S = \frac{P_{pep} \times DF \times TR \times G}{4 \times \pi \times R^2} = \frac{0.25 \times P_{pep} \times DF \times TR \times G}{\pi \times R^2}$$

4.4.0 Antenna Power Gain (G)

Antenna Power Gain is a crucial parameter that measures how effectively an antenna directs or concentrates radio frequency (RF) energy in specific directions compared to a reference antenna, typically an isotropic radiator (which radiates equally in all directions). Gain quantifies an antenna's ability to focus energy in particular directions, enhancing signal strength and range.

Antenna manufactures and readily available data for general antenna types (e.g., dipole, G5RV, Windom, etc.) usually express gain for the antenna in decibels relative to either an isotropic antenna (dBi) or a dipole antenna (dBd) - both logarithmic values. However, the Antenna Power Gain (G) value we declare, for the purposes of our calculations, must be converted to **numeric gain** using the following formula:

$$G = 10^{\left(\frac{dBi}{10}\right)}$$

where:

G = Antenna Power Gain (numeric gain) (**dimensionless number**)
dBi = Antenna Gain in Decibels (**dimensionless number**)

4.5.0 Refactoring and Adding Variables to the Power Density Equation

As demonstrated earlier in this section, the **Power Density Equation** can be stated as:

$$S = \frac{PG}{4\pi R^2}$$

where:

S = Power Density (**mW/cm²**)
P = Total Effective Power Radiated from the Antenna (**mW**)
G = Antenna Power Gain in the Direction of Interest Relative to an Isotropic Radiator (**dBi**)
R = Distance to the Antenna's Center of Radiation (**cm**)

However, we subsequently demonstrated that the numerator, or the "power component" portion of the equation doesn't fully represent the complete "power profile" required to determine the true MPE limits we desire. Consequently, we detailed why Peak Envelope Power (**PEP**) must be multiplied by additional factors such as transmission "Duty Factor (**DF**)" and transmission "On/Off Ratios (**TR**)" to more accurately reflect the **average exposure power**, or **effective power** radiated.

Finally, because we are evaluating truly "worst case" scenarios of power density near surfaces, such as ground-level areas or rooftops, 100% reflection of incoming radiation represents can be assumed. Thus, an optional Ground Reflection (**GR**) constant can be multiplied to the Peak Envelope Power (**PEP**) to complete a more true representation of the the **average exposure power**, or **effective power** radiated. The resulting equation is:

$$\mathrm{S} = \frac{\mathrm{GR} \times \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR} \times \mathrm{G}}{4 \times \pi \times \mathrm{R}^2}$$

where:

- **R**: Minimum distance from the antenna (**cm**)
- **GR**: Ground Reflection Multiplier (**dimensionless number**)
- **P**: Effective Power (**mW**)
- **DF**: Duty Factor (**dimensionless number**)
- **TR**: Transmit Time Ratio (**dimensionless number**)
- **G**: Antenna Numeric Gain (**dimensionless number**)
- **S**: MPE limit (**mW/cm²**)

However, the previous equation computes Power Density. The value we are truly attempting to derive is the minimum distance that individuals in either controlled and uncontrolled environments can be located from the center of the radiating source (antenna) and not exceed the FCC mandated MPE limits for the power and frequency of operation.

However, we need the equation to yield the value of a distance (**cm**) and not a power density value (mW/cm²). Therefore we algebraically manipulate the equation by multiplying both sides of the equation by R^2 and by dividing both sides of the equation by S. The result of this algebraic operation is listed below:

$$\frac{\mathrm{R}^2 \times \mathrm{S}}{\mathrm{S}} = \frac{\mathrm{GR} \times \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR} \times \mathrm{G}}{4 \times \pi \times \mathrm{R}^2 \times \mathrm{S}} \times \mathrm{R}^2$$

The result of the algebraic operation is listed below:

$$\mathrm{R}^2 = \frac{\mathrm{GR} \times \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR} \times \mathrm{G}}{4 \times \pi \times \mathrm{S}}$$

Finally, to calculate the minimum distance required to meet MPE limits, we simply take the square root of both sides to derive the final equation:

$$\mathrm{R} = \sqrt{\frac{\mathrm{GR} \times \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR} \times \mathrm{G}}{4 \times \pi \times \mathrm{S}}}$$

Section 5.0 – Computing Minimum Compliance Distance

Using the concepts and equations developed in Section 4.0, we will manually compute the **Minimum Compliance Distance** (R)—the distance from an antenna that meets the **Maximum Permissible Exposure Limits** (MPE) for that antenna and its radiated power.

To perform these calculations, we will use the standard test data detailed in **Appendix A**. This data represents the values typically entered into the **RF Exposure Report Calculation Worksheet** for a common 20-meter dipole antenna connected to an HF transceiver transmitting at 100 watts. We will also assume that our calculations are based on an operator transmitting in Single Side Band (SSB) mode while using the transmitter's built-in speech processing. Finally, the antenna is understood to be located in an environment classified by the FCC as Occupational/Controlled Exposure.

5.1.0 Required Calculations

As derived in the previous section, the equation to calculate the minimum distance that satisfies the **Minimum Compliance Distance** (MPE) limits is as follows:

$$\mathrm{R} = \sqrt{\frac{\mathrm{GR} \times \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR} \times \mathrm{G}}{4 \times \pi \times \mathrm{S}}}$$

This equation determines R, the minimum distance required to meet MPE limits. The equation includes variables highlighted in both **red** and **yellow**. The variables highlighted in **red** require computations before being entered into the equation. The single variable S, highlighted in **yellow**, is a table lookup variable pre-computed by the FCC for the entire frequency range, including the MF, HF, VHF, and UHF bands.

Each of these required variables is listed in the table below, along with a memo describing the definition of the variable from the previous section, as well as the expected units or dimensions for the variable.

Variable/Constant	Memo	Units
GR: Ground Reflection Multiplier	Calculated in Section 5.1.1	Dimensionless

Variable/Constant	Memo	Units
P: Power (PEP)	Calculated in Section 5.1.2	mW
DF: Duty Factor	Calculated in Section 5.1.3	Dimensionless
TR: Transmit Time Ratio	Calculated in Section 5.1.4	Dimensionless
G: Antenna Numerical Gain	Calculated in Section 5.1.5	Dimensionless
S: MPE Limit	Table Lookup/Calculation in Section 5.1.6	mW/cm²
R: Minimum Distance from Antenna	Calculated in Section 5.2.0	cm

5.1.1 Ground Reflection Multiplier

As discussed in the previous section, **Section 4.3.0 Ground Reflection (GR)**, to create a truly "worst-case" calculation of power density near surfaces—such as ground-level areas or rooftops—100% reflection of incoming radiation is assumed. Therefore, if the application's **Use Ground Reflection** option is selected, a value of **2.56** is applied to account for the increase in field strength. If the option is not selected, a value of **1** (i.e., no change) is applied to the equation results.

In our "Standard Test Data" defined in Appendix A, we see that the **Use Ground Reflection in Analysis** option is selected. Therefore, we will use the value of **2.56** as our **Ground Reflection Multiplier** (GR) value.

Ground Reflection:

- Use Ground Reflection Effects in Analysis: **"Checked/Selected"**
- **GR** Value = **2.56**

5.1.2 Power (PEP)

In our "Standard Test Data", we also see that the **Power** delivered to the antenna is **100 watts**. As discussed in **Section 4.2.1 Peak Envelope Power (PEP)**, we will ignore **"line losses"** and use the actual power at the antenna feed point (worst case scenario for power) and convert this value to milliwatts.

$$\text{Power}_{pep} = 100 \text{ W} \times 1,000 \frac{\text{mW}}{\text{W}} = 100{,}000 \text{ mW}$$

Therefore, we will use the value of **100,000** as our **Peak Envelope Power** (P_{pep}) value.

5.1.3 Duty Factor (DF)

The **duty factor** in RF exposure calculations refers to the proportion of time a transmitter actively radiates RF energy during a specific period. It is a crucial component in evaluating RF exposure, as it accounts for the actual transmission time rather than assuming continuous operation. This consideration is particularly important for intermittent modes like SSB or CW.

RF exposure limits are typically based on **average power**, not peak power. The duty factor adjusts the peak power value to an equivalent average power, reflecting the transmitter's activity level. For modes such as CW (Morse code), SSB (Single Sideband), and digital modes, the duty factor varies depending on the operator's usage and the characteristics of the mode.

The duty factor is estimated using the following equation:

$$\text{Duty Factor} = \frac{\text{Time Transmitting (min.)}}{\text{Total Transmission Time (min.)}}$$

For Duty Factor, we will not directly calculate a value. Instead we will refer to the Duty Factor table in **Section 4.2.2 Duty Factor (DF)** for a value. From this table we will select the value of **50%** which is associated with **SSB (Conversational, Speech Processing)**.

Therefore, we will use the value of **0.5** as our **Duty Factor (DF)** value.

5.1.4 Transmit Time Ratio (TR)

The **6-minute and 30-minute averaging periods** are time-averaging intervals used by the FCC to assess compliance with Maximum Permissible Exposure (MPE) limits for human exposure to RF electromagnetic fields. These periods account for how exposure is averaged over time, reflecting realistic scenarios rather than assuming constant exposure.

As demonstrated in **Section 4.2.3: Transmit Time Ratio (TR)**, the value of **TR** can be calculated using the following equation:

$$\text{Transmit Time Ratio} = \frac{\text{Time Transmitting (min.)}}{[6 \text{ or } 30] \text{ (min.)}}$$

In our "Standard Test Data," we see that **Transmit Time** is equal to **one minute**, just as **Receive Time** is equal to **one minute**. In other words, for each minute the operator is transmitting SSB, they will also receive one minute of SSB signals from another operator. Therefore, during a six-minute period, the operator will transmit for three minutes and receive for three minutes.

Thus, during a six-minute averaging period associated with occupational/controlled exposure, the operator will be transmitting for three minutes out of every six-minute period:

$$\text{Transmit Time Ratio} = \frac{3 \text{ min.}}{6 \text{ min.}}$$

Therefore, we will use the value of **0.5** as our **Transmit Time Ratio** (TR) value.

4.1.5 Antenna Numeric Gain (G)

The values provided by antenna manufacturers, as well as readily available data for general antenna types (e.g., dipole, G5RV, Windom, etc.), usually express antenna gain in decibels relative to either an isotropic antenna (**dBi**) or a dipole antenna (**dBd**)—both logarithmic measurements. Because the **Antenna Power Gain (G)** value declared in the "Standard Test Data" is logarithmic, it must be converted to **numeric gain** using the following formula:

$$\mathrm{G} = 10^{\left(\frac{\mathrm{dBi}}{10}\right)}$$

Substituting the Antenna Power Gain (G) value from the "standard test data", we determine the Antenna Numeric Gain (G):

$$\mathrm{G} = 10^{\left(\frac{2.2}{10}\right)} = 1.6595$$

Therefore, we will use the value of **1.6595** as our **Antenna Numeric Gain** (G) value.

4.1.6 Power Density (S)

To calculate the **Power Density (S)** for a frequency of **14.350 MHz**, we must first refer to the two tables labeled **FCC Limits for Maximum Permissible Exposure (MPE)** provided in **Appendix B**.

For **Occupational/Controlled Exposure** at a frequency of **14.350 MHz**, we perform a table lookup and find that this frequency falls within the **Frequency Range** (Column One) of **3.0 – 30.0 MHz**. Next, we locate the corresponding **Power Density** (S) formula in Column Two of the table. Thus, we determine that the maximum Power Density for a frequency of **14.350 MHz** can be computed using the following formula:

$$S = \frac{900}{f^2} \frac{\mathbf{mW}}{cm^2}$$

Substituting **f=14.285**, where **f** is the frequency in MHz, yields:

$$S = \frac{900}{(14.350)^2} = \frac{900}{205.922} \approx 4.3706 \frac{mW}{cm^2}$$

Therefore, we now have a value of **4.3706** as our **Power Density** (S).

4.2.0 Calculating Minimum Compliance Distance (R)

In the previous section, we derived the following equation to calculate the minimum distance required to meet **Minimum Compliance Distance** (MPE) limits.

$$\mathrm{R} = \sqrt{\frac{\mathrm{GR} \times \mathrm{P}_{pep} \times \mathrm{DF} \times \mathrm{TR} \times \mathrm{G}}{4 \times \pi \times \mathrm{S}}}$$

In **Section 5**, we completed calculations that return values for each of the required variables in the equation. These values, displayed in the table below, are based on the standard test data detailed in **Appendix A**. This data represents the values typically entered into the **RF Exposure Report Calculation Worksheet** for a common 20-meter dipole antenna connected to an HF transceiver transmitting at 100 watts. Additionally, we assume that the calculations are based on an operator transmitting in Single Side Band (SSB) mode using the transmitter's built-in speech processing. The antenna in question is located in an environment classified by the FCC as Occupational/Controlled Exposure.

Variable/Constant	Value	Units
GR: Ground Reflection Multiplier	2.56	dimensionless
P: Effective Power	100,000 mW	mW
DF: Duty Factor	0.5	dimensionless
TR: Transmit Time Ratio	0.5	dimensionless
G: Antenna Numeric Gain	1.6595	dimensionless
S: MPE limit	4.3706	mW/cm²
R: Minimum distance from the antenna	To Be Calculated	cm

Now, we assign the values from the table above to the variables into our derived **Minimum Compliant Distance** equation:

$$R = \sqrt{\frac{\mathbf{2.56} \times \mathbf{100,000}\ mW \times \mathbf{0.5} \times \mathbf{0.5} \times \mathbf{1.6595}}{\mathbf{4} \times \pi \times \mathbf{4.3706}\ \mathrm{mW/cm^2}}}$$

After performing basic algebraic multiplication, division, and canceling of units, we are left with the following:

$$R = \sqrt{\mathbf{1,933.78}\ \mathrm{cm^2}}$$

Finally, after taking the square root on the right side of the equation, we are left with the distance from an antenna that meets the **Maximum Permissible Exposure Limits** (MPE) for that antenna and its radiated power.

$$R = \mathbf{43.9747}\ \mathrm{cm}$$

Appendix A

To demonstrate the use of the equations detailed in Section 4.0, we will construct a theoretical (but typical) set of data and equipment capabilities that describes a common 20-meter dipole antenna connected to a 100-watt HF transceiver. Each data field we generate corresponds to a field in the application's **RF Exposure Report Calculation Worksheet**. The data we will use to enter in each field of the **RF Exposure Report Calculation Worksheet** is as follows:

Standard Test Data

Field Description	Value
Report Personalization	
Report Description	20-Meter Dipole Operating at 100 Watts
First and Last Name	Roy G. Biv
Call Sign	W5BDB
Email Address	roygbiv@pcig.net
Single or Multi-Band Exposure Analysis	
Multi-Band Group	MF/HF (137.8 kHz - 54.0 MHz)
Frequency Position in Band	Highest Frequency in Band (14.350 MHz for 20-Meter Band)
Single Frequency Exposure Analysis	N/A
Antenna Specifications	
Antenna Description	20-meter dipole positioned on East side of backyard and oriented North-to-South
Antenna Gain	2.2
Transmission Specifications	
Ground Reflection (boolean)	True: Use Ground Reflection Effects in Analysis
Transmitter Power (watts)	100
Mode Duty Factor	SSB (Conversational, Speech Processing) [50%]
Transmit Time (min.)	1.00

Field Description	Value
Receive Time (min.)	1.00
Generate RF Exposure Report	
Report Calculations (boolean)	True: Include Calculation Pages in Report

Appendix B

FCC Limits for Maximum Permissible Exposure (MPE)

(A) Limits for Occupational/Controlled Exposure

Frequency Range (MHz)	Power Density (S) (mW/cm^2)	Averaging Time (minutes)
0.3-3.0	(100)*	6
3.0-30	($900/f^2$)*	6
30-300	1.0	6
300-1500	f/300	6
1500-100,000	5	6

(B) Limits for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Power Density (S) (mW/cm^2)	Averaging Time (minutes)
0.3-1.34	(100)*	30
1.34-30	($180/f^2$)*	30
30-300	0.2	30
300-1500	f/1500	30
1500-100,000	1.0	30

Notes:

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

Appendix C – References

10. References

1. FCC OET Bulletin 65 Supplement B

   (Edition 97-01)

   - Section 2: FCC Exposure Guidelines
   - Section 3: Predicting RF Exposure
   - Section 4: Compliance Distances and Calculations
   - Appendix A: MPE Limits
2. **ARRL RF Safety Committee**, technical resources for amateur radio compliance.

This expanded explanation provides both the theoretical foundation and practical context for understanding and performing RF exposure calculations in compliance with FCC regulations.