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**Draft Laboratory Division Publication**

**Title:** Guidelines for Determining the Effective Radiated Power (ERP) and Equivalent Isotropically Radiated Power (EIRP) of a RF Transmitting System

**Short Title:** Determining ERP and ERIP

**Reason:** New Publication

**Publication:** 412172

**Keyword/Subject:** Guidance Determining ERP and ERIP

**First Category:** Administrative Requirements

**Second Category**: Measurement procedure

**Third Category:**

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**Question:** How do you determine ERP and ERIP Values for a RF Transmitting System?

**Answer:** The attached document 412172 D01 Determining ERP and ERIP v01 provides methods for determining the Effective Radiated Power (ERP) and Equivalent Isotropically Radiated Power (EIRP) of a RF Transmitting System.

**Attachment List:**

412172 D01 Determining ERP and ERIP v01

**<u>Attachment</u>**

## Guidelines for Determining the Effective Radiated Power (ERP) and Equivalent Isotropically Radiated Power (EIRP) of a RF Transmitting System

### 1. Introduction

1.1. Many FCC rule parts specify power and/or emission limits in terms of the transmitter system (transmitter, radiating antenna, and cable connector) effective radiated power (ERP) or equivalent (or effective) isotropically radiated power (EIRP).

1.2. These guidelines are intended to demonstrate how to determine the EIRP or ERP from the results of a power measurement.

1.3. EIRP and ERP are similarly defined as the product of the power supplied to the antenna and the antenna gain (when the power and gain are represented in linear terms). The primary difference between them is that for ERP, the antenna gain is expressed relative to an ideal half-wave dipole antenna whereas with EIRP, the antenna gain is expressed relative to an ideal (theoretical) isotropic antenna. The EIRP and ERP can be expressed mathematically as follows[1]:

1.3.1. Field Strength Approach (linear terms):

$$\mathbf{eirp = p_t \times g_t = (E \times d)^2/30} \qquad (1)$$

where:

- $\mathbf{p_t}$ = transmitter output power in watts,
- $\mathbf{g_t}$ = numeric gain of the transmitting antenna (unitless),
- $\mathbf{E}$ = electric field strength in V/m,
- $\mathbf{d}$ = measurement distance in meters (m).

$$\mathbf{erp = eirp/1.64 = (E \times d)^2/(30 \times 1.64)} \qquad (2)$$

where all terms are as previously defined.

1.3.2. Power Approach (logarithmic terms):

$$\mathbf{ERP/EIRP = P_T + G_T - L_C} \qquad (3)$$

where;

- **ERP/EIRP** = effective (or equivalent) radiated power (in same units as $P_T$, typically dBW, dBm, or power spectral density (psd)), relative to either a dipole antenna (ERP) or an isotropic antenna (EIRP);

[1] Derivations of the equations presented herein are not provided in this document. Readers interested in how these equations are derived are referred to NTIA Technical Memorandum TM-10-469, *Derivations of Relationships among Field Strength, Power in Transmitter-Receiver Circuits and Radiation Hazard Limits,* Frank H. Sanders, U.S. Department of Commerce, National Telecommunications and Information Administration, June, 2010.

- $\mathbf{P_T}$ = transmitter output power, in dBW, dBm, or psd (power over a specified reference bandwidth);
- $\mathbf{G_T}$ = gain of the transmitting antenna, in dBd (ERP) or dBi (EIRP);
- $\mathbf{L_C}$ = signal attenuation in the connecting cable between the transmitter and antenna, in dB.[2]

1.4. Relationship Between ERP and EIRP:

1.4.1. The numeric gain of an ideal half-wave dipole antenna is 1.64 and the numeric gain of an ideal isotropic antenna is 1.0.

1.4.2. The gain of an ideal half-wave dipole antenna relative to an ideal isotropic antenna is 10log1.64 or 2.15 dBi.

1.4.3. Therefore, if the antenna gain in dBd is unknown, it can be determined from the gain in dBi via the following relationship:

$$\mathbf{G_T(dBd) = G_T(dBi) - 2.15\ dB}. \qquad (4)$$

1.4.4. Alternatively, the EIRP can be determined from Equation 3 and then converted to ERP based on the maximum antenna gain relationship by applying the following equation:

$$\mathbf{ERP = EIRP - 2.15\ dB}. \qquad (5)$$

1.4.5. Similarly, the EIRP can be determined from the ERP as follows:

$$\mathbf{EIRP = ERP + 2.15\ dB}. \qquad (6)$$

2. The following paragraphs discuss the appropriate methods for applying the equations presented above depending on the power measurement configuration used.

2.1. DUT power measured in a conducted test configuration

2.1.1. When the DUT power is measured using a direct connection between the transmitter antenna port and the measurement instrumentation via a coaxial cable (conducted test), and the transmit antenna gain is a known quantity, then the ERP/EIRP can be calculated by direct application of Equation 3 and using the relationships defined in Equations 4, 5 or 6, as appropriate.

2.1.2. The value to be used for $P_T$ in these equations is the measured power level (in dBm, dBW or psd), adjusted to account for external test peripherals (cable loss, external attenuation, and/or external amplification).

2.1.3. The value to be used for $G_T$ is the gain associated with the DUT transmit antenna, expressed in either dBd (ERP) or dBi (EIRP).

[2] NOTE: In personal/portable radios utilizing an integral antenna, this factor is typically negligible. However, in a fixed station transmit system that utilizes a long cable run between the transmitter and transmitting antenna, this factor can be significant.

2.2. Direct calculation from the DUT power measured in a radiated test configuration (*i.e.*, signal/antenna substitution techniques not used).

When the DUT power is measured using a radiated test configuration, the EIRP can be directly determined using the power (logarithmic) approach as follows:

$$\mathbf{EIRP = P_R + L_P} \quad (7)$$

where;

- **EIRP** = equivalent (or effective) isotropically radiated power (in same units as $P_R$);
- $\mathbf{P_R}$ = adjusted received power level, in dBW, dBm, or psd;
- $\mathbf{L_P}$ = basic free space propagation path loss, in dB.

3. The received power level is the measured power adjusted for measurement antenna gain, connecting cable loss, and any external signal amplification or attenuation used in the test configuration. Mathematically:

$$\mathbf{P_R = P_{Meas} - G_R + L_C + L_{Atten} - G_{Amp}} \quad (8)$$

where;

- $\mathbf{P_{Measured}}$ = measured power level, in dBW, dBm or psd;
- $\mathbf{G_R}$ = gain of the receive (measurement) antenna, in dBi;
- $\mathbf{L_C}$ = signal loss in the measurement cable, in dB;
- $\mathbf{L_{Atten}}$ = value of external attenuation (if used), in dB;
- $\mathbf{G_{Amp}}$ = value of external amplification (if used), in dB.

4. The free space propagation path loss is determined from the following equation:

$$\mathbf{L_P = 20 \, Log \, F + 20 \, Log \, D - 27.5} \quad (9)$$

where:

- $\mathbf{L_P}$ = basic free space propagation path loss, in dB;
- **F** = center frequency of radiated DUT signal, in MHz;
- **D** = measurement distance, in meters.

5. The ERP can then be determined from the EIRP by applying Equation 5.

When the DUT power is measured using a radiated test configuration, the eirp can be directly determined using the field strength (linear) approach by applying Equations 1.

The erp can then be determined from the eirp by applying Equation 2.

6. DUT power measured in a radiated test configuration using the signal/antenna substitution techniques.

The ERP/EIRP can be determined from the power setting of a signal generator used in the signal/antenna substitution test configuration as follows:

$$\mathbf{ERP/EIRP} = \mathbf{P_{SigGen}} + \mathbf{G_T} - \mathbf{L_C} \qquad (7)$$

where:

- $\mathbf{P_{SigGen}}$ = power setting of the signal generator that produces the same received power reading as the DUT, in dBm, dBW or psd;
- $\mathbf{G_T}$ = gain of the substitute antenna, in dBd (ERP) or dBi (EIRP);
- $\mathbf{L_C}$ = signal loss in the cable connecting the signal generator to the substitute antenna, in dB.