Effective Radiated Power

(By H. Ward Silver, N0AX, reprinted from the 2018 ARRL Handbook)

When evaluating total station performance, accounting for the effects of the entire system is important, including antenna gain. This allows you to evaluate the effects of changes to the station. Transmitting performance is usually computed as *effective radiated power* (*ERP*). ERP is calculated with respect to a reference antenna system — usually a dipole but occasionally an isotropic antenna — and answers the question, "How much power does my station radiate as compared to that if my antenna was a simple dipole?" Effective isotropic radiated power (EIRP) results when an isotropic antenna is used as the reference. If no antenna reference is specified, assume a dipole reference antenna.

ERP is especially useful in designing and coordinating repeater systems. The effective power radiated from the antenna helps establish the coverage area of the repeater. In addition, the height of the repeater antenna as compared to buildings and mountains in the surrounding area (*height above average terrain*, or *HAAT*) has a large effect on the repeater coverage. In general, for a given coverage area, with a greater antenna HAAT, less effective radiated power (ERP) is needed. A frequency coordinator may even specify a maximum ERP for a repeater, to help reduce interference between stations using the same frequencies.

ERP calculations begin with the *transmitter power output* (*TPO*). (This is assumed to be the output of the final power amplification stage if an external power amplifier is used.) Then the *system gain* of the entire antenna system including the antenna, the transmission line, and all transmission line components is applied to TPO to compute the entire station's output power.

System Gain = Transmission Line Loss - Transmission Components Loss + Antenna Gain

There is always some power lost in the feed line and often there are other devices inserted in the line, such as a filter or an impedance-matching network. In the case of a repeater system, there is usually a duplexer so the transmitter and receiver can use the same antenna and perhaps a circulator to reduce the possibility of intermodulation interference. These devices also introduce some loss to the system. The antenna system then usually returns some gain to the system. (See the **Antennas** chapter for information on antenna gain and the **Transmission Lines** chapter for information on feed line loss.)

ERP = TPO × System Gain

Since the system gains and losses are usually expressed in decibels, they can simply be added together, with losses written as negative values. System gain must then be converted back to a linear value from dB to calculate ERP.

$$\text{ERP} = \text{TPO} \times \log^{-1}\left(\frac{\text{System Gain (dB)}}{10}\right)$$

It is also common to work entirely in dBm and dB until the final result for ERP is obtained and then converted back to watts.

ERP (in dBm) = TPO (in dBm) + System Gain (in dB)

Suppose we have a repeater station that uses a 50 W transmitter and a feed line with 4 dB of loss. There is a duplexer in the line that exhibits 2 dB of loss and a circulator that adds another 1 dB of loss. This repeater uses an antenna that has a gain of 6 dBd. Our total system gain looks like:

System gain = –4 dB + –2 dB + –1 dB + 6 dBd = –1 dB

Note that this is a loss of 1 dB total for the system from TPO to radiated power. The effect on the 50 W of TPO results in:

$$\text{ERP} = 50\text{ W} \times \log^{-1}\left(\frac{\text{system gain (dB)}}{10}\right) = 50 \times \log^{-1}(-0.1) = 50 \times 0.79 = 39.7\text{ W}$$

This is consistent with the expectation that with a 1 dB system loss we would have somewhat less ERP than transmitter output power.

As another example, suppose we have a transmitter that feeds a 100 W output signal into a feed line that has 1 dB of loss. The feed line connects to an antenna that has a gain of 6 dBd. What is the effective radiated power from the antenna? To calculate the total system gain (or loss) we add the decibel values given:

System gain = – 1 dB + 6 dBd = 5 dB

and

$$\text{ERP} = 100\ \text{W} \times \log^{-1}\left(\frac{\text{system gain (dB)}}{10}\right) = 100 \times \log^{-1}(0.5) = 100 \times 3.16 = 316\ \text{W}$$

The total system has positive gain, so we should have expected a larger value for ERP than TPO. Keep in mind that the gain antenna concentrates more of the signal in a desired direction, with less signal in undesired directions. So the antenna doesn't really increase the total available power. If directional antennas are used, ERP will change with direction.

Example: What is the effective radiated power of a repeater station with 150 W transmitter power output, 2 dB feed line loss, 2.2 dB duplexer loss and 7 dBd antenna gain?

System gain = –2 dB – 2.2 dB + 7 dBd = 2.8 dB

$$\text{ERP} = 150\ \text{W} \times \log^{-1}\left(\frac{\text{system gain (dB)}}{10}\right) = 150 \times \log^{-1}(0.28) = 150 \times 1.9 = 285\ \text{W}$$

Example: What is the effective radiated power of a repeater station with 200 W transmitter power output, 4 dB feed line loss, 3.2 dB duplexer loss, 0.8 dB circulator loss and 10 dBd antenna gain?

System gain = –4 – 3.2 – 0.8 + 10 = 2 dB

$$\text{ERP} = 200\ \text{W} \times \log^{-1}\left(\frac{\text{system gain (dB)}}{10}\right) = 200 \times \log^{-1}(0.2) = 200 \times 1.58 = 317\ \text{W}$$

What is the effective isotropic radiated power of a repeater station with 200 W transmitter power output, 2 dB feed line loss, 2.8 dB duplexer loss, 1.2 dB circulator loss and 7 dBi antenna gain?

System gain = –2 – 2.8 – 1.2 + 7 = 1 dB

$$\text{ERP} = 200\ \text{W} \times \log^{-1}\left(\frac{\text{system gain (dB)}}{10}\right) = 100 \times \log^{-1}(0.1) = 200 \times 1.26 = 252\ \text{W}$$