POWER	×	125%	=	+1dB
POWER	×	160%	=	+2dB
POWER	×	200%	=	+3dB
POWER	×	1000%	=	+10dB
VOLTAGE	×	125%	=	+2dB
VOLTAGE	×	160%	=	+4dB
VOLTAGE	×	200%	=	+6dB
VOLTAGE	×	1000%	=	+20dB

Quick power and voltage decibel conversions.

To avoid diving into a deep mathematical presentation, I'll demonstrate the important part of the use of these field-intensity measurements as a practical matter.

How much signal level does a field intensity of 1 μ V/m produce across the input to a receiver (assuming a 50Ω system throughout)? Assuming that the antenna gain is 0dBd (0dB as referenced to a dipole) then a field intensity of 1 μ V/m at the antenna will produce a signal level of 1 μ V across the antenna terminals.

If there is no line loss, then the same level, 1 μ V, will appear across the receiver input terminals.

This relationship is true *only at a frequency of 40MHz*. At other frequencies, this 1:1 relationship changes. At other frequencies, the signal level at the receiver input must be adjusted according to the formula:

where *F* = frequency in MHz and dB is the correction factor in *decibels per meter*.

To calculate the signal level at the input to the receiver, we must take the antenna gain and the line loss into consideration.

For example, given 1 μ V/m of field intensity at the antenna on an operating frequency of 40MHz, an antenna gain of 3dB and a line loss of 2dB, the input to the receiver will be 1dB above 1 μ V (antenna gain minus line loss), or 1.12 μ V.

Now, if the operating frequency changed from 40MHz to 160MHz, with all other things being equal, the input to the receiver would be reduced by a factor of -12dB. So, the receiver input level would be 12dB *below* 1.12 μ V, or 0.28 μ V. Because -6dB represents a voltage change to 50% of the *initial value*, then -12dB represents a voltage change to 25% of the initial value.

This correction factor is caused by the change in *antenna factor*. Antenna factor is *frequency dependent*. It can be a negative or positive value, or it can be zero.

At *about* 40MHz, the antenna factor (for 50Ω antennas) is zero. Above 40MHz, the antenna factor is negative. Below 40MHz, the antenna factor is positive.

Another unit of measurement for field intensity is *dBu*. The definition of dBu is “decibels referenced to 1 μ V/m.” Therefore, +6dBu would be 6dB *above* 1 μ V/m, or 2 μ V/m, and -6dBu would be 6dB *below* 1 μ V/m, or 0.5 μ V/m. The advantage of using dBu instead of μ V/m can be demonstrated in the following example.

Suppose the field intensity of a 160MHz signal is 12dBu at an antenna, with a gain of 6dBd, connected to a receiver through a transmission line with 2dB loss. At 160MHz, the antenna correction factor is -12dB. So we add the antenna gain of +6dB and subtract the line loss (-2dB) and the antenna correction factor (-12dB) to get a final value of:

+ 12 - 12 + 6 - 2 = +4dB μ V

or 4dB *above* 1 μ V. In terms of voltage, an increase of 4dB represents an increase of about 60% over the reference voltage level.

So, the input signal level at the receiver is 1.6 μ V.

Quick dB estimations

The rules shown in the table at the left can help when trying to mentally calculate decibel conversions to and from voltage or power levels.

We know that a 25% increase in the *power* level is about equal to a 1dB increase, and a 25% increase in the *voltage* level is about equal to a 2dB increase. A 60% increase in power is roughly equal to a 2dB increase, and a 60% increase in voltage is roughly equal to a 4dB increase. A doubling of the power is equal to a 3dB increase, and a doubling of the voltage is equal to a 6dB increase. Likewise, a tenfold increase in power is equal to a 10dB increase, and a tenfold increase in voltage is equal to a 20dB increase.

Using these basic numbers from memory, we can closely estimate any conversion to and from decibels, to and from voltage, or power level changes.

Now, suppose that we need to convert a 125dB increase in voltage and that the initial voltage is 0.25 μ V. For each 20dB increase, there is a 10× increase in voltage. Within 125dB there are six 20dB changes, so there would be 10 × 10 × 10 × 10 × 10 × 10. To account for this, we could simply move the decimal point six places to the right to make the voltage equal to 250,000 μ V.

That leaves 5dB. Now, 6dB would be a doubling of the voltage to 500,000 μ V, but we are 1dB short of that. Remember, a 2dB increase in voltage was equal to a 25% increase, so a 2dB decrease would be equal to 1 ÷ 1.25, or 0.8 times the reference voltage. So, we can linearly interpolate to arrive at 0.9 as the multiplication factor for a 1dB decrease. Therefore, multiplying 500,000 × 0.9 = 450,000 μ V. Now to check our calculations we run the formula:

So, our estimation missed by only one-tenth of a decibel.

Suppose that we need to increase our power level by 32dB over the current level of 5W. What multiplication factor would we use? Well, 30dB would be 10 × 10 × 10, or 1,000, and the additional 2dB would be an increase of 60%. So the final multiplication factor is 1,600. Now, 1,600 × 5 = 8,000W. Check this out with the formula:

Our estimation was close — close enough for our practical purposes.

Converting dBm to μ V

Many times, receiver sensitivity or signal levels are stated in terms of *dBm* instead of microvolts (μ V). The term "0dBm" refers to "1mW in 50Ω." To change this to voltage level, simply use the formula:

or 223,607 μ V. This is the voltage level required to produce 1mW of power in a 50Ω load. It is almost a *quarter of a volt*. It is easier to remember one-quarter volt than 223,607 μ V. If we used 0.25V as the 0dBm reference voltage, we would be in error by less than 1dB. So, if we wanted to convert 0.35 μ V to dBm we could do the following:

Multiply by a factor of 10 until we approach the 0.25V (250,000 μ V) point and add 20dB for each factor of 10. This 10 × 10 × 10 × 10 × 10 progression, would yield 35,000.

Now, multiply by a factor of 2 to approach 250,000: 35,000 × 2 × 2 = 140,000. Another increase of about 80% to get to 250,000 would add another 5dB. (Remember, 4dB is a voltage increase of about 60%, and 6dB is a voltage increase of 100%. So for 80% we linearly interpolate to get 5dB.)

Now, we add the equivalent decibels for each multiplication factor used. We had five 10s, two 2s and an additional 80%, or 1.8, increase, so:

5 × 20dB + 2 × 6dB + 5dB = 117dB

Thus, 0.35 µ V is equivalent to -117dBm.

It takes longer to write about it than to do it. This calculation has a margin of error of about 1dB.

Conversely, to convert dBm to microvolts follow this example:

Convert -110dBm to microvolts. Start with 0dBm = 0.25V, or 250,000 µ V. Now, for each -20dB, move the decimal point one place to the left. Moving five places to the left, we get 2.5 µ V. Now, six more decibels would yield a level of 1.25 µ V. Another 4dB reduction would be a multiplication factor of 1 ÷ 1.6, or 0.625, to yield:

1.25 × 0.625 = 0.78 µ V.

This is also accurate to within 1dB.

Calculating ERP

It is easy to work with power levels in *dBm* by remembering that 100W is equal to 50dBm. It is easy to calculate ERP by using dBm units for power measurement.

For example, say a transmitter has an output of 100W and a line loss of 2dB. The bandpass cavity has an insertion loss of 1dB, and the antenna has a gain of 6dB. What is the effective radiated power?

First, 100W is equal to 50dBm. Now, we simply add the gains and losses of the transmitter chain to get the ERP:

+50 - 1 - 2 + 6 = 53dBm

Because 50dBm = 100W and the level is 3dB greater, we multiply 100 × 2 to get an ERP of 200W.

The dBW

The term *dBW* means “decibels referenced to 1W in a 50Ω load.” A 0dBW signal equals +30dBm, and 0dBm is equal to -30dBW. So, just remember to add 30 to the dBW figure for the equivalent dBm figure. Conversely, subtract 30 from the dBm figure to get the dBW figure. In the previous example, the ERP of 53dBm would be 23dBW. To convert to watts, 20dBW is 20dB above 1W. The increase would be 100 × 1W to get 100W, and then the additional 3dB would double the power to 200W.

Using dB µ V

The *dB µ V* unit of measure is occasionally found. It simply uses 1 µ V as the reference level. A level of +6dB µ V is simply 2 µ V because 2 µ V is 6dB above 1 µ V. Conversely, -6dB µ V is 0.5 µ V. Do not confuse dB µ V with dBu. They are not the same, although sometimes the term dBu is *erroneously* used to mean dB µ V. Watch out for that error.

The dBc

The term *dBc* is used to refer to a signal power level as “so-many decibels referenced to the carrier.” To be accurate, the proper value sign — almost always negative — should precede it.

For example, suppose the level of a spurious signal is stated as -95dBc. This means that the carrier power is the 0dB reference level and that the spurious signal is 95dB below the carrier level.

Suppose that the carrier level is 100W or 50dBm. Then the spurious level is at -45dBm. This is an absolute measurement.

The dBd versus dBi

Watch out for the antenna gain specifications from some manufacturers. The antenna gain specification for land mobile radio work should be stated in *dBd*, that is, “gain in decibels as referenced to a dipole antenna.”

If you see the antenna gain stated in terms of *dBi*, you can convert it to dBd by subtracting 2.15 from the stated gain. In other words, an antenna gain of 2.15dBi is equal to a 0dBd gain. The “i” signifies *isotropic* radiator, a theoretical spherical antenna that radiates equally in all directions from the center of the sphere. Using the isotropic radiator as a reference makes the antenna appear to have more gain. Don't be fooled.

You can convert RF measurement units as long as you follow a few simple rules — if you know the reference on which a unit of measure is based. With a little practice, you can make quick mental conversions and get pretty close — at least close enough for our purposes as communications technicians.

Until next time — *stay tuned!*

Contributing editor Kinley, MRT's technical consultant and a certified electronics technician, is regional communications manager, South Carolina Forestry Commission, Spartanburg, SC. He is the author of Standard Radio Communications Manual, with Instrumentation and Testing Techniques, which is available for direct purchase. Write to 204 Tanglewylde Drive, Spartanburg, SC 29301. Kinley's email address is *hkinley@home.com.*

Using and converting RF units of measure

By Harold Kinley

Mobile Radio Technology, Apr 1, 2001

Many RF measuring units, as well as various *forms* of those measuring units, are in use today.

It is important to understand what the measuring units mean and how they are used. It is also important to remember that the decibel is a *relative* measurement unit unless it is based on an *absolute level*.

For example, “6dB” does not tell us the absolute level of a signal. But “+6dB*m*” *does* because it is referenced to an absolute level.

Field strength/intensity

Field strength or *field intensity* is an indication of the strength of the electromagnetic field present at an antenna or at a distance from an antenna. Generally, communications technicians refer to field intensity as a measure of volts per meter (V/m) and more often as microvolts per meter (µ V/m).