

APPENDIX A

Making Sense of Decibels

Joel R. Hallas, W1ZR

Much of the technical data found in *QST* and other ARRL publications is expressed in decibels, generally shown as *dB*. Contrary to the belief of some, this is not done to mystify beginners, but rather is intended to make comparisons easier and avoid the use of very large or small numbers.

So What's this Decibels Business All About?

Decibels are just a way of expressing ratios, often power ratios. If we are looking at the gain of an amplifier stage, the pattern of an antenna or the loss of a transmission line we are generally interested in the ratio of the power out to the power in, or the ratio of the power in front of a beam antenna to that coming from the back. These are some of the places that we will find the results expressed in dB.

Decibels are a logarithmic function. Logarithms are a handy mathematical tool based on exponents. An important feature of logarithms is that multiplication can be performed by adding the logarithmic quantities instead of multiplying them. Similarly, divisions can be accomplished by subtracting in the same manner. This becomes a benefit if you are dealing with multiple stages of amplification and attenuation — as we often are in radios — snatching a minuscule signal from the ether — amplifying and processing it so we can hear it out the loudspeaker. Instead of having to multiply and divide at each stage to keep track of the progress of our signal processing — often with signal levels with many zeros to the right of the decimal point — we can just tally all the dB and have total gain of the system.

So How do We Compute the Decibels?

The *deci* in decibels refers to a factor of $\frac{1}{10}$, as in *deciliters* for $\frac{1}{10}$ of a liter, while the *bel* relates to the idea of a logarithmic ratio, originally used to define sound power.

- To convert a power ratio into decibels, just:
 1. Find the base 10 logarithm of the power ratio.
 2. Multiply by 10.

For example, if we have an amplifier with a power gain of 275, we find the logarithm of 275 (see below, if you don't do logs in your head) to be 2.44. We multiply by 10 and the result is that a power gain of 275 can be represented as 24.4 dB.

- To convert decibels to a power ratio, we do the opposite:



Figure 1 — The *Windows Scientific Calculator* ready to calculate the effect of a 2 dB cable loss.

1. Divide by 10.
2. Find the base 10 antilog of the result.

Note that the base 10 antilog of a number is just 10 raised to the power of the number. This is also something you probably don't do in your head, so let's see how to easily perform the computations.

Understanding a few characteristics of logs will help avoid problems interpreting results. Note that a gain of 0 dB means that there is no change to the signal — not that the signal has vanished! The other important fact is that a power ratio of less than one (a loss rather than a gain) is represented as a negative number in decibels.

Enter the *Windows Scientific Calculator*

In the *very old* days, engineers and technicians used tables to make accurate logarithmic calculations, and mechanical slide rules if three significant digits was sufficient precision.¹ Starting around 1970, scientific calculators became available. Initially they were expensive typewriter-sized devices that were typically shared within an engineering department. Within a few years pocket-sized units were available for less than \$200, and now everyone could make calculations to a precision of nine significant digits, whether warranted by the data accuracy or not. Tables and slide rules were relegated to the pages of history with spark transmitters.

The dawn of the reasonably priced personal computer seemed to push the fancy scientific calculator out of sight only about 10 years later. Unfortunately, for many functions a calculator may be a better choice, and decibel calcula-

¹See, for example, *Standard Mathematical Tables*, CRC Press, any edition. In addition to tables of logarithms and trigonometric functions, it includes many handy formulas from geometry, trigonometry and calculus.

tions may be one. The calculations may be easily performed on a PC by putting the equations in cells of an Excel spreadsheet, but not everyone can do that without a lot of thought.

If you have a suitable scientific calculator, that should easily make the calculations. Not all have an ANTILOG button, but if not, they will likely have a button that says X^Y , which can be used as above. If you don't have a handheld calculator, you may not know that there is a very capable one included as an "accessory" within the Microsoft *Windows* operating system! Just click START then ALL PROGRAMS then ACCESSORIES. You should find an icon for the *Windows Calculator*. You could open it, but why not drag it onto your desktop first.

On first opening, you may find a four-function grocery store type calculator. Have no fear, just click on VIEW then SCIENTIFIC to get the one you want. It should look about like Figure 1.

Give it a Test Drive

Let's say you have a mismatched coax cable with a loss of 2 dB. You may want to know how many of the 100 W from your transmitter actually reach your antenna. Remember a 2 dB loss is a "gain" of -2 dB! We'll go through the inverse dB calculation of column 2. Using your *Windows Calculator*, either hit 2 on your keyboard, or:

- Click on the 2 on the calculator "keypad," then:
- Click on the +/- key; the display should show -2, as in Figure 1.
- Click on the / key to select the "divide by" operation. Enter the digits 1 and 0 for the number 10 and hit ENTER or =. Make note of the result (-0.2) or store it in memory (M+).
- Enter the digits 1 and 0 for the number 10.
- Click on X^Y to raise 10 to a power.
- Enter your earlier result, -2 and hit ENTER.
- The display should show 0.63095734448019324943436013662234 or about 0.63. That is the fraction of your power left after a 2 dB loss. That means your antenna sees 63 W and 37 W is heating your transmission line.

While you are using the *Windows Scientific Calculator* look over its other features. It provides painless conversion between decimal and binary, octal or hex numbers, for example.

Joel R. Hallas, W1ZR, is *QST* Technical Editor. He can be reached at w1zr@arrl.org. **Q57-**