Saved by the Bel — Understanding Decibels

Originalartikel

Backup

<html> <p>If you’ve hung around electronics for any length of time, you’ve surely heard of the decibel (often abbreviated dB). The decibel is a measure of a power ratio. Actually, the real measure is a bel, but you almost never see that in practice. If you are versed in metric, you won’t be surprised to learn a decibel is 1/10 of a bel. Sometimes in electronics, we deal with really large ratios, so the decibel is logarithmic to cope with this. Doubling the number of decibels doesn’t double the ratio, as you will soon see. It’s all about logarithms, and this ends up being extremely useful when measuring something like antenna or amplifier gain.</p> <p>Besides antennas, decibels are often used to measure sound and light. The reason is that human ears and eyes have a logarithmic response to those quantities. Your ear, for example, has a huge dynamic range. That is to say, you can hear a whisper or a space shuttle launch. That ratio is about 1 trillion to 1, but that’s only 120 dB. This is also why potentiometers made for volume controls have a logarithmic taper. A linear pot would seem off because, for example, a tenth of a turn at one extreme will affect the apparent volume much more than a tenth of a turn at the other extreme. This holds true whether or not those knobs go up to eleven.</p> <p/> <h3>History</h3> <p>The decibel can trace its roots back to the old phone system. Originally, the unit used to measure loss in telephone and telegraph cables was “miles of standard cable” (MSC). There was an elaborate definition of what a standard cable was and 1 MSC was the amount of loss of a predefined signal over a mile of this cable. This went on until 1924.</p> <p>That was the year Bell telephone introduced the Transmission Unit (TU) which was later (in 1928) called a bel, to honor Alexander Graham Bell (the chap on the left). We don’t know what happened to the last L in Bell’s name. It

caught on, and we still use it today to measure gain and loss (loss shows up as a negative number).</p> <h3 style=„clear:none;“>Why?</h3> <p>In addition to being handy for representing large ratios, the decibel also makes it easy to calculate system gain or loss. For example, if you have a transmitter that feeds coax with a -3 dB loss, an amplifier with a 25 dB gain, a cable run with -3.3 dB loss, and then an antenna with a 3 dB gain, you can simply add them all up: -3 + 25 – 3.3 + 3 = 21.7 dB. That’s a total gain of about 148 times (log(148)=2.17 bels=21.7 dB — see the section below for help with these calculations).</p> <p>Notice how losses show up as negative decibels? You may wonder, though, what does it mean to have an antenna with 3 dB gain? By the formula, that means the output of the antenna is 3 dB (right around twice) the input. However, it is difficult (and perhaps not too useful) to measure the power output since it isn’t really a two terminal device. Instead, antennas are measured by their gain over an isotropic antenna (an unbuildable antenna that is a single point in space that radiates the input power evenly in all directions). Of course, that’s not really practical, so sometimes you measure the gain over a dipole’s antenna’s peak gain. To avoid confusion, you almost always see an antenna gain written as 3 dBi (for isotropic) or 3 dBd (for dipole). The dBd number is always 2.15 dB less than the dBi number.</p> <figure id=„attachment_247098“ style=„width: 196px“ class=„wp-caption alignright“><img data-attachment-id=„247098“
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href=„https://commons.wikimedia.org/w/index.php?curid=960123“ target=„_blank“>Dipole antenna pattern CC-BY-SA 3.0</figcaption></figure><p>Another thing to consider when thinking about antennas is direction. For example, a dipole’s gain is 1.64:1 (2.15 dBi) peak. But in some directions, it is much less. You can see the radiation pattern for a dipole in the figure to the right. An isotropic pattern would be a perfect sphere.</p> <h3 style=„clear:none;“>Crash Course on Logs and dB Math</h3> <p>If your math is a bit rusty, you might want a quick review of logarithms.</p> <p>For decibels, you’ll need base 10 logarithms so that’s all we’ll talk about. Consider the number 100:</p> 10 squared (that is 10 to the second power) is 100, so the logarithm of 100 is 2 The log of 1000 is 3 (because 10 to the 3rd power is 1000) The log of 10 is 1 Any number raised to the 0 power equals 1, so the log of 1 is 0 We can talk about the antilog which is the reverse operation, so the antilog of 2 is 100 (essentially, to take the antilog of X, you find 10 to the X power) <figure id=„attachment_247097“ style=„width: 800px“ class=„wp-caption aligncenter“><img data-attachment-id=„247097“
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href=„https://commons.wikimedia.org/wiki/File:Graph_of_common_logarithm.png“
target=„_blank“>by Ellywa CC-BY-SA 3.0</figcaption></figure><p>Logarithms are handy when you have a large range of numbers because it compresses things. There are also some handy math facts that you’ll need to know if you want to do more than just memorize the decibel formula. Adding two logs is like multiplying the two original numbers and taking the log:</p>
100×10=1000 and the log of 1000 is 3 log(100)+log(10)=2+1=3
<p>By the way, this is how <a
href=„https://hackaday.com/2015/11/05/slide-rules-were-the-original-personal-computers/“>slide rules (like the ones below) work.</p> <p><a
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data-permalink=„http://hackaday.com/2015/11/05/slide-rules-were-the-original-personal-computers/sliderule-2/“ data-orig-file=„https://hackadaycom.files.wordpress.com/2015/10/sliderule.png“ data-orig-size=„800,358“ data-comments-opened=„1“ data-image-meta=„{"aperture":"0","credit":"","camera":"","caption":"","created_timestamp":"0","copyright":"","focal_length":"0","iso":"0","shutter_speed":"0","title":"","orientation":"0"}“ data-image-title=„sliderule“ data-image-description=„“ data-medium-file=„https://hackadaycom.files.wordpress.com/2015/10/sliderule.png?w=400&h=179“ data-large-file=„https://hackadaycom.files.wordpress.com/2015/10/sliderule.png?w=800“ class=„size-medium wp-image-175421 alignright“
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https://hackadaycom.files.wordpress.com/2015/10/sliderule.png?w=250&h=112 250w, https://hackadaycom.files.wordpress.com/2015/10/sliderule.png?w=768&h=344 768w, https://hackadaycom.files.wordpress.com/2015/10/sliderule.png 800w" sizes="(max-width: 400px) 100vw, 400px"/></p> <p>What’s even more important, is how easy it is to raise a number to a power using logarithms. Suppose you want to find 20 to the 9th power (written as 20^9). You could multiply 20 by itself, of course. But you can also find the answer by taking the log of 20 (about 1.3) and multiplying by 9. The answer will be the same as log (20^9).</p> <p>You’ll see that the formula used for decibels will sometimes use a factor of 10x (converting bels to decibels) and sometimes 20x (a combination of the 10x and squaring the ratio). Why? Remember that the bel is a measure power ratio. If you just want to remember a rule of thumb, the formula (see below) with the 10 in it is for power and the one with 20 in it is for voltage or current ratios. Why? Keep reading.</p> <h2>Ratios and Reference Values</h2> <p>In simple terms, then, a bel is just the logarithm of the ratio of output power to input power. So if you put in 1 watt and get out 10 watts, that’s a gain of 10X and that’s 1 bel. But like I said, no one uses bels, so multiply the answer by 10 to get decibels (10dB).</p> <p>That’s all there is to know, right? Not quite. There are two other things to think about. First, what if you are measuring voltage instead of power? The decibel is a power measurement, but you know that power is proportional to voltage squared. So if you take the voltage ratio, you have to multiply the computed value by 2 because multiplying the value by 2 is like squaring the ratio and then taking the log. Since you still have to multiply by 10, the result is you multiply your bel value by 20 instead of 10 if it is refering to a voltage or current ratio..</p> When dealing with power dB=10*log(output/input) When dealing with voltage or current dB=20*log(output/input) <p>However, there is one more catch: many times you hear a dB measurement applied to a single value. How can you measure one value and get a ratio? The answer is: you can’t. When you see a single value that appears in dB it means there is an assumed reference value. Sometimes this is made explicit and sometimes it is just implied. For example, if you see a measurement of 5 dBm, this means the measurement is relative to 1 milliwatt. In audio work, you may encounter the dBu or dBv which is relative to .775 VRMS. That’s the voltage that delivers roughly a milliwatt into a 600 ohm load.</p> <p>Think about the math behind this. For the example of 5 dBm, 5=10*log(output/.001). A little algebra will tell you that the output, then, is about 3.16 mW. 20 dBm is 100 mW. You’ll sometimes see dBV which is referenced to 1 volt RMS.</p> <h2>Back to Basics</h2> <p>If you only take away two things from this about decibels, let it be these two:</p> Use 10 for power and 20 for amplitudes Always ask yourself what are the two parts of the ratio being expressed. <p>If you keep those in mind, decibels are pretty easy to handle.</p> <p>These days you can do some pretty complicated things with integrated circuits. It is easy to lose sight of the basics given all this complexity. While the decibel isn’t going to allow you to build anything new, it is useful to understand how it works for everything from filter insertion loss to attenuation in fiber optics (usually represented by dB/m or decibels per meter).</p> <p>There are many other basic topics that you may gloss over these days or perhaps forgot from some long-ago class. Sometimes it is worthwhile to go read a fundamental book. Or revisit control theory. Either way, going back over old ground with more experience often gives you some new insights.</p> </html>

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