The Mysterious dB
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The Decibel, usually abbreviated dB, is very often used in our hobby but do you really understand what it is? The book, Reference Data For Radio Engineers defines the decibel as, "... a unit used to express the ratio between two amounts of power..." "It is also used to express voltage and current ratios." The problem most people have in understanding decibels is that the ratio is expressed in a logarithmic form. This causes what we think of as a large power change to cause the same number of dB change as a smaller appearing power change. It gets more confusing when we see something like antenna gain rated in dB without a ratio anywhere in sight! Another confusing aspect is how amplifier gain, cable loss, and antenna gain relate to things like "S" units. To add even more confusion, you often see dB represented as dBd, dBi, dBm, dBmv, and dBW!

Don't Panic! It is far simpler than it looks! In this article I will try to clarify the dB, relate it to amateur radio, and do it with a minimum of math. If you have a calculator with Log and Antilog (10^x) functions it will be helpful but not necessary.

Let's get the math out of the way first. The decibel is a logarithmic representation of a power, a voltage, or a current ratio. The following formulas convert these ratios into dB:

For a Power ratio: $dB = 10 * \log_{10} (P1/P2)$ where P1 = One Power level. P2 = Another Power level

For a Voltage ratio: $dB = 20 * \log_{10} (E1/E2)$ where E1 = One Voltage level. E2 = Another Voltage level

For a Current ratio: $dB = 20 * \log_{10} (I1/I2)$ where I1 = One Current level. I2 = Another Current level

In plain English, the power form reads, dB is equal to ten times the base ten log of the ratio P1 over P2. The voltage and current form is, dB is equal to twenty times the base ten log of the ratio E1 over E2 or I1 over I2.

We can also work these backwards if we know dB and want to determine the result of the ratio:

For Power: Power ratio multiplier = $\text{antilog}_{10} (dB/10)$ where dB = known power loss or gain

For Voltage: Voltage ratio multiplier = $\text{antilog}_{10} (dB/20)$ where dB = known voltage loss or gain

For Current: Current ratio multiplier = $\text{antilog}_{10} (dB/20)$ where dB = known current loss or gain

Before we go much farther we have to learn some rules.

Rule #1 I call the "Expected Result" rule because when we think about decibels we also need to think about whether we are *expecting* to see a gain or loss of power, voltage, or current. In general, amplifiers and most antennas will provide gain while cable, filters, diplexers, and splitters provide loss. However, if we know an amplifier's output power and gain in dB but do not know it's input power we can calculate it by *expecting* that the amp will *lose* power if it worked backwards.

Rule #2 says that, *in most cases*, your ratios will really be Power Out/Power In, Voltage Out/Voltage In, and Current Out/Current In. This assumes that if the output of something is greater than it's input you will want to see a positive dB value. Conversely, if the output is lower than the input your result will be negative dB or loss.

Rule #3 I call the "Relativity Rule". Decibels are always related to something as they represent change rather than some absolute value like Volts, Watts, or Amps. dB by itself represents change from some previous value expressed in some absolute form. This is why you will often see dB referenced to some value. There are many reference points but those typically used by amateurs are:

dBd dB gain over a dipole or the ratio of signal strength produced by the test antenna over that produced by a standard dipole. dBd is used to rate antenna performance. A dipole is a real antenna with 2.14 dB gain in relation to an isotropic radiator, a theoretical antenna that has zero gain. Antennas compared to a dipole look less effective than equivalent antennas compared to an isotropic. It is generally believed that dBd measurements have more relevance toward actual antenna performance.

dBi dB gain over an isotropic. dBi is also used to rate an antenna's performance. All real antennas have about 2.14 dB better performance than an isotropic antenna so gain referenced to the isotropic looks better than a reference to a real world antenna. For example if one antenna has a gain of 9 dBi and one has a gain of 6.9 dBd, which has more gain? Answer: They are both the same!

dBm dB gain over one milliwatt. dBm is usually used in audio work where 0dBm means 1 milliwatt into a 600 Ohm load. 1 Watt is 30 dB greater than 1 milliwatt. You can also specify power output in dBm if you wish. For instance, 100 Watts = 50dBm (50dB greater than one milliwatt)

dBmv dB gain over one millivolt. Though not often used in amateur radio circles, dBmv is an old standby in the Cable TV industry. 0 dBmv represents 1 millivolt or the minimum signal that will give a good picture on most TVs. 1 Volt is 30 dB greater than 1 millivolt.

dBW dB gain over one Watt. dBw is typically used to rate amplifiers and certain transmitting systems though not commonly used by amateurs. 1000 Watts is 30dB greater than 1 Watt.

Let's do a few examples to get the feel of how all of this works. Feel free to check my math with your calculator.

Say you just bought a 2 Meter amplifier that promises to give you 35 Watts out for 5 Watts in. How many dB is that? First we do the P1 over P2 ratio: 35/5 = 7. Then we take the $\log_{10}$ of that which is 0.845. Multiply that by 10 and we get: 8.45 dB gain. In other words: $\{8.45\text{dB} = 10 \log_{10}(35/5)\}$

OK, let's work that backwards. We start with 8.45 dB and divide by 10 to get: 0.845. Next we take the antilog (10^x) of 0.845 and get 6.998. Well... we did round off the number and this is pretty darn close to 7! $\{6.998 = \text{antilog}(8.45/10)\}$ Now that we know the result of the ratio, we can determine either the input or output power as long as we know one of them. If we know the input power (5 Watts) and we *expect* to gain power because we are amplifying, we simply multiply 5 Watts times 7 and get 35 Watts. If we know the output (35 Watts) and *expect* to lose power, in this case going backwards through the amp, we divide 35 Watts by 7 and get 5 Watts.

Let's say, an amplifier manufacturer says that their 2 Meter amp will give you 12 dB of gain with 5 Watts of drive. What will the output power be? First, we need to come up with something that we can multiply 5 Watts by to get our output power. This will come from the 12 dB. First divide 12 by 10 because we have to work the problem backwards to get a multiplier. We get 1.2. We then take the antilog of 1.2 and get: 15.85 We multiply 5 Watts by 15.85 because we are expecting gain and we get 79.25 Watts. $\{15.85 = \text{antilog}(12/10)\}$

Every Sunday night we check into a 2 Meter net using our 5 Watt HT, a few feet of coax and a home made dipole antenna. Net control says we're, "just making the system" so we decide to beef up our system. We are thinking about buying an "EtherBlaster" antenna at $350 which has a rated gain of 9dBd to use with our HT. The EtherMaster Antenna Company Catalog says that we will "get out better" than with the 7dBd gain, "HorizonHopper" antenna priced at $125. How much more effective power would we have with the EtherBlaster? This requires two calculations because we need to calculate Effective

Radiated Power (ERP) for both antennas. To do this we will work the power formula backwards because we know dB and want to know power. The power ratio result for the EtherBlaster is: 7.94 = antilog(9/10). We then multiply 7.94 times 5 Watts and get 39.7 Watts effective power output from the EtherBlaster. The HorizonHopper calculation is: 5.01 = antilog(7/10) and that would give us 25.05 Watts effective power. So, an extra $225 gets us almost 15 more Watts. Sounds good but before you dig out your wallet, read on!

The real beauty of the decibel is that it can be used to translate power changes into voltage or current changes. The best amateur application for this is in determining how much amplifier or antenna gain will affect the received signal. The "S" unit is the ultimate number by which our signal level is judged. The S unit, though not a standard in the strictest sense, became a near-standard during World War II when several receiver manufacturers agreed that S9 would represent a 50 microvolt signal and each S unit would represent a 6dB change in signal strength. Since a dB derived from a power ratio is equivalent to a dB derived from a voltage ratio it is a simple matter to translate a power increase at the transmitter into a voltage ("S" Unit) increase at the receiver.

Let's look back at our "EtherBlaster" vs "HorizonHopper" example. Frankly, we didn't have to do the power calculations but it was good exercise! The two dB difference between the EtherBlaster and the HorizonHopper would amount to not more than a 1/3 S unit change at the receiver. Is that 1/3 S unit really worth an extra $225? Probably not! However, we really started out to see if we could boost our signal into the repeater. Since we were "just making the system" with our HT and dipole what would happen if we bought the HorizonHopper and plugged it in instead of the dipole? Since the HorizonHopper had 7 dBd of gain, our signal into the repeater should go up by a little over one "S" unit. This would make the difference – let's do it!

Since we're going to spend some money, let's do it right. We'll move the operating position down into the basement – the XYL really didn't like all that stuff in the bedroom anyway! We'll need about 100 ft of coax to go from the new antenna mount on the chimney down to the cubbyhole we're allowed to have between the furnace and the sump pump. We know from listening to the old timers that long runs of RG-58A/U are too lossy on 2 Meters (it loses 6dB per 100ft at 144 MHz) so we plan to buy some RG-8/U which loses only 2.2 dB per 100 feet at 144 MHz. One of our buddies told us that we REALLY need an amplifier (one of those 35 Watt output jobs) in order to really be heard. Hey, it's only money, right??!! So, we dig out the credit card, call "HamHeaven" and buy a 5 Watts in - 35 Watts out amplifier, the 7dBd "HorizonHopper" antenna, and 100 feet of RG-8/U coaxial cable.

While waiting for the stuff to arrive we decide that a little calculation is in order. Since we're intending to receive as well as transmit we decide to calculate gain and loss on receive and transmit. Let's look at the transmit first. Since we're trying to determine how much of an "S" unit improvement over our "bedroom setup" we will make at the repeater we need to convert everything to dB. The transmitter puts out 5 Watts which the amplifier will boost that to 35 Watts. This will give us an 8.45 dB power gain over just the HT ($8.45dB = 10 \log_{10}(35/5)$. There will be a 2.2 dB loss in the coax which we subtract from 8.45 dB to get 6.25 dB. This is the gain over the HT available at the antenna input connector. This is the equivalent of putting about 21 Watts into the antenna (4.22 power multiplier = antilog(6.25/10)). The "HorizonHopper" will add 7dB to this so we will realize a total of 13.25 dB gain or about 105 Watts ERP (21.13 power multiplier = antilog(13.25/10)) This will give us about a 2¼ "S" unit increase at the repeater. That should guarantee a "solid copy" report!

Now let's look at the receive side. A signal reaching our antenna will be 7 dB stronger entering the coax than if it were received by a standard dipole. The signal now travels down the coax, losing 2.2 dB as it goes. Which means that when the signal enters your receiver it will be 4.8 dB stronger than a signal received by a dipole antenna connected directly to the receiver without lossy coax or a little more than ¾ “S” unit. This is OK but you have created what we hams call an “alligator”, a creature with a large mouth and tiny ears. The analogy is that your system will have a loud signal but will not “hear” as well as it can be heard. The addition of a receiver preamp with approximately 13 dB gain would balance the system and give you 2¼ “S” unit gain on receive.

Then there is the case of the Power twins, Morris and Hiram. Moe and Hi each live with their families in a small town about 2 miles apart from each other. The boys have a nightly schedule on 80 meter phone and to make sure they get “armchair copy” they fire up their 1500 Watt linears for their nightly QSOs. It’s not unusual for them to be giving each other signal reports like, “Sounds real fine, yer just pinin’ the meter brother!”. In case you didn’t know, most “S” meters “pin” at about +50dB over S9. This means that each brother is receiving a signal of at least 15,800 microvolts or 15.8 millivolts if you prefer.

One night Hi said, “Ya know Moe, I’ve been hearin’ about somethin’ called QRP. Seems like ya turn the power down a bit and see how well ya can talk. It kinda sounds like fun – wanna try it?”

Hi agreed and Moe turned back the power a bit – now he was putting out only 1000 Watts. Moe was really surprised by Hi’s next signal report.

“Yeah right Moe are you messin’ with me or somethin’”, bellowed Hi, “My needle didn’t budge!”

In all fairness, Hi’s glasses were a bit dirty but he would have had to look pretty hard to notice a 1.8 dB drop. Now it was Hi’s turn to go QRP and he decided to really outdo his brother. He backed his amplifier all the way down to 600 Watts or a 4dB power drop. Moe figured his brother was fooling around because Hi was still coming in at about 46 over. They argued about this for awhile but finally decided to turn off their linears and go “barefoot” with 100 Watts or an 11.8 dB drop.

Moe was the first to exclaim, “Gee, you’re still solid copy at just a smidge under 40 over old man!”

Hi finally said, “Moe let’s turn ‘em all the way down to 10 Watts and see what happens.”

That’s almost 22 dB down from 1500 Watts and 10 dB down from 100 Watts. The brothers couldn’t believe their eyes as their meter needles now hovered just under +30. That night, Hi and Moe became diehard QRP disciples and began preaching about their new “religion” to anyone who would listen. The still kept up their nightly skeds and secretly began competing with each other to see who would be the first to get their signals down to only S9. Moe won the competition when he cooked up a rig that used a carbon microphone modulating an oscillator powered by a 9 volt battery. It sounded terrible but it put out only 15 milliwatts (50 dB down from 1500 Watts) and Hi’s meter registered S9.