How Do I?

An Occasional Series

This week: Antenna Topics
Gain. What is it? Why does it matter?

Listen to nearly any two amateur radio operators talk about antennas, or read any advertising for an antenna, and sooner or later you will hear the word "gain". This is especially true with VHF and UHF antennas where SWR typically is not an issue.

There are many manufacturers of commercial antennas and parts so you can 'roll your own". Today we going to start by defining gain, then use some topics from the Larsen Amateur Radio Catalog to illustrate some points.

Any antenna discussion about **gain** begins with a completely perfect, theoretical antenna-the *isotropic radiator*. No, this not some sort of device to keep you cool in the tropical parts of the world. As the *ARRL Antenna Book 21st ed*. Says on page 2-6

> Envision, if you will, an infinitely small antenna, a point located in outer space, completely removed from anything else around it. Then consider an infinitely small transmitter feeding this infinitely small, point antenna. You now have an isotropic radiator. The uniquely useful property of this theoretical *point-source* antenna is that it radiates equally well in all directions. That is to say, an isotropic antenna favors no direction at the expense of any other—in other words, it has absolutely no *directivity*. The isotropic radiator is useful as a *measuring stick* for comparison with actual antenna systems. You will find later that real, practical antennas all exhibit some degree of directivity, which is the property of radiating more strongly in some directions than in others. The radiation from a practical antenna never has the same intensity in all directions and may even have zero radiation in some directions. The fact that a practical antenna displays directivity (while an isotropic radiator does not) is not necessarily a bad thing. The directivity of a real antenna is often carefully tailored to emphasize radiation in particular directions. For example, a receiving antenna that favors certain directions can discriminate against interference or noise coming from other directions, thereby increasing the signal-to-noise ratio for desired signals coming from the favored direction. Or to put this into one sentence: The increase in effective radiated power in the desired direction of the major lobe.

Wait. I thought we were talking about **gain** and here you are off in the weeds talking about radiation pattern. Next thing 'ya know, you will have me making a Smith Chart!

Yep, it's all related. If we had the time and resources to plot the radiation pattern based on the antenna polarization and the azimuth and elevation angles, we would have a Smith Chart. For today's discussion, we are working with commercial antennas where the manufacturer has done the math. Gain is typically expressed in Decibels or dB.
Or as the *ARRL Antenna Book 21st ed* page 2-9 explains

Introduction to the Decibel

The power gain of an antenna system is usually expressed in decibels. The decibel is a practical unit for measuring power ratios because it is more closely related to the actual effect produced at a distant receiver than the power ratio itself. One decibel represents a just-detectable change in signal strength, regardless of the actual value of the signal voltage. A 20-decibel (20-dB) increase in signal, for example, represents 20 observable steps in increased signal. The power ratio (100 to 1) corresponding to 20 dB gives an entirely exaggerated idea of the improvement in communication to be expected.

The number of decibels corresponding to any power ratio is equal to 10 times the common logarithm of the power ratio, or

$$dB = 10 \log_{10} \frac{P1}{P2}$$

If the voltage ratio is given, the number of decibels is equal to 20 times the common logarithm of the ratio. That is,

$$dB = 20 \log_{10} \frac{V1}{V2}$$

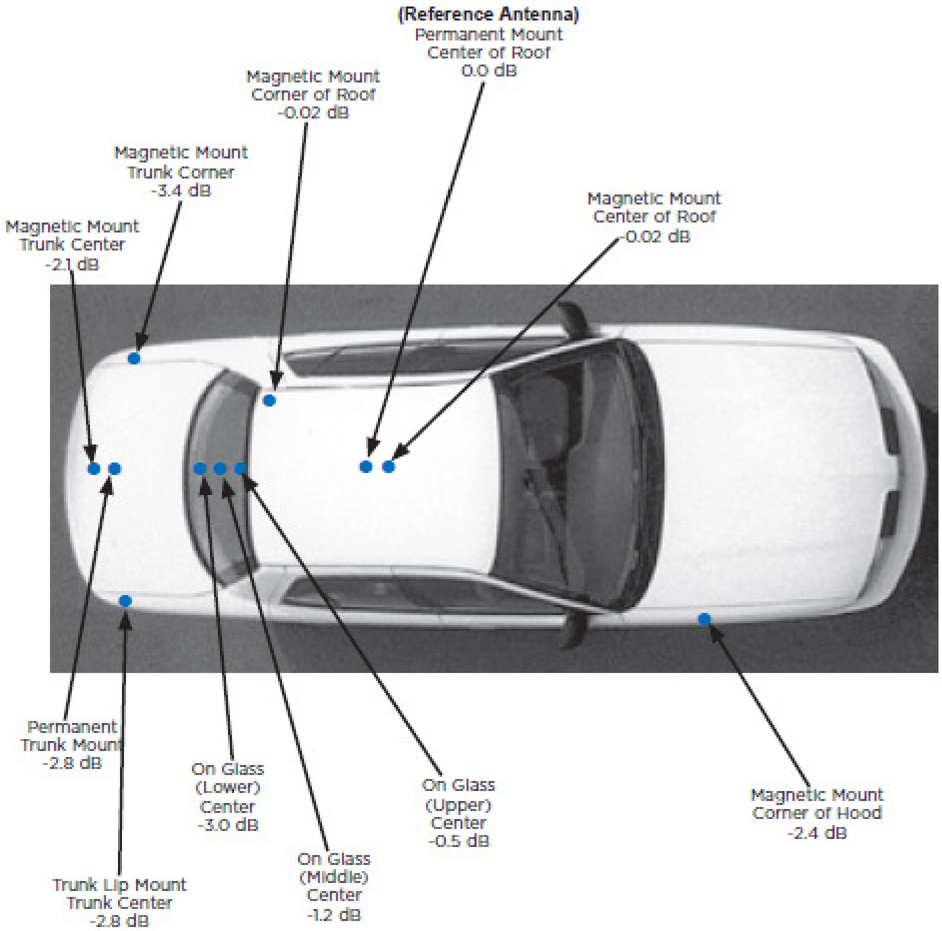
When a voltage ratio is used, both voltages must be measured across the same value of impedance. Unless this is done the decibel figure is meaningless, because it is fundamentally a measure of a power ratio.

The main reason a decibel is used is that successive power gains expressed in decibels may simply be added together. Thus a gain of 3 dB followed by a gain of 6 dB gives a total gain of 9 dB. In ordinary power ratios, the ratios must be multiplied together to find the total gain. A reduction in power is handled simply by subtracting the requisite number of decibels. Thus, reducing the power to ½ is the same as subtracting 3 decibels. For example, a power gain of 4 in one part of a system and a reduction to ½ in another part gives a total power gain of 4 × ½ = 2. In decibels, this is 6 – 3 = 3 dB. A power reduction or loss is simply indicated by including a negative sign in front of the appropriate number of decibels.

OK! Enough with the math! How does this work?

Let's say we are shopping for a mobile VHF or UHF antenna for a car. The Larsen catalog has a neat photo. See below.

Note that right in the middle of the roof is the perfect, mythical, reference antenna. Compared to the other antennas, there is no gain. A popular option is to place a 1/4 wave mag mount antenna directly in the middle of the car roof. Compared to the reference antenna, we lose 0.2 dB of gain. Not too bad. Interestingly, if we place the same antenna at the left rear corner, we lose the same amount. You often see antennas mounted on the trunk lid. Compared to our reference antenna, we lose 2.8 dB there. Placing the antenna on the hood only costs us 2.4 dB.



If we take a look at Larsen 136-174 MHz VHF antennas:

			GAIN				
NMO150B	5/8 λ	144-174	3/5.2	51.5	200	Black	C
NMO150C	5/8 λ	144-174	3/5.2	51.5	200	Stainless	C
NMO150BHW	1/2 λ	144-174	0/2	51.5	200	Black	C
NMOQW144	1/4 λ	144-152	0/2	21	200	Stainless	C
NMOQW152	1/4 λ	152-162	0/2	21	200	Stainless	C

Why are there two numbers in the GAIN column? The number on the left is the dBd. The number on the right is the dBi. Together, the chart numbers represent dBd/dBi.

The dBi is the gain versus our isotropic radiator and the dBd is the gain versus a reference dipole. Just remember i= isotropic and d = dipole.

So in this case our 5/8 wave has a gain of 3 dBd and 5.2 dBi. A 1/4 antenna is 0 dBd and 2 dBi. So the 5/8 wave is better? Not so fast. Where are you using it? Urban areas tend to have taller buildings that obstruct signals. The 1/4 wave signal radiates in a more vertical pattern and can overcome those obstacles. The 5/8 wave shines in flat areas. Quarter wave antennas do better in mountain and urban areas.

We have just trimmed about 9 pages in the ARRL antenna book down to about 2.
To say we didn't scratch the surface is an understatement.
Hopefully you learned about gain and some tips on antenna shopping.

Catch ‘ya on the air!

Links:

ARRL: Antenna and Antenna Analyzer books:
http://www.arrl.org/arrl-antenna-book

https://www.arrl.org/shop/Understanding-Your-Antenna-Analyzer

CARC:
https://www.radioclub-carc.com/resources/

Larsen Antenna:
www.pulseelectronics.com