Newcomers and Elmers Net 7-7-13: Basic Antenna Theory

Radio Waves
Radio waves are a combination of both an electric field and a magnetic field traveling perpendicular to one another at roughly the speed of light (186,282 miles/s).

This means there is a magnetic portion to a wave and an electric portion. A wave travels outward from the radiating source and travels through the atmosphere with varying results.

A vertical antenna, like the one on a handheld radio, sends out waves parallel to the ground- think of a placing a donut over your index finger while pointing your finger straight up in the air
- the radiation pattern of a vertical antenna (your finger) goes in the direction of the donut, perpendicular to your finger
- for a horizontal antenna, think of the same donut/finger combination, but this time with yopur finger pointing at someone in front of you
- some of the signal would go up, so would go to the side, and some would go into the ground

Radio frequencies are determined by how many waves (or cycles) a signal goes through per second.
- For example, household current is roughly 60 cycles (Hz) per second, or 60 wavelengths per second.

By contrast, a radio signal transmitted on 14.25 MHz is traveling at a speed of 14,250,000 cycles per second.

(Sounds really fast, doesn't it?! In radio terms, it's rather slow compared to, say, 444,000,000 cycles per second on the UHF band, or 1,200,000,000 cycles per second on the 23 cm band!)

That takes care of the time element, but what about the length of an actual wave?
-Well . . . since light is our constant, at 182,282 miles per second (or 300,000,000 meters per second), and radio waves travel at the speed of light (roughly), we can calculate the distance by dividing 300,000,000 m/s by the number of wavelengths to get the length of each wave.
-Thus a signal traveling at 14.25 MHz has a wavelength of 300,000,000/14,250,000 (move 6 decimal places to the left to get an easier number to work with and you get 300/14.25) = 21.05 meters.

A 7 MHz signal travels 300/7 = 42.85 meters
A 3.8 MHz signal travels 300/3.8 = 78.9 meters
A 1.8 MHz signals travels 300/1.8 = 166.66 meters

Notice the pattern? Of course you do – these are the common amateur radio bands, 20, 40, 80, and 160 meters. Aren't you glad you don't have to carry all that math around in your head?!

For our purposes here, radio wavelengths are significant because differing frequencies have differing antenna needs and different propagation patterns to them (*propagation* refers to how signals get from one place to another).

Antennas need to be suited to the signals they are going to send or receive, and this is where the above calculations come into play. An antenna designed to work efficiently at the 14.25 MHz frequency needs to be equal to either one whole wavelength (λ) in size, or a length which is divisible by 2, 4, 8 etc.

In practical terms antennas are usually either 1λ, ½ λ, or ¼ λ. The ratios can get smaller, but there is usually too great a signal loss much below 1/8 or 1/16 λ.

The magic size for many antennas is ½ λ due to the nature of radio waves. In fact, a ½ λ dipole is considered an antenna standard, particularly for HF frequencies, due to its electrical properties.

When an antenna is ½ λ of the transmitted frequency, the two parts to the wave, the peak and the trough, line up exactly as the wave travels down the antenna wires and back again, thousands of times a second.

When this ½ λ is achieved, the wave pattern (if you could see it) matches perfectly with itself every time, giving you an SWR of 1:1. This match produces an even and consistent radiation pattern from the antenna. This is called resonance.

If an antenna is something other than ½ wavelength, then as one wave travels down the antenna and back again, it runs into the next wave out of sync – the signals sort of fight each other and efficiency is reduced

--The more inefficient, the greater the standing wave ratio – 3:,4:,5:, even 10:1 or greater.

Many of the antennas we use for VHF and UHF are ¼ wavelength antennas and depend on the radials of a ground plane antenna or the metal roof on the car, for example, to complete the other ¼ wavelength to equal that half wavelength we need

For HF signals, a ¼ vertical antenna takes up a lot less room than ½ wave horizontal antenna, and so these are fairly popular for 40 and 80 meters.

Gain

Antennas can exhibit something called gain, sometimes mistakenly thought of as an antenna adding power to a signal.

-Unless the antenna has some form of mechanical amplifier, gain actually refers to how well an antenna performs compared to a given standard.

-The standard used to measure gain is an important one, and it is not always the same from one manufacturer to another! The old "buyer beware" adage applies here: when an antenna is claimed to have a "gain" of 3 dB over a dipole, the question is which kind of dipole?

- Is it an isotropic antenna (dBi) or a real world dipole (dBd)? An isotropic antenna is an imaginary dipole which has perfect radiation in all directions, useful when talking about the properties of an antenna or when talking about antenna theory.

When an antenna is measured in dBd, it is assuming a more real-world antenna which starts with the dBi number built in. dBd measurements assume an antenna does not radiate perfectly in all directions, but does exhibit directional gain over an isotropic antenna.

Real gain is directional, meaning it favors one direction over another. Think of an omni-directional mike versus a directional mike—the omni-directional mike covers more area but with less sensitivity in any one direction.

Antenna Efficiency

One way an antenna is considered efficient is if it radiates the same amount of power given out by the transceiver. Ideally you want 100 watts out for 100 watts in.

Even under the best of circumstances you will not get a full 100 watts out (assuming your transceiver is really putting out a true 100 watts!); there will be unavoidably slight losses from radio to antenna, but if everything is working properly these losses are negligible.

Your goal, of course, is to make everything work as well as you can, including the transmitter, the feedline, and the antenna. Assuming proper antenna design, more often than not the feedline poses the biggest obstacle to antenna efficiency by interjecting losses to the signal before it ever reaches the antenna.

let me underscore here the importance of using high quality, low-loss coax (assuming coax is your feedline choice). Don't get cheap here! I would rather have good coax and a less-capable rig than the other way around. You can't work stations if they can't hear you!

A second measure of antenna efficiency is more subjective: does the signal go where it is supposed to go? In other words, given the antenna's design, location, and bandwidth, is it doing what it is supposed to do?

Ground conditions have a significant impact on how well some antennas radiate.

A horizontal dipole strung between posts at a height of ½ λ typically has good range for medium and long distance communications on HF because ground effects are minimized.

Lower that same antenna to ¼ λ or less and ground conditions become significant. Generally the higher the frequency the greater effect ground conditions have on a signal, to the point where VHF and UHF signals are considered "line of sight" since there is almost no reflection off the ground or from the atmosphere.

The reflectivity of ground is dependent on the ground composition.

Saltwater makes a superb ground material because it is highly reflective. Freshwater, on the other hand, is a poor conductor.

Sand has low conductance, as does clay and volcanic soil.

Farmland has somewhat better conductivity, meaning it reflects a larger portion of the signals aimed at it. Still, overall it absorbs more than it reflects, so vertical antennas, in particular, require some form of electrical ground to make more of the signal usable.

While you can estimate the effects of ground close in, the further you get away from your antenna the more difficult it becomes to determine how your signal will react.

We may have hills or valleys or cities surrounding us, which will unavoidably affect our signals, so we just try to do the best we can.

Keep in mind when I am discussing antenna theory the point is not to overwhelm you with problems, calculations, or hopeless analysis paralysis!

First and foremost, get on the air! The theory is here to help you build upon your initial experiences and to develop an innate sense of how antennas work in order to slowly but surely improve your station.

Whatever you do, don’t get lost in the details! This hobby is about having fun while you learn.