NewcomerNotes: What is Ground, Anyway?   3-8-15

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-- Most signals are a combination of a ground element and an atmospheric element, and this affects not only the distance a signal will travel, but also its quality.
-- When receiving a radio transmission the main things that determine what we hear are the frequency and the type of modulation of the signal.
-- The Earth is a relatively poor conductor of electricity overall, so signals dependent on ground travel alone don't go very far.
-- While ground effect is more of an issue with transmitting than with reception, knowing which factors most impact a signal will help you understand why some signals come in better than others.

Conditions such as mountainous terrain may block some signals while helping others. Steel buildings and concrete roads all impact what one hears, sometimes in very strange ways.
-- *Diffraction* is the term most often used to describe how radio signals are bent, bounced, and otherwise redirected from their source to their final destination.
-- Trying to determine what factors impact radio signal reception is an inexact science at best, but when looked at from the transmission side of things, reception issues will make a lot more sense.
-- How a signal leaves its point of transmission and what impacts it along the way determines to a great extent how that signal will be received.

Near- Field Reactivity and Far-Field Radiation
Two common areas of study in the effects of ground on RF signals involve *near-field reactivity* and *far-field radiation*.
-- Near-field reactivity involves somewhat complex impedances as the physical surroundings of an antenna influence how much energy is allowed to radiate from the antenna.
-- The antenna can act like a capacitor or inductor depending on the interaction with ground.
-- Perhaps I should also mention here that when *ground* is discussed it does not refer to the actual surface of the ground where we walk, but rather a point somewhat below the surface of the earth.
-- This point changes depending on location and on the conductivity of the material making up the "ground" (such as liquid, rock, soil, etc.)
-- This interaction can greatly increase signal losses as well; this is why ground effect must be considered in any antenna setup.

-- *Far-field radiation* refers to the effect of ground on the radiation pattern of an antenna once the signal leaves the antenna.
-- Antenna orientation, elevation, terrain, wavelength, strength and modulation type all impact how well a signal is transmitted to a receiver.

Height Above Ground

Just as we assume bigger is always better, more is better than less, and its easier to ask for forgiveness rather than permission, we assume higher is always better than lower. This is not always the case.

An antenna's height above ground will greatly impact how that ground interacts with a transmitted signal.
-- If an antenna is too low to the ground much of the signal is absorbed or *dissipated* into the ground. Too high above ground and the positive effects of ground reflection can be lost.
-- Each antenna design has its own rule of thumb concerning elevation and this should be used as a starting point for testing the antenna.
-- Every situation is different, even when ground conditions seem fairly uniform. Soil composition, dielectric constant (its ability to conduct electricity), and physical shape all combine to impact the effectiveness of a signal.
-- Some RF energy being created at the antenna radiates downward and will be reflected right back up into the antenna causing an interaction with signal current, helping or hurting the overall signal strength
-- If the reflected current is in phase with the radiating current, the signal is stronger as a result. If the reflected current is out of phase with the radiating current, the signal strength is diminished.

The closer an antenna is to the ground the higher the take-off angles will be—or more accurately, the more ground will interfere with the desired take-off angles. The radiation pattern is what it is for an antenna, but local conditions both block and reflect parts of the radiation pattern. The higher up the antenna (within the bounds we will discuss below), the less likely it is for the critical lower take-off angles to be blocked.

Higher take-off angles mean shorted hops and therefore more hops are needed to get to a particular destination. Each hop off the ground means more signal absorption, and thus a weaker signal making each successive hop.

As a general rule, for bands between 10 and 20 meters antennas will work optimally with a height of about 1.5 wavelengths. This means for these bands the antenna height would need to be approximately 104 ft on 20 meters, 83 ft on 17 meters, 73 ft on 15 meters, 60 ft on 12 meters and 50 ft on 10 meters.

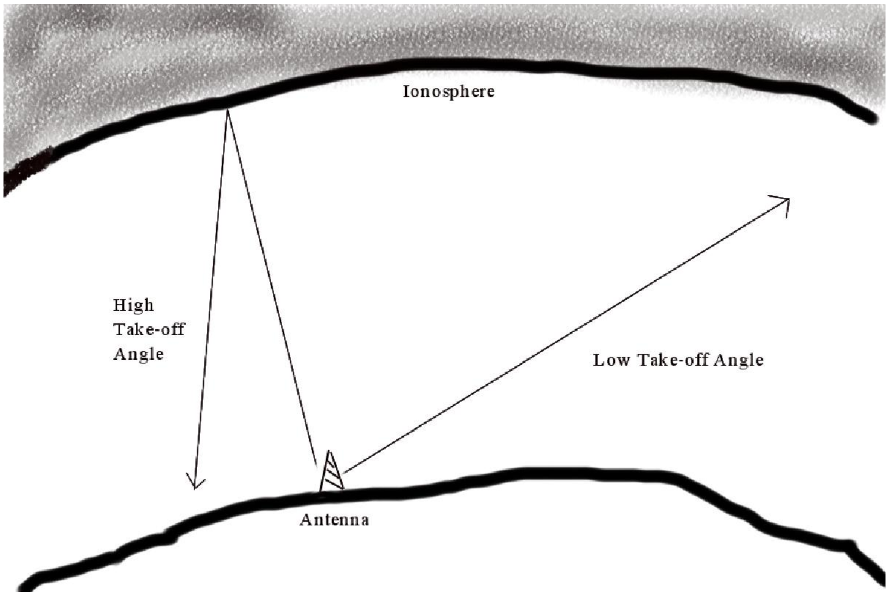
Changing the height of the antenna will change the current, so if possible, try different heights and compare the results both in terms of the VSWR readings and of the real-world reception/transmission capabilities of the antenna.
-- You may also find your readings differ when the height remains constant but you change locations for the antenna.
-- This is particularly true when working in areas where the terrain is uneven or there is a mix of ground materials such as concrete, metal or grass.
-- Keep in mind with any RF radiation there are two fields being generated: a magnetic field and an electronic field, with each being at 90° to one another.
-- Both of these fields can be reflected, or disrupted by the effects of ground.
-- While there are many resources available on the net to study the theoretical effects of near-field reactivity, you can't beat experimentation in the real world for getting a handle on what impacts your signal.

Even with a tower a Yagi for 20 meters might be rather difficult to erect anything approaching 100 feet, and so optimal performance will likely have to take a back seat to practicality. Even at 70 feet, one full wavelength's height, the structure requirements may be a bit steep for many, but our goal here is to understand height above ground from the perspective of antenna theory which will then get worked out (or around!) in the real world.

As is obvious from the antenna height requirements for 20 meters, rare is the person who can put up a horizontally polarized antenna which can be optimized for 40 meters or higher. Rather for these bands the decisions come down to space and the distance coverage desired, essentially meaning a choice between horizontal or vertical antenna designs.

Take-Off Angles

Take-off angles refer to the angle at which a radio signal leaves the antenna.
-- A high take-off angle means that the signal angles up to the sky more sharply than a low take-off angle (see illustration).



While some RF energy is absorbed into the ground regardless of the take-off angle, DX operators shoot for low take-off angles which allow for the greatest travel distance for their signals.
-- (Note: when local coverage is desired vertical or *NVIS* antennas are often used specifically for their short-range, high take-off angles. Emergency systems almost always use vertical antennas to provide the best coverage of a local area.)
-- As might be imagined, larger waves travel greater distances, so lower frequency transmissions are affected by ground conditions further out from the transmitting antenna than frequencies in the VHF range of the RF spectrum.

Take-off angles and reflections are determined in part by the type of antenna being used and in part by the antenna's height above ground.
-- Again speaking in generalizations, horizontal antennas produce *horizontally polarized* signals, while vertical antennas produce *vertically polarized* signals.
-- Unless the signal travels over a long expanse of flat land equal to its wavelength, predicting the ground effect on the radiation pattern becomes almost impossible to any degree of accuracy.
-- There are just too many variables to take into account. This is where one must rely on an "educated guess" and go from there.
-- While the ground effect may not be able to be changed, other factors such as antenna direction, orientation and near-field reactance are able to be controlled and tweaked for best performance.

The lower bands simply do not reach *optimum* height above ground very often, and this may be where we decide the take-off angles of a vertical antenna are better suited for our needs.

These same conditions do work in our favor for short-range communications, say out to 1000 miles, and allows for great camaraderie participating nets covering North America, for example, or European community nets. Also such properties are used to good advantage to have very local coverage on 80 meters when propagation allows, such as in the evenings or overnight.

The question may arise "How can I eliminate the effects of (near) ground?" For HF work a practical rule of thumb is that an antenna height of 2λ virtually eliminates the close-in effects of ground, all else being equal. By this I mean assuming a clear area around the antenna. Local structures may have an impact which simulates ground, such as an antenna raised to a height where part of its radiation pattern covers a metal roof garage, for example. For our purposes here we will keep things simple and assume no nearby objects will interfere with our radiation pattern.

As an aside, note that VHF and higher frequencies are more affected by ground conditions at the same height than are HF signals, but the principle still applies—greater than 2λ will all but negate ground influences.

The elevation angle (or take-off angle) and height above ground not only affects the gain of the antenna, but also the beam width. Below 1λ the beam width is greater than the angle of elevation, but at 1λ or above, the beam width and the angle of elevation match up closely. This means that if one knows the take-off angle of an antenna that is at least 1λ in height, then the beam width is also known.

40-160 Meters: Different Considerations

As mentioned previously, logistical issues will likely prevent getting these antennas to even one-wavelength in height, much less two-wavelengths. If such heights are possible, the radiation patterns and ground effects would be basically the same, just over a larger area. Since most antennas cannot be place at even ½λ, take-off angles remain rather high. In fact, with ground absorption/attenuation of such signals, often a vertically polarized antenna is the best solution for lowering take-off angles.

Vertical antennas present their own issues such as the space required for radials, and the presence (or lack) of radials will greatly influence coverage. Even here, however, height above ground can make a difference if only for any slight reductions in ground noise which might be achieved. Sloping radials can allow for heights which reduce ground noise and provide more safety, without significantly affecting the antenna design itself.

Just as a vertically polarized antenna can be used to compensate for the height above ground limitations of a large horizontally polarized antenna, an horizontally polarized antenna at heights significantly less than ½ wavelength can enhance close-in communications with high take-off angles and sharp reflections. Both types of antennas would be an ideal solution for the lower frequencies.