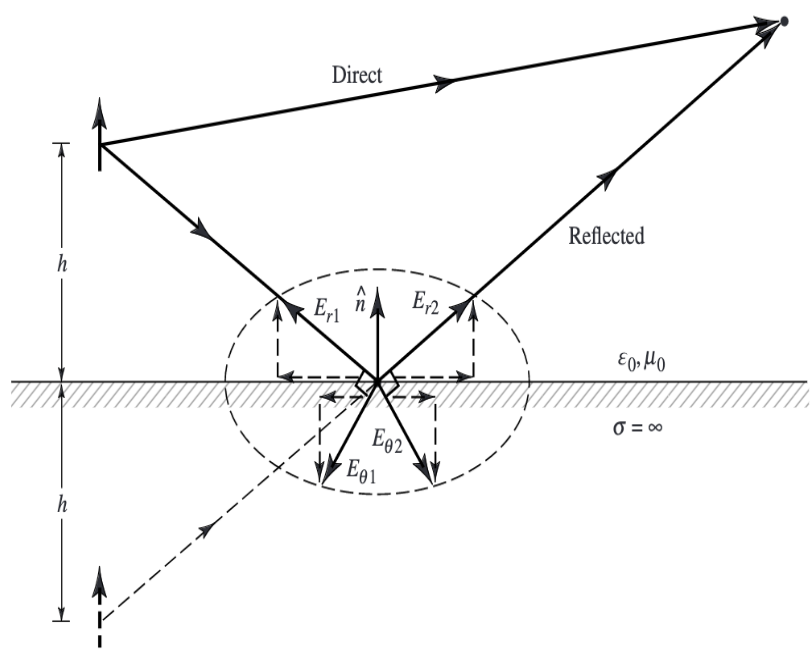
Waves & Coffee - Grounds & Verticals

Why do we need a good ground plane?
By Stephen W2WF

As we've seen, solar activity affects our radio propagation; however, equally as important as looking up at the ionosphere is looking down at the ground. Let's delve into the effects of the ground on vertical antenna performance.

We've all heard how ground systems such as the placement of radials or transmitting close to salt water improve our antenna's performance. Why is this so?

It turns out that the theoretical model that we use for this problem is called the "method of images". This is a calculation technique that assumes a "virtual antenna" below ground as a mirror image of our vertical antenna above ground. The radiation pattern is then made up of a direct and a reflected E&M wave, with the reflected wave behaving as if it was radiated by the virtual antenna.



The E&M waves radiated from our antenna hit the ground and are reflected up into the ionosphere. So in a practical sense the ground behaves like a "mirror" for our E&M waves. To make a better mirror at radio frequencies we need to make an electrically conductive surface. The more conductive the surface, the better the "mirror".

The other effect of the ground that concerns us are the ground losses. When our E&M wave hits the ground, it can present a high resistance to our wave, which makes the efficiency of our vertical antenna suffer. Looking at the definition of power efficiency for radiated and ground power,

$$\eta = \frac{P_r}{(P_r + P_g)}$$

Where,

$\eta = efficiency$

$P_r = Radiated\ Power$

$P_g = Ground\ Power$

Or since $P_r = R_r I_0^2$ and $P_g = R_g I_0^2$

$$\eta = \frac{R_r}{(R_r + R_g)}$$

$R_r = Radiated\ Resistance$

$R_g = Ground\ Resistance$

Since R_g is in the denominator, this tells us that the larger the ground resistance, the less efficient our vertical antenna.

In order to make this low resistance electrically conductive surface, hams have used different techniques. One of the more popular is the use of "radials". These radials are nothing more than wires typically 10 – 15ft in length and from 11 to 30 in number, arranged in a radially outward pattern from the base of our vertical antenna. The number, length, and pattern of radials has been studied and can be found in various articles listed at the end of this note. The use of wire meshes over the ground under our vertical antenna accomplishes the same function and is another technique used by hams. Lastly, rigging up our vertical antenna near a large body of salt water, or fresh water, is also reported to be good for DX propagation.

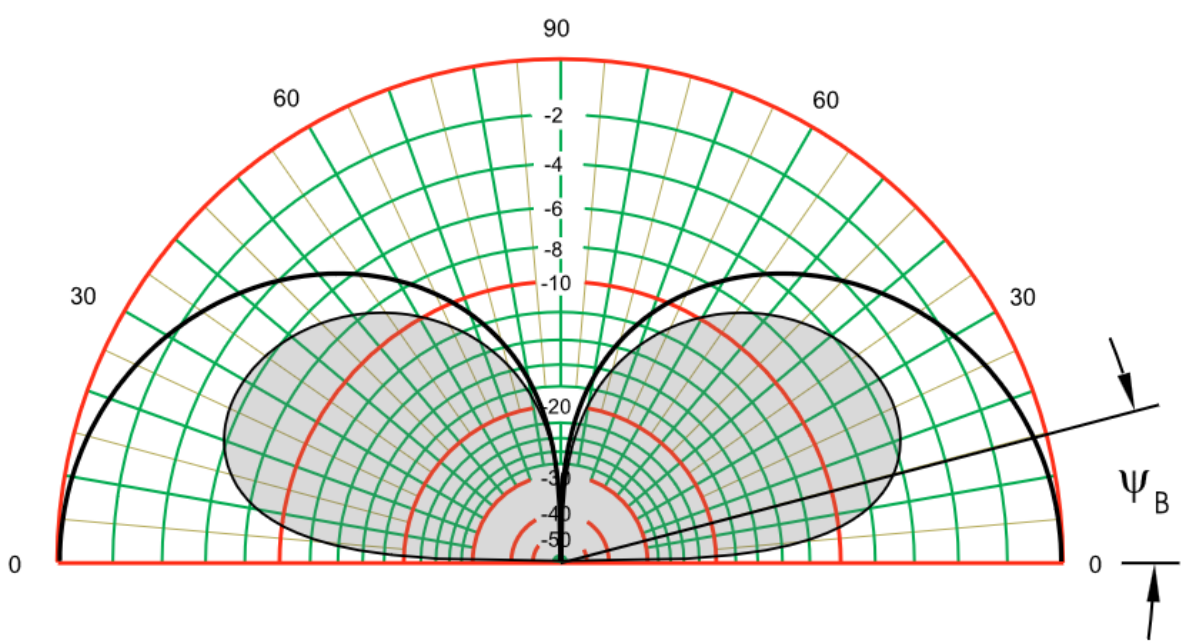
To quantify these effects, it's of particular interest to consider two parameters: the Dielectric Constant & the Conductivity of common types of earth.

Surface Type	Dielectric Constant	Conductivity (S/m)	Relative Quality
Fresh water	80	0.001	
Salt water	81	5	
Pastoral, low hills, rich soil typ Dallas, TX to Lincoln, NE areas	20	0.0303	Very good
Pastoral, low hills, rich soil typ OH and IL	14	0.01	
Flat country, marshy, density wooded, typ LA near Miss. River	12	0.0075	
Pastoral, medium hills and forestation, typ MD, PA, NY (exclusive of mountains and coastline)	13	0.006	
Pastoral, medium hills and forestation, heavy clay soil, typ central VA	13	0.005	Average

Rocky soil, steep hills, typ mountainous	12-14	0.002	Poor
Sandy, dry, flat, coastal	10	0.002	
Cities, industrial areas	5	0.001	Very poor
Cities, heavy industrial areas, high buildings	3	0.001	Extremely poor

This table shows that Salt water has the best conductivity followed by rich soil, marshy soils, dry soils, and lastly city urban environments. Fresh water has a good dielectric constant but a low conductivity though that depends on ion content. Actually, all of these parameters exhibit ranges so be aware that average values are listed here and real soils usually don't have these *exact* values.

Now, for good DX propagation we'd want the mirroring effect to be very good. The reason for this is that in the theoretical limit we'd have a "Perfectly Conducting Surface" and so the maximum gain would be at 0 degree elevation. This is shown in the following radiation profile with the black double lobes extending to zero degrees. In practical work we can't reach this since we don't have a perfect ground. Rather according to antenna modeling, the best we can do is to make the ground plane as conducting as possible. This is shown with the gray shaded lobes that get close to the x-axis in minimum elevation angle but don't reach the zero elevation angle.



So based on this brief analysis, we have gotten some insight. Number one, it may be better to setup our vertical antenna near the beach in Galveston for example. Now if we happen to be near a fresh water lake, we probably should consider setting up close to that lake. Number two, if we're not close to salt or fresh water, then radials or a wire mesh become more important. Finally number three, the dryer the soil the more important the laying down of radials/wire mesh is.

Vertical antennas are a fascinating topic as we've seen in this brief article. Of course, dipole antennas are good as well though we'd have to place them quite high off the ground which may or may not be practical. Hopefully this brief note has succeeded in piquing your interest and let's not forget that the important thing for us hams is to get out, experiment, make contacts, and have fun!

References:

ARRL Antenna book 18th and 24th editions. Dean Straw N6BV Editor (18th edition). H. Ward Silver N0AX editor (24th edition).

Antenna Theory Analysis and Design 4th edition. Constantine A. Balanis.

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