# Assorted Grounding Hints and Kinks and Technical Correspondence

## What is an RF Ground?

***RF ground*** is a vague term: People claim they know what it is when they see it, but can't define it. Many radio amateurs are easily misled by untruths about RF grounds. What follows is by no means the last word on RF grounding, but should help fill a void in the radio amateur's literature.

In my opinion, an RF ground is something that presents a low impedance at all frequencies of interest on the desired ground surface. ***All frequencies of interest*** usually means just the transmission frequency and all spurii. *Spurii* usually include harmonics, but may include mixing products. **The *ground surface* is the tricky part. *What* do you want to be at ground potential?** Surely you don't expect your microphone to be at ground potential on all frequencies, do you? Think about it: A coiled microphone cord is a bigger radiator than many "rubber duck" antennas! With proper matching, you could probably make a better antenna out of the mic cord shield! In this case, low impedance means "small reactance and resistance." Some radio amateurs just look at the resistive part of the impedance and forget about the reactance, which often is huge!

**The size and *shape* of conductors are very important in evaluating a ground surface.** Take, for example, a tall, thin aluminum structure that is grounded at one end. No matter how well you ground that one end, the structure still radiates and receives RF energy--that's why it's called an antenna. The shape that offers the lowest impedance is a sphere. (The Earth is a pretty good approximation of a sphere.) Size is also important--you wouldn't expect a metal-covered tennis ball to present a low impedance on 160 meters.

Now that we have some idea what a ground should be, the question remains as to how to achieve it. It's pretty ridiculous to have to buy a large metal sphere the size of the Earth just to get a good ground (although it would work well!). The closest practical approximation--a short, thick wire connected to the Earth--works pretty well as long as the wire is much shorter than a *wavelength*. Notice that I said *wavelength*. If you expect your "good RF ground" to eliminate the second harmonic of a 10-meter signal (56 MHz), you need a wire much *shorter* than 8 feet long. (No, four feet is *not* much shorter, and would not work. In fact, a 4-foot "grounding wire" hooked up to the Earth might be a good *radiator* at 56 MHz. *Much shorter* means 2 feet or less in length-at 56 MHz, that is.)

Following this line of reasoning, it may seem impossible to get a good ground at UHF. Actually, you can get a good ground at UHF by using a large metal plate, which is often called a ground plane. A large, flat surface also presents a low impedance at UHF. (Yes, a "flat Earth" would work just as well as a spherical one-at least in terms of grounding-if you were far enough from its edge.) But if you live in a second-floor apartment (as I do), **how do you get a good MF/HF ground?** First, you should determine whether or not a ground is needed. (An ac ground should be considered a necessity for those operating equipment from commercial power lines.) Many antennas, however, such as dipoles and loops, operate just fine without an RF ground.

As for TVI, many amateurs mistake TV fundamental overload as a grounding problem. (It is highly unlikely that TV sets will ever be designed to operate in a strong RF field.) First, install a high-pass filter on the TV set. If the transmitter is indeed radiating energy on a TV channel, try to improve the transmitter shielding, and try an absorptive harmonic filter (See the 1988 ARRL *Handbook, p 40*-9). Grounding will help if the chassis or mic cord of the rig is hot with RF. In this case, a quarter-wave, tuned counterpoise will provide grounding at one frequency (and its harmonics) on a small surface area. Grounding may or may not help situations involving RF feedback. It may be easier to dissipate and isolate the RF from various cords and wires using ferrite beads and toroids. Some people have asked me about measurement techniques for evaluating RF grounds. Well, if you connect a meter between two points that are at the same RF voltage, you may get a nonzero reading anyway! The meter leads can act as a loop antenna that can be expected to pick up RF fields. If you find an easy way around this problem, let me know about it. Zachary Lau, *KH6CP*, ARRL *Lab* Engineer

## Grounding Techniques

The US Army Signal Corps recently reported on the results of improved grounding techniques for mobile field tactical radio stations.[1] These mobile stations are usually installed in trucks, and use vertical antennas. The ground system consists of a cable connected to a copper rod driven several feet into the earth. The typical ground resistance and RF impedance obtained, therefore, are often not optimal.

In order to improve the effective ground, field tests were made employing a number of ground rods mechanically connected in parallel around the mobile radio station. The ground rods were driven into the earth at various depths, and the resultant ground resistance and RF impedance measurements were recorded. Then the tests were repeated with ground rods mechanically connected in series and driven to different depths in the earth.

Analysis of the recorded data and the field radio transmission tests indicated that the use of four *series-connected ground* rods, driven only a foot or two into the earth, provided the most efficient ground system. These improved field-grounding techniques should be applicable to Amateur Radio stations, particularly during Field Day operations. Lt Col A US (ret) *David Talley, W2PF, Suite 1533-S, 10275 Collins Ave, Bal Harbour, FL 33154*

[1] Signal, Mar 1988, pp 79-80.

## Conductivity in the Cold, Cold Ground

*Assistant Technical Editor Steve Ford, WB81MY, said he'd received a query from a reader of the new "The Doctor is IN" column. (Unfortunately, we can't find a trace of that letter to identify who it was that wrote!) The fellow wondered what happens to ground conductivity when the ground is frozen. His antenna is a vertical, equipped with wire radials lying on top of the soil. Steve enlisted the help of Technical Advisor Roy Lewallen, W7EL. Here's Roy's response:*

That's an interesting question. I honestly don't know the answer. But whether the conductivity of the ground changes when frozen probably won't make any significant difference in the operation of a vertical. This is because the ground currents are flowing not just on the surface: They exponentially decay as one gets deeper [into the ground], but a skin depth at HF in most types of grounds is on the order of a meter or two. So, unless the ground freezes to a depth of several feet, even a large change in conductivity wouldn't make much difference. The effect will be further diluted by the fact that the impedance of the radial system is effectively in parallel with the ground resistance.

You've aroused my curiosity, though. I passed the question along to an old friend, Herb Holeman, WL7BIL. Herb works for the State of Alaska and is involved in sitting broadcast stations for the

State Public Radio Network. Since some of their stations are over permafrost, he should be able to find the answer if anyone can.

Herb did reply, and Roy wrote again to say:

Herb recalled some experiments, which were run, and they agree pretty much with the following information, located by a coworker, Linley Gumm:

... Measurements have revealed earth conductivity and permittivity coefficients of relatively small percentages at "normal" temperature ranges while at the freezing point both these constants manifest dramatic variations.

In the book[4] is a table, which shows among other entries--the information presented in Table 1. From the table, it appears that arctic land is about half as conductive as poor ground. When it freezes, water seems to drop in conductivity on the order of 100 times! Not surprisingly, the high dielectric constant of water drops to an earth-like value when it freezes. This moderates the effect of the lowered conductivity, but frozen seawater is equivalent only to poor earth.

"Let me point out, however, that this won't have an appreciable effect at HF unless the ground or water is frozen to a depth of several feet. Roy Lewallen, W7EL, ARRL Technical Advisor, 5470 SW 152nd Ave, Beaverton, OR 97007

[4]P. Saveskie, *Radio Propagation Handbook* (Blue Ridge Summit: TAB Books, 1980).

Table 1

**Comparison of Earth Type with Conductivity and Permittivity**

| *Earth Type* | *Conductivity (S/m)* | *Permittivity* |
|---|---|---|
| Poor | 0.001 | 4.0-5.0 |
| Fresh water | 0.001-0.01 | 80.0-81.0 |
| Sea water | 3.0-5.0 | 80.0-81.0 |
| Polar water | 0.001 | 4.0 |
| Polar ice | 0.000025 | 3.0 |
| Arctic land | 0.0005 | 3.0-5.0 |

## No Ions in the Cold, Cold Ground

I read with great interest Roy Lewallen's discussion of the conductivity of frozen soil and its effect on the performance of ground dependent antennas.[2] The effect of freezing on the electrical properties of soil is actually quite straightforward.

Few superficial soils contain high enough quantities of metallic conductors for this conductivity mechanism to contribute significantly to the soil's overall conductivity. Real soil conductivity is primarily a function of the medium's behavior as an aqueous solution of a dissociated electrolyte. Electric charges are conducted through such solutions by ion migration through the solvent under the influence of an applied electric field, analogous to electron movement through a metallic conductor carrying an electric current. As a result, seawater conductivity is high, owing to the high concentration of sodium chloride, as well as calcium, magnesium and other conductive, ionic salts, whereas fresh-water conductivity is quite low given the very low concentration of diffusible ions. Pure water is largely an insulator, with only about $10^{-7}$ molar concentration of $H^+$ and $OH^-$ ions available to carry current.

Real-world soils owe their conductivity to two major effects: the soil's wetness and its relative content of available ionic salts to function as a conductive electrolyte in solution. Soil conductivity can be poor either because of low concentrations of these salts, or dry conditions where there exist no solvent medium for the transport of the ionic charges, and hence, electric currents.

Freezing represents a special case of functionally "dry" soil since ionic mobility--the ability of the ions to diffuse through the solvent medium--is reduced nearly to zero as the solvent makes the transition from liquid to solid. Further, the solubility of most common ionic salts decreases with falling temperatures--often dramatically when freezing--further reducing the concentration of available charges to carry current. The conductivity values from Saveskie[3] show this effect. Polar water, poor soil, arctic land and fresh water have nearly identical conductivities. Polar ice and frozen arctic land have even lower conductivities, with polar ice (nearly pure, ion-free water) virtually dielectric, as would be expected. Steven *Jones, KQ4WB,* -1101 *Lamorelle Ct, Virginia Beach, VA 23452*

[2] R. Lewallen, "Conductivity in the Cold, Cold Ground," Technical Correspondence, QST, Jun *1993, p 73.*

[3]P. Saveskie, *Radio Propagation Handbook* (Blue Ridge Summit: TAB Books, 1980).

## Is Your Radio Equipment REALLY Grounded?

You may believe your radio equipment, antenna and tower are well grounded. After all, you drove the ground rods into the earth yourself and connected the ground wire to the rods with heavy-duty clamps.

This was my situation. Then I started snooping to locate some new QRN that seemed to be power-line related. I didn't discover the QRN source, but in the process I stumbled across something surprising about my ground connections.

With an ohmmeter, I measured an open circuit from the ground wire to its grounding clamp! This was true for both the equipment ground outside my radio room and for the ground at the base of my beam antenna.

I do understand that contact points oxidize and their resistance increases. But the ohmmeter's needle didn't move even on the instrument's X 1000 range! I had no grounds that worked!

Correcting this situation seemed to be simple: Just solder or weld the ground wire to the ground rod. I did so, but this did not entirely solve the problem. Testing the grounds' resistance now mainly indicated the contact resistance between the ground rod and the earth itself. That resistance was too high. I realized that if the resistance between the wire and the top of the ground rod was high, the resistance between the bottom of the rod is probably high as well.

I installed my ground rods in 1979. They were neither copper nor copper-covered. I replaced them with 8-foot-long, 5/8-inch diameter rods that essentially consisted of 1/2-inch copper pipe with their centers solidly filled by iron rods.

**Fig 1-Overview Of grounding at NB3T. The letters indicate test points for diagnostic use as described in the text.**

Hints and Kinks readers may be interested in how I checked the resistance from rod to earth. Fig 1 shows my setup, an arrangement that is probably quite common. If an ohmmeter is connected across B and C with the GROUND switch open, the indicated resistance is that of the entire closed loop of A to B to C to D and back to A through the earth. The wire part of this complete loop is less than 3 ohms.[1] The earth distance from A to D is about 45 feet. The overall resistance of the complete loop runs between 10 to 15 ohms. I am recording this value periodically to notice any changes due to soil moisture or shifts in conductor resistance. Perhaps you should measure the resistance and effectiveness of your complete ground system! Martin L. *Cardwell, NB3T, Baltimore, Maryland*

[1]If you want to check the resistance of only the wire and cable portion of the complete loop: (1) Run a jumper between A and D. (2) Measure the loop resistance as usual at B and C with the GROUND switch open. (3) Subtract from this the resistance of the jumper wire. The answer provides a resistance test of the wire, cable and connections in the loop.