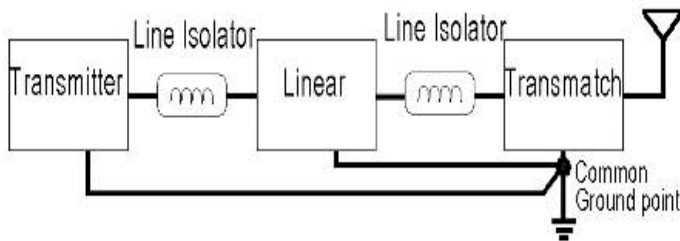


Line Isolators

The RFI Quick Fix™

Multiple ground loops around various pieces of equipment can cause all sorts of problems. But, rather than getting deeper into a technical discussion, let's just try to avoid problems before they cause trouble. Solving the ground loop problem may be as simple as adding Line Isolator™ in series with the interconnecting coaxial cables between station equipment.

The Ground Loop Solution



Suggestions - Single Point Grounding

First, eliminate the heavy copper strap running along the back of the station equipment. Use the transmatch (tuner) as a common ground point, 'Ground Central.' The heavy-gauge wire from your outdoor ground system will connect directly to the 'common ground point' on the back of your transmatch (tuner). Each piece of equipment will then be connected directly to this 'common ground point'. This is 'single point grounding.'

Actually, each piece of equipment is already connected, in a round about way, to the transmatch (tuner) through the various pieces of coax that interconnect station equipment. Of course, it is this "round about way" that contributes to the ground loop problems. We can't eliminate the ground braid on the coax, but we can break up the external ground loops they can cause with Line Isolator™.

LINE ISOLATOR™ The Line Isolator™ installation shown above works well for most stations. When a transmatch (tuner) is not used, it is often very effective to use a second, grounded Line Isolator™ between the Linear and antennas. This grounded Line Isolator is located at ground level and has a built-in strap that connects directly to a ground rod. This greatly enhances the effectiveness of a Line Isolator™ by providing a direct path to ground in combination with the very high isolation inductance.

Customers report that Line Isolator™ inserted in series with the cables interconnecting the transceiver, linear and transmatch (tuner) have eliminated stubborn RFI problems that resisted solutions by any other means.

HOW IT WORKS A Line Isolator™ prevents RF from traveling along the outer surface of a coaxial cable's shield. Any RF current flowing on the coax cable's shield can be radiated or coupled to other equipment. With Line Isolators™ in the circuit, that unwanted RF is forced to ground by the very high impedance of the Line Isolator™. RF current takes the path of least resistance. Of course, the Line Isolator™ does not affect the signal inside the coaxial cable.

As a secondary benefit, a Line Isolator™ installed between your transceiver and linear amplifier helps the transceiver's output filters perform more effectively by breaking secondary leakage paths and forcing the transceiver's output to function properly.

RF GROUND SYSTEMS

The UN-GROUND Ground systems that aren't

General Rules

1. You must have an RF ground system.
2. Any ground run over 8-feet will be ineffective on some bands!
3. Use "single-point" grounding.
4. Never, ever use the ground terminal of an a.c. electrical socket as station ground!
5. Don't use water pipes for grounds.
6. Always install a proper RF ground system using large gauge wire, or preferably, wide copper straps. If 2" or 3" wide copper strap is not practical, use flexible, tinned-braided ground strap between ½" and 2" in width.
7. Do not take your ground system for granted. It is just as important as your antenna.
8. It is impossible to establish an effective RF ground system if your station is on the second floor or higher.

From the telephone calls we receive, many of you are having problems with RF ground systems. RF ground? Yes, most of us have ground systems that provide adequate DC grounding. Unfortunately, a good DC ground system may not be a good RF ground system. In fact, you may have a 'UN-GROUND.'

UN-GROUND? Absolutely. There are situations where your ground system may actually un-ground your station. The reason lies in the fundamental difference between DC and RF circuits.

Impedance Definition

The total opposition (resistance and reactance) a circuit offers to the flow of alternating current. Impedance is measured in ohms. The common symbol is Z.

Reactance Definition

Symbolized by X, it is the opposition to the flow of alternating current. Capacitive reactance (X_C) is the opposition offered by capacitors, and inductive reactance (X_L) is the opposition offered by a coil or other inductance. Both are measured in ohms.

Any wire will have inductance and, therefore, inductive reactance. The longer the wire, the higher the inductive reactance and the higher the opposition to the flow of RF current. The fatter or larger the wire, the lower the opposition to the flow of RF current. The effect is similar to the DC resistance of a wire. The longer the wire, the higher the DC resistance will be.

The fatter the wire the lower the DC resistance for the same length wire. There is an important 'however,' that we must consider. When the X_L (inductive reactance) is measured along the length of a wire, the magnitude of X_L (the opposition to RF current flow) varies from very low to very high values. It continues to alternate between low and high values in cycles that have a direct relationship between the length of wire and the frequency of the applied RF energy. DC resistance, on the other hand, has no cycle. It simply increases linearly with the length of the wire.

When measuring X_L , its value is very high when the length of the wire is around one-quarter wavelength long. Increasing the length wire to one-half wavelength, returns X_L to a low value.

The length of the wire does not have to be very long for this effect to be observed. For example, at 28 MHz **an 8' ground wire** (or any wire for that matter) is approximately one-quarter wavelength long. If this 8 foot long ground wire connects your 10 meter rig to your ground system, the ground wire may actually prevent RF from traveling to ground. This is an **UN-GROUND!**

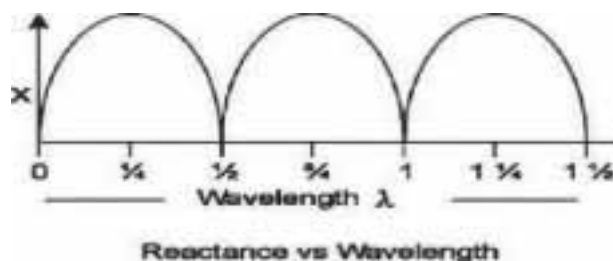


Figure 1

Why? As illustrated above, the inductive reactance of wire that is one-quarter wavelength long is very high and impedes RF current flow (thus the term - impedance).

On other bands, where the length of the wire is not an odd multiple of a quarter wavelength long, the inductive reactance (X_L) is at some intermediate or low value.

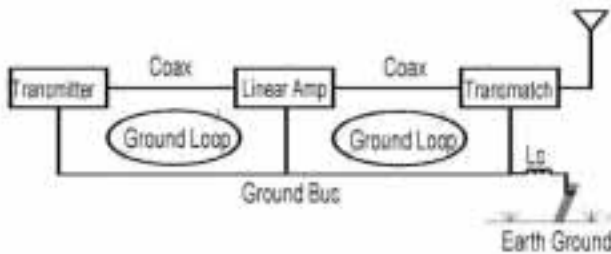
High RF Voltage

Figure 2 shows a grounding diagram of a typical ham station. There is a heavy ground strap running along the back of the equipment. The ground strap eventually reaches the earth ground system, a ground rod, through a heavy gauge copper wire 11 feet in length. The ground connection for each piece of equipment goes directly to the heavy ground strap that runs behind the station equipment. **The antenna is a ladder-line fed, 80 meter dipole** used on all bands. The ladder line is brought directly into the operating position where it connects to the balanced output of the transmatch.

The ladder line is about 60 feet long and goes directly to the antenna but passes very close to a metal rain gutter. Such a station should be effective and trouble free. Unfortunately, this station is experiencing problems on the higher HF bands. There is RF feedback distorting the transmitted signal, and there are some TVI and RFI problems. What could be wrong?

If we tune up on 20 meters, the 80 meter dipole becomes a center-fed, two wavelength antenna. **The feedpoint impedance is around 4500 ohms.** The length of the ladder line feeding the antenna is about one wavelength long. It is a characteristic of a transmission line that it will duplicate its load impedance every half-wave along its length. So, the very high antenna feedpoint impedance appears right at the transmatch's output terminals. However, before reaching the transmatch, the ladder line runs very close to a metal rain gutter. Feedline balance is upset, and it begins to radiate at that point.

The transmatch uses a voltage-type balun to create a balanced output. Baluns do not work well in high impedance circuits, and **voltage-type baluns are especially bad in this application.** With a high impedance load, the voltage balun's core will saturate even at moderate power levels. Output balance is poor. This contributes to additional radiation from the balanced



In this illustration, we have several problems, each compounding the other. First, all of the ground system and ground loop problems still exist, but we now have a transmatch balun that is saturating and generating high level harmonics. Signal distortion may be noticeable because the balun is no longer operating in its linear region. The ladder-line is not balanced so it radiates, and the equipment at the operating position becomes part of the antenna system. Here is a real shocker! There is RF all over the equipment. The Microphone is biting your lips. Your computer crashed. The packet TNC will not talk to you anymore, but none of this matters because the station power supply shut itself down and you are off the air. Sound impossible? Unfortunately, it's not. This is a true story and this isn't the end.

The ground wire is about 11 feet long. On 15 meters, this length is almost exactly 1/4 wavelength. One end is at low impedance, (i.e. earth ground) so the other end of the ground wire presents a high impedance to the circuit connected to it. In other words, the ground wire is near zero impedance at the ground end, but due to the impedance inverting characteristic, the station equipment 'sees' a very high impedance at the equipment end of the ground wire. In effect, the equipment is UNGROUNDED at high RF frequencies. Refer to figure 1.

On 20 meters, the 11 foot ground wire is .15 wavelengths long. Referring to figure 1 and interpolating between zero and 1/4 wavelength, the inductive reactance of the ground wire is still quite high. To our station equipment, the **ground wire simulates an inductive reactance in series with the resistance of the ground wire.** This is illustrated by the coil L_g in figure 2. We'll disregard the DC resistance of the ground wire.

Without getting into great detail, let's just agree that it would be better if the station had a direct, low impedance path to ground. In this illustration, this is not the case. **The path to ground is a high impedance on the higher frequency bands.** In fact, there are alternate grounds available to the station equipment. Other, undesirable, ground paths may present a lower impedance path to earth or may act as a counterpoise. Unfortunately, one of those ground systems is the electrical power lines at the operating position. RF from the transmitter, seeking a ground path, may have to pass by or through several electronic appliances (TVs, VCRs, etc.) that would work better if they were isolated from your transmitting equipment.

Due to the inductive reactance of the ground system, none of the equipment in this station is effectively grounded on the higher HF bands. If an RF potential exists on the station ground system, **the entire station may 'float' up** to that RF potential. Thus, the earth ground reference is actually several volts above ground. All sorts of RFI problems can be the result, including RF feedback into station microphones, computers, TNCs, power supplies, etc.

Solid state equipment is especially sensitive to ground problems

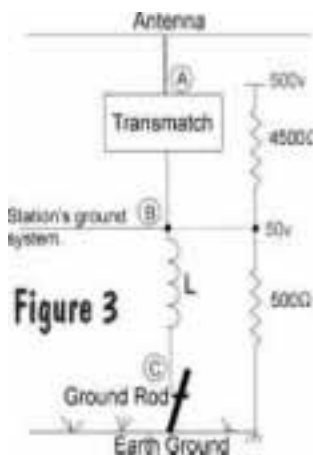
Solid state equipment is especially sensitive to ground problems. Each piece of equipment in figure 2 is interconnected by two ground paths, a ground strap and the coaxial cable that interconnects the equipment. The two paths form a ground loop, as shown in figure 1. Since there is high system gain involved from the millivolts of the transceiver's input circuits to the kilovolts of the linear's output circuit, ground loops can be a serious problem. It's even worse if the ground system is ineffective and the entire station is 'floating' above ground. Breaking the ground loops can lead to the solution to long unsolved RFI problems.

The RADIO WORKS' Line Isolators™ are very effective at solving ground loop problems.

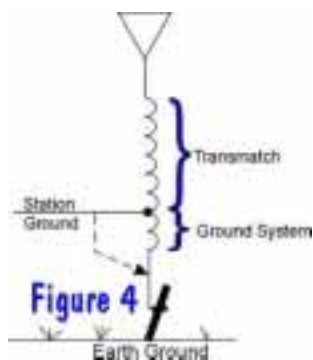
The Shocking Truth

Have you ever calculated what the voltage across a 4500 ohm reactive load is at 1.5 KW? It is more than a few volts. Actually, it's a few thousand volts. It's unbalanced, and it's looking for somewhere to go. As we predicted in previous paragraphs, the antenna feedpoint impedance and corresponding high RF voltage is transferred directly across the output terminals of the transmatch. **Several thousand volts of RF** is only a few feet away and at RF, the station is poorly grounded.

I'm not going to bore you with a lot of math, but let's simplify this situation to a simple series circuit. In figure 2, the antenna, transmatch, and ground system are represented by a simple voltage divider. This simple circuit will allow me to illustrate what is happening to the ground bus in the ham shack.



Reducing the problem to its simplest terms, we have a 4500 ohm resistor in series with a 500 ohm resistor. The ground system is the tap between the two. In this example, if there are 500 volts at the transmatch, the station ground system will 'float' above earth ground. The potential is about 50 volts. Your ground system and all your equipment, in effect, have 50 volts of RF applied to the equipment grounds. **This is just like having a 50 volt input signal** if the input circuits were at ground potential.



keep RF off the station equipment and station ground is to move the point where the rig is tapped into the coil closer to ground.

First, let's assume the voltage at point 'A' on the transmatch is 500 volts. It is really much higher. The impedance at the output terminals of the transmatch is 4500 ohms, and the reactance of the ground system is 500 ohms. I did not calculate the value for the ground system, the 500 ohm value is for illustration.

Another way to look at this problem is to visualize the antenna and ground system as a big coil that represent the inductive reactance of the ground system and transmatch. The antenna is at one end of the coil and the ground is at the other. We are tapped several turns up the coil. The higher the impedance of the ground system, the higher up the coil the 'tap' is located. The only way to

Of course, it's never this simple. My numbers are only representative, but they do serve as an illustration. **The RF voltage on the station ground system does reach very high levels** under some circumstances. I have had hams tell me of severe RF burns and visible 'arcing' from microphones, equipment chassis, ground busses. Obviously, at these levels of RF voltage, there will be terrible problems. But, what happens when the RF voltage on the ground system is only a few volts? You may not know that RF energy is there, causing RFI or other problems.

An Effective Station Ground

The station ground must provide both effective DC and RF grounding. Creating a good DC ground is not a problem, but an effective RF ground must be carefully planned.

GROUND SYSTEMS

The ground system should generally follow these suggestions:

1. The ground wire should be as short as possible, preferably much shorter than a quarter-wavelength long on the highest frequency band operated.
2. The ground wire should be very large. I sometimes use the braid removed from a piece of RG-213. Better yet, use one or more lengths of 1/2" or 1" tinned braided copper strap.
3. Clamp this short, heavy ground wire to your ground rod(s) or radial system. Better yet, use one or more lengths of 1/2" or 1" tinned braided strap. 2" solid strap is even better.
4. Use several different lengths of ground wires in parallel, each connected to a separate ground rod. This provides multiple, parallel ground paths.

SIMPLE - a single ground rod driven into the earth just outside the ham shack.

INTERMEDIATE - Several ground rods, connected in parallel with very heavy wire, solid copper strap or braided strap.

ELABORATE, and very effective - 25 short (6-12") ground rods spaced approximately 4' apart and interconnected in series by a 100' length of heavy braided or solid strap. This system is very efficient. The original design used stainless-steel pegs for ground rods and stainless steel wire to prevent efficiency reducing corrosion. Copper will loose it effectiveness with time. Regular ground system maintenance is necessary.

What appears on these three pages is only part of an article that has appeared in several of my publications. You can read the entire article by going to my web site at www.radioworks.com and looking in "Jim's Notebook" under "Ground System Problems and Solutions"

A note from Doug DeMaw, W1FB

You saw Doug DeMaw's columns in the pages of Ham publications for many years.

"Speaking of the 4KRF-LI and T-3 (both now replaced by the even more effective T-4), Doug writes "have just now had the opportunity to test the products in my system (as isolators between the Transmatch and the remainder of the station). Both units work beautifully. There was no SWR change from my homemade, ferrite-loaded isolator choke, and no evidence of heating existed at maximum legal amateur power!"

..... "One of the applications I want to mention in the review is that of isolating solid-state transceivers from the currents that flow on the outer conductor of coax when operating from RVs at fixed locations. My Kenwood TS-140S and TS-450S go bananas at power levels above 50 watts when I try to operate from my camp trailer without an earth ground. The Terminator-3 (now T-4) cures the problem, and RF energy does not disrupt the functions of the transceiver. Of course the units will be recommended also for isolators at the feed points of Tribanders, etc."

Used with permission



Jim's Shack



Here I am in my main shack at operating position #1. This is the high tech station that uses all of the recommended ergonomic, AF and RF isolation and grounding techniques I've suggested in my various publications. All audio systems are on the left side of this layout, and all RF on the right side. The only RF cables in this arrangement are the output coax from the rigs. All RF switching is done remotely at "ground-central," located just under the PW-1 amplifier (which is located behind the console. Only the remote control head is on the console.). All audio lines are isolated with ferrite cores. All RF lines have Line Isolators. Single-point grounding is used with "ground-central" at the PW-1 linear. This is a second floor installation, and RF feedback has been a problem in the past. With this installation, all of those problems are absent.

This station features an ICOM IC-7800 with PW-1 linear., FT-100D (VHF & UHF), and remote switching of antennas and routing of RF to three other operating positions. Also, shown in these photos are two 15" LCD monitors driven from a single Dell 2.6 GHz P4 computer. A special video card is used to drive the dual monitors which permits a very flexible display. Sounds Sweet™ speakers take advantage of the separate outputs from the two receivers in the 7800. I must say that the audio from this rig sounds great. A W2IHY noise gate and equalizer sweetens the transmitter audio. There is also a Kenwood SM-220 monitor to keep the PW-1 clean, and it always is. It's a nice amp. The tuner for all the RADIO WORKS' antennas is the internal tuner in the PW-1. The keyboard and mouse are RF-linked to avoid cables. This operating position was built to demonstrate both station ergonomics and RF isolation techniques. Full details with many photographs will be on my web site.