Grounding is key to good reception

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Modified for marine applications by John Gregory, D.Sc.

***What's ground? If I connect** the shield of my coax (which is grounded outside) to the antenna input of my Radio receiver, I hear lots of junk, indicating that there is an RF voltage difference between the coax shield and the Radio receiver chassis.*

The other day this measured about Signal strength of 5.5 on the meter of the receiver, which is about -93 dBm (preamp off, 6KHz bandwidth). That's a lot of noise: it was 18 dB above my antenna's "noise floor", and 26 dB above the receiver's noise floor.

This sort of disagreement about ground potential is characteristic of electrically noisy environments. The receiver will, of course, respond to any voltage input that differs from its chassis ground. (Important issue)

The antenna, on the other hand, is in a very different environment, and will have its own idea of what ground potential is. If you want to avoid noise pickup, you need to deliver a signal, referenced at the antenna to whatever its ground potential is, in such a way that when it arrives at the receiver, the reference potential is now the receiver's chassis potential.

***Coaxial cable** represents one way to do this. Coax has two key properties:*

1. The voltage between the inner conductor and the shield depends only on the state of the electromagnetic field within the shield.

2. The shield prevents the external electromagnetic field from influencing the internal electromagnetic field (but watch out at the ends of the cable!).

So, it's easy, right? Run coax from the antenna to the receiver. Ground (shorting) at the antenna end will be whatever the antenna thinks it is, while ground at the receiver end will be whatever the receiver thinks it is. The antenna will produce the appropriate voltage difference at the input side, and the receiver will see that voltage difference uncontaminated by external fields, according to the properties given above.

***Unfortunately, it doesn't** quite work that way. It's all true as far as it goes, but it neglects the fact that the coax can also guide noise from your vessel to your antenna, where it can couple back into the cable and into your receiver. To see how this works, let me first describe how this noise gets around.*

The noise I'm talking about here is more properly called "broadband electromagnetic interference" (EMI). It's made by computers, lamp dimmers, televisions, motors,Inverters of some manufactures type, and certain digital display devices, and other modern gadgets. In many cases, I can't get them turned off, because it would provoke intrafamilal rebellion.

However, even when I turn them off, the noise in the vessel doesn't go down very much, because my neighboring vessels while close by all have them too. In any case, one of the worst offenders is my computer, inverter,which is such a handy radio companion I'm not about to turn it off.

Some of this noise is radiated, but the more troublesome component of this is conducted noise that follows rifer (refrigeration), inverter, and battery chargers,in the grounding wires.

Any sort of cable supports a "common mode" of electromagnetic energy transport in which all of the conductors in the cable are at the some potential, but that potential differs from the potential of other nearby conductors ("ground"). The noise sources of concern generate common mode waves on power, telephone, and CATV cables which then distribute these waves around your marina. They also generate "differential" mode waves, but simple filters can block these so they aren't normally a problem.

***So, let's say** you have a longwire antenna (back Stay) attached to a coaxial cable through an MLB ("Magnetic Longwire Balun" [sick]). Suppose your next door neighbor turns on a dimmer switch or any electrical component.*

The resulting RF interference travels out his grounding and positive power lines on the dock box, in couples through yours, through your receiver's power cord to its chassis, and out your coaxial cable to your MLB. Now on coax, a common mode wave is associated with a current on the shield only, while the mode we want the signal to be in, the "differential" mode, has equal but opposite currents flowing on shield and inner conductor. The MLB works by coupling energy from a current flowing between the antenna wire and the coax shield into into the differential mode. But wait a second: the current from the antenna flows on the coax shield just like the common mode current does.

Does this mean that the antenna mode is contaminated with the noise from your neighbor's dimmer?
The answer is a resounding, and unpleasant, yes! The way wire receiving antennas work is by first moving energy from free space into a common mode moving along the antenna wire, and then picking some of that off and coupling it into a mode on the feedline. In this case, the common mode current moving along the antenna wire flows into the common mode of the coax, and vice versa. The coax is not just feed-line: it's an intimate part of the antenna! Furthermore, as we've seen, it's connected back through your electrical wiring to your neighbor's dimmer switch. You have a circuitous but electrically direct connection to this infernal noise source. No wonder it's such a nuisance!

***The solution is** to somehow isolate the antenna from the common mode currents on the feed-line. One common way to do this is with a balanced "dipole" antenna. Instead of connecting the feed-line to the wire at the end, connect it to the middle. Now the antenna current can flow from one side of the antenna to the other, without having to involve the coax shield. Unfortunately, removing the necessity of having the coax be part of the antenna doesn't automatically isolate it: a coax-fed dipole is often only slightly quieter than an end-fed longwire. A "balun", a device which blocks common mode currents from the feedline, is often employed. This can improve the situation considerably. Note that this is not the same device as the miscalled "Magnetic Longwire Balun".*

Another way *is to ground the coaxial shield, "short circuiting" the common mode. Antenna currents flow into such a ground freely, in principle not interacting with noise currents. The best ground for such a purpose will be a earth ground (sea water grounding plate) near the antenna and away from other noise making devices.(Rope Antenna ground shoe).*

Unfortunately, *none of these methods is generally adequate by itself in the toughest cases. Baluns are not perfectly effective at blocking common mode currents. Even the best balun can be partially defeated if there's any other unsymmetrical coupling between the antenna and feedline. Such coupling can occur if the feedline doesn't come away from the antenna at a right angle. Grounds are not perfect either. Cable burial generally lets some energy leak through. A combination of methods is usually required, both encouraging the common mode currents to take harmless paths (grounding) and blocking them from the harmful paths (baluns and/or burial).*

The required isolation to reach the true reception potential of the vessel can be large. According to the measurements I quoted above, for my vessel the antenna noise floor is 18 dB below the conducted noise level at 10 MHz. 18 dB of isolation would thus make the levels equal, but we want to do better than that: we want the pickup of common mode EMI to be insignificant, at least 5 dB down from the antenna's floor. In many locations the situation gets worse at higher frequencies as the natural noise level drops and therefore I become more sensitive: even 30 dB of isolation isn't enough to completely silence the common mode noise (but 36 dB is enough, except at my computer's CPU clock frequency of 25 MHz).

Getting rid of *the conducted noise can make a huge difference in the number and kinds of stations you can pick up: the 18 dB difference between the conducted and natural noise levels in the case above corresponds to the power difference between a 300 kW major world broadcaster and a modest 5 kW regional station.*
The method I use is to ground the cable shield at two ground plates or connecting two thru holes and isolating from the vessel DC grounding system. Rope Antenna has two such devices, DC Block for the antenna tuner and other other DC Blocker that isolates the ground loop and reduces the noise at the receiver.
The scheme of alternating blocking methods with grounds will generally be the most effective. The ground sea plate on the outside bottom of the vessel provides a place for the common mode noise current to go, far from the antenna where it cannot couple significantly. The ground plate at the base of my Rope Antenna provides a place for the antenna current to flow, at a true ground potential relative to the antenna potential.

I'm no expert on *electrical codes, and codes differ in different countries. However, I believe that any such requirement must refer only to grounds used for safety in an electric power distribution system: I do not believe this applies to RF grounds.*

Remember that proper grounding practice for electrical wiring has very little to do with RF grounding. The purpose of an electrical ground is to be at a safe potential (a few volts) relative to non-electrical grounded objects like plumbing. At an operating frequency of 50/60 Hz, it needs to have a low enough impedance (a fraction of an ohm) that in case of a short circuit a fuse or breaker will blow immediately.

*At RF such low impedance s are essentially impossible: even a few centimeters of thick wire is likely to exhibit an inductive impedance in the ohm range at 10 MHz (depends sensitively on the locations and connections of nearby conductors). Actual ground connections to real soil may exhibit resistive impedances in the tens of ohms. Despite this, a quiet RF ground needs to be within a fraction of a microvolt of the potential of the salt or fresh water.
This is difficult, and that's why a single ground is often not enough.*

***Yes, you have a** "ground loop". It's harmless. In case of a nearby lightning strike it may actually save your receiver. My R718 and Icom 802, isn't grounded like that, so I had to take steps to prevent the coax ground potential from getting wildly out of kilter with the line potential and arcing through the power supply. I'm using a surge suppressor designed to protect my TNC and computer equipment: it has both AC outlets and feedthroughs with varistor or gas tube clamps to keep the various relative voltages in check. Of course the best lightning protection is to disconnect the receiver, but I'm a bit absent minded so I need a backup.*

Just as a reminder, That with the Rope Antenna, there is a dis-connect at deck level, so that when leaving your vessel, you only need to detach your antenna and protect your tuner and radio.

All of the above measurements were conducted with a spectrum analyzer, grid dip meter, HP signal generator with tracking. Digital volt meter, RF field strength meter,

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In the past. Old rumors, and Elisa's law.

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