RF Interference

Solving RF Interference Problems

Radio transmitters have a great fondness for causing interference. This is not surprising, since their primary job is to pump 100 watts or more of radio energy into the sky. Ideally all of this energy would be sent off towards the distant receiver, but this is not the case. Antennas, particularly small ones, radiate in all directions, and worse yet, any imbalance in the antenna system causes the coax cable, power wires, and every other interconnection to becme part of the antenna system and radiate also. In the days before digital communications this was a nuisance at worse, but when modems and computers get interconnected with transmitters and radios the potential for chaos is great. This is especially problematic for small installations such as boats and RV's where the antenna and ground system literally wrap around the radio and other components.

With respect to HF email, there are two primary symptoms that can be traced to wayward RF energy: distortion of the transmitted audio signal, and data errors between the computer and modem. The distortion problem is subtle because you will rarely hear it yourself. But if your transmitted signal gets back into the audio connection between the modem and transmitter, then it can be rectified and produce its own audio signal, which will be transmitted and produce more interference, etc.. It is very much like the "howl" that emits from a public-address system when the gain is turned up too high, noise feeding upon itself.

Data errors can occur in the modem's serial-port connection. These will usually be detected by the error checking associated with binary modes but it will not be at all obvious that RF is to blame. And if ASCII mode is used then the errors may simply be missed. Errors can happen either sending or receiving messages. If sending, then errors are likely at the beginning of the message transmission, as the computer is busy sending data to the controller's buffer memory at the same time that the controller is sending the beginning of the message over the radio. When receiving a message, the incoming data is usually being transferred to the computer at the same time that the controller is transmitting the "Ack" (Acknowledge) burst back to the sending station. In either case there are serial data transfers happening at the same time that the radio is transmitting digital data.

If an ASCII transmission is in progress then the usual symptom is that characters are lost from the message. Given the general lack of attention paid to spelling these days, such errors usually go unnoticed. If a binary transfer is in progress then a format or checksum error generally occurs because the binary protocol includes error checking. If an error is detected then an error message is sent and a disconnect occurs. Errors of this type are almost always related to RF interference related to ground system problems.

Airmail logs incoming serial-port errors in its Logfile.txt file, located in the c:\program files\airmail\ folder. Open this file and look for something resembling "comm: Error reported to input: 2", this indicates a framing error detected by airmail's serial-input driver. This may also correlate to a disconnect due to a binary format or checksum error. Note that errors in outgoing data would be detected by the controller and not by Airmail, and usually result in lost characters with no other indication of trouble. For the PTC-II controller, Airmail now uses CRC-Host mode which was developed for precisely this reason and which detects and corrects serial-port data errors. (There will be a "retry" entry in Airmail's log file).

Ground systems:

The usual marine antenna/ground system consists of an automatic tuner at the base of the backstay or stern-mounted vertical antenna, a grounding strap from the tuner to a ground system, and a coax cable to the transceiver which itself is usually grounded. Ideally all of the antenna current flows between the antenna wire and the seawater ground system through the tuner, and with a perfect ground system at the tuner then that is what would happen (see Fig. 1).

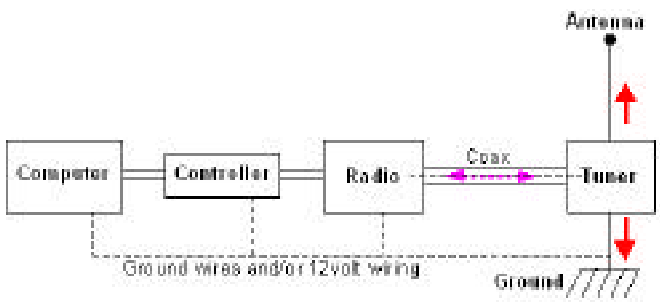

Fig. 1: This shows the ideal path of the radio signal to the antenna and ground. All of the antenna current flows between the antenna and the primary ground connection, there is no ground current on the coax shield or through the secondary ground wires.

But grounds are never perfect, and even a ground connected to a large external metal keel has a ground strap of some length which can develop some resistance (impedance) at certain frequencies. If there were no other path then the impedance of the ground system wouldn't matter, but the radio itself is always grounded, either directly or via the DC power wiring, and the nice fat shield on the coax cable provides a good ground conductor. Note that the transmitted signal is balanced between the inner conductor and shield, this can be considered "inside" the coax caable and will not radiate. The stray ground path is on the shield alone, an unbalanced current, and will radiate. This is called a ground loop (see Fig. 2). Other loops are formed by the cables that connect the controller and computer, and their 12V power connections (which themselves are always grounded somewhere).

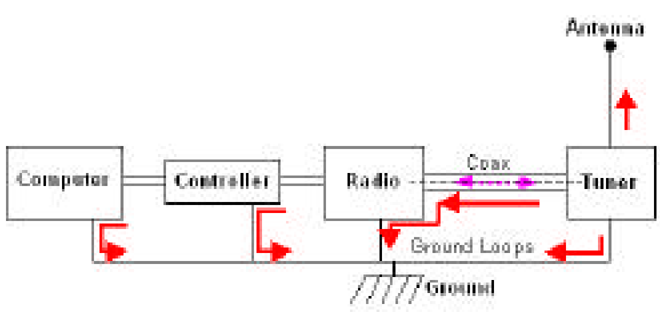

Fig 2: This shows a more realistic scenario. There are additional ground paths via the coax shield to the radio and other equipment, as well as via secondary ground paths. Antenna ground currents follow (and radiate from) all of these available paths.

These ground loops have impedance just like any other wire, and DC wiring in particular makes a pretty poor ground conductor. RF antenna currents using these ground loops as alternative ground paths will radiate interference signals into other cables (just like an antenna) as well as by simple voltage drops due to the impedance of the ground loops themselves. These interference signals will raise havoc with everything.

It would seem attractive to simply beef up the ground system, i.e. reduce its impedance and make that path more attractive. This will certainly help and is a good first step, but it is equally important to make the unwanted paths less attractive.

The solution:

Changing frequencies will typically change the problem, making it better or worse depending on how the impedance of the various ground paths change with frequency. Reducing the output power will always reduce the interference, and is a definitive test to verify that the problem is RF-related (as long as there is enough power to maintain a good link). A permanent solution has three parts:

- Make the primary ground system as good as possible;
- Make the tuner-to-radio-to-ground path via the coax shield less attractive by using a ferrite "line isolator" add impedance to that loop;
- and break up any additional ground loops between radio, controller and computer with clip-on ferrite chokes.

Task 1.

The first task is a careful review of the ground system connected to the tuner. The backstay or vertical antenna is only half of the antenna system, the other half being the ground system. Different frequencies will "see" the ground differently, so what works on one frequency band may not work well on another. Higher frequency signals (21-28 MHz) have a shorter wavelength and need a few square meters (tens of square feet) of metal surface located close to the tuner. Because the square-footage requirement is lower, a direct seawater connection is less important. Lower frequencies (7 to 10 MHz) have a longer wavelength and need more square footage of ground plane than can easily be provided, so a good seawater connection is required. This requires a few square feet of seawater contact but does not need to be as close as it would in order to be effective at high frequencies.

So the ideal ground system is a combination of a ground plane laid against the hull near the tuner, plus a connection to the engine, metal tanks, and any other large metal, and a connection to an external keel or other large underwater metal. These should all be interconnected with a network of 3-4" copper strap which will have a low impedance at all frequencies.

Consider electrolysis when connecting external metal parts (such as a through-hull or prop strut) to the ground system. You will never create a new problem by connecting underwater metal that are already connected to the green-wire DC bonding system, but connecting metal that was previously isolated can create a new electrolysis problem. If in doubt then provide a DC block. Stan Honey's method is simple and effective: cut a quarter-inch gap in the copper foil, and bridge that gap with a dozen ceramic disc capacitors (.01uF line-bypass caps would be a suitable choice). This blocks DC electrolysis currents while providing a low-impedance RF path for antenna currents.

Henry VE0ME, a Canadian ham of some considerable experience, favors an separate antenna ground with no connection to the rest of a vessel's ground system. In other words, run a ground strap from the tuner ground to a large underwater plate (such as the largest-sized Dynaplate), but do not connect this plate to the rest of the ship's ground system. Splitting the ground system this way would break up the major ground loop shown in fig. 2. The key to making this method work is providing a large enough ground plate for the isolated tuner ground, the smaller Dynaplates are not adequate. The disadvantages are those associated with grounding plates in general, drag unless the plate is set flush, and concerns about electrolysis.

For more information on grounding and electrolysis, see Stan Honey's excellent article in *Practical Sailor* , October 15, 1996 issue.

Task 2.

After we've done what we can with the ground, the second job is to make the alternative ground paths less attractive to the antenna currents. That is done by adding RF impedance to the coax, in the form of a Line Isolator (a large ferrite choke) or multiple clip-on ferrites. This adds impedance to unbalanced common-mode currents such as the ground currents using the shield as an RF path. The transmitter output to the tuner is a balanced signal, i.e. there are equal and opposite currents flowing in the shield and inner conductor). The net current from a balanced signal through the ferrite is zero, so there is no attenuation at all, i.e. zero impedance. But antenna currents using the shield as a ground path flow in one direction only and see the ferrite as an impedance (see Fig 3).

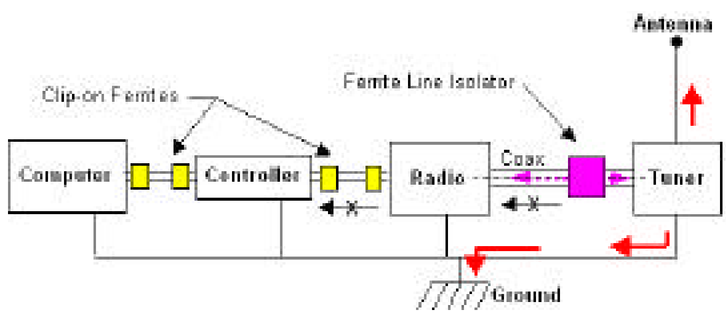

Fig 3: This is the same configuration as above with ferrite chokes added to block the alternative ground paths. Differential signal currents in the coax are not effected by the ferrite, but common-mode ground currents are blocked.

A typical line isolator is about 20 turns of RG-8X around a ferrite rod inside a plastic housing with a female coax connector on each end. Our favorite is the Radio Works model T-4 (ungrounded), about $30 from Radio Works (http://www.radioworks.com/ which also has a good discussion of grounding techniques), or also available for a few extra dollars from Farallon Electronics (gofarallon@aol.com) or HF Radio in Alameda (Don@hfradio.com). You will also need a male-male coax jumper to connect the line isolator to the tuner, as the line isolator comes with two female connectors. Clip-on ferrites will do the same job, but it would take a dozen or more to have the same effectiveness.

The best place to locate a line isolator is close to the tuner itself. In terms of ground currents it doesn't matter where it is located, but if the coax is long then it will still be able to radiate some signal if the line isolator is located at the radio end of the coax.

In addition to the line isolator on the tuner coax, one or more clip-on ferrites should also be added to the tuner control wires. These control signals are usually grounded to the tuner ground, and provide an alternative ground path if not blocked. An alternative to multiple ferrites is to use the large size and loop the wire through it a few times.

Adding a line isolator (and ferrites to the tuner control cable) should stop most of the ground currents from taking the detour through the "radio shack", but will not substitute for an adequate ground system. And of course never add any sort of ferrite choke to the ground connection itself. Many users have also reported that adding a line isolator also cleans up other problems such as autopilot interference, but that will depend on how the other equipment is configured.

Task 3.

Providing a good tuner ground and isolating the alternative coax path are the most important tasks, but while we are cleaning things up we should also break up the ground loops between the radio, controller and computer.

Isolating the ground loops is again done by adding common-mode impedance, in this case in the form of clip-on ferrites (see Fig 3 again). These are small split ferrite cylinders, about 3/4" in diameter, 1-1/4" long, with a 1/4" hole through the middle for a cable. Clip-on ferrites are sold by Radio Shack, but better ones are made by Fair-Rite, their part number for type-43 material in a 1/4" hole size is P/N 04-43-164-251 and available from Newark Electronics (http://www.newark.com/). Fair-Rite's type-31 material performs a little better at HF radio frequencies, their part number is 04-31-164-281 for the 1/4" hole size, and 04-31-164-181 for the 1/2" hole size. The type-31 parts are not sold by Newark but are available with a $50 minimum from Amidon and stocked by many dealers.

Use one ferrite to each end of the computer-to-controller cable, and one at each end of the controller-to-radio cable. And don't forget the tuner cable as noted above. The signals inside the cable will not be effected, only the ground currents trying to use the cable shield as an "sneak" path.

Important: The ferrite halves must meet perfectly in order to be effective. If in doubt, remove the ferrite halves from their plastic housing and secure with tape and/or tie-wraps.

And also make sure that the cables are properly shielded, with the shield connected to the connector shell (and equipment chassis) at both ends. This can be verified with an ohmmeter, and if the metal shells of the DIN or DB-style rectangular connector at each end are connected, then the shield is terminated correctly.

Metal boats:

Steel or aluminum boats don't have a problem with the ground system, but aluminum boats in particular usually have isolated 12V neutral wiring to protect against electrolysis and are subject to significant interference problems. In some cases the problem seems to be much worse than with a fiberglass or wood boat, probably because any stray RF energy is trapped inside a shielded box (the hull), analogous to the proverbial "fox in the henhouse".

The steps outlined above should be equally effective with metal boats. The line isolator in particular should eliminate the stray RF at the source and would be the logical first step. If additional help is needed, the 12V negative connections to the computer, controller and radio can be RF-grounded using capacitors to provide a RF ground with DC blocking. Also provide a similar capacitively-coupled RF ground for the radio chassis. Ceramic-disc capacitors are a good choice for this duty, and a dozen 0.01 line-voltage type capacitors wired in parallel will provide an inexpensive and low-impedance path for HF frequencies.