

Demystifying Electromagnetic and Radio Frequency Interference

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Electrical interference can take on several forms, including electromagnetic or EMI, and radio frequency, or RFI. In the latter case, placement and the interrelationship of antennas plays an important role.

On more than one occasion I've responded to complaints that start with the observation "when I key the microphone the boat makes a hard turn to port/starboard" or "there are wavy lines on my TV screen". It's a phenomenon I've encountered on a number of occasions during my marine industry career. The causes are simple and easily understood, while the solutions can be maddeningly elusive. The side effects can be everything from static or distortion on an otherwise high quality television screen to humming or buzzing on a VHF radio and in some cases malfunctions in autopilot control systems, some of which may be dramatic, to name just a few. In one case, aboard a boat whose construction I was involved with, the windshield wipers activated themselves each time the windlass was used. After some investigation, and ruling out any inadvertent crossconnection between switches, it was determined that the control cable for the wiper's electronic membrane keypad was run alongside high current carrying cables used to supply the windlass. Separating these wires and having them cross each other only at a right angle where it was necessary resolved the problem.

A few years ago I attended a seminar on the subject of advanced

electrical and electronic troubleshooting, one of the sub-topics of which was indentifying and resolving electromagnetic and radio frequency interference, otherwise known as EMI and RFI respectively. The fact that this subject represented a major portion of the presentation, and generated the most questions from the audience, is telling indeed. Distilled into a single phrase, cruising vessels have become significantly more complex, especially electrically and electronically, in the two and a half decades I've worked in the industry.



Paralleling disparate cables, a practice that is difficult to avoid on many vessels, can exacerbate interference issues.

Unfortunately, the industry itself, while becoming adept at selling and installing the gear, hasn't kept pace with prevention, mitigation or resolution of EM and RF interference issues. Not long ago I received an e mail from a reader, referencing a recent column on the subject of high output charging systems and their associated wiring, which exemplified the interference issue. In part, it reads;



Top: Paint is an insulator, which makes installation of electrical terminals over painted surfaces undesirable. Bonding terminals should always be installed over clean, paint-free surfaces. Using a conductant paste and then coating the completed installation with corrosion inhibitor further improves conductivity and reliability.

Bottom: Radio frequency energy travels on the surface of cables, which is why copper foil is often used instead of wires. A conventional cable has been attached to this SSB

antenna tuner ground stud, significantly reducing its effectiveness.

2. We had a problem with the CruiseCommand (ZF Marine) on our Nordic Tug 37 recently. Both ZF Marine and Cummins pointed to the Balmar Alternator as being a source of electromagnetic interference and the source of the problem. It was determined that there was a problem with the CruiseCommand unit and a replacement board was exchanged. However, we did find that the case of the CruiseCommand was not bonded. Balmar also suggested adding "drains" to the positive alternator output as well as spiraling the ground wire for the MC-612 harness to affect a drain for it, as well. I point this out, because this may be a concern for others as well.

To this, I responded:

Thanks for your note and comments regarding high output charging systems. Indeed, you are correct, if a shunt-style ampere or amp-hour meter is used, all negative cables, both house supply and charging, regardless of charge source, must be attached to the side of the shunt that is not connected to the battery. This is a common protocol and one that's well understood by experienced marine electricians. I'm a strong advocate of including negative output cables in high output alternator installations as well as wiring both positive and negative output cables directly to the house bank to minimize loss as much as possible. Engine blocks and attached components are typically made of iron and steel, which are a poor conductor when compared to properly-sized copper cable. Thus, sending alternator output current via this path is undesirable. It's important to remember that positive and negative cabling run from an alternator or battery charger (or *any* high current consumer or producer) to a battery bank must be routed in such a way that they remain very close to each other, touching is preferable, to minimize the production of electromagnetic interference. Interestingly, separating the cables, often by just a few inches, while maintaining their

parallel paths can actually amplify the production EMI.



A common installation oversight, sensitive satellite receivers should not be installed in the swept path of radar scanners. In addition to potentially interfering with their operation, doing so can overload these receivers (it's also discouraged by most satellite transceiver manufacturers), leading to their failure, which is often chalked up by electronics technicians as a 'surge' or 'lightningstrike'.

As far as the alternator acting as a source of electromagnetic interference, this is true to an extent, however, virtually all electrical gear, especially electric motors, generators and transformers as well as cables carrying high current, has the potential to create EM and/or RF interference including starters, inverters, chargers, radar, single sideband and VHF radios etc.



Not all metal chassis components are equipped with bonding connections. However, if they are, it's safe to assume the manufacturer intended that they be bonded.

Provided a few anti-EM and RF interference protocols are followed, this won't present a problem. In my experience it's rare in modern high output alternators, Balmar's included. For example, the alternator output cables should not be run parallel and adjacent to control cabling for any sensitive gear such as and especially electronic shift and throttle controls, engine instruments, autopilots, thrusters and windshield wiper circuits to name a few as they can lead to interference-inducing current on these cables.

Occasionally an alternator's regulator can suffer from interference caused by nearby equipment (regulators should not be installed adjacent to inverters for instance). In these

cases there regulator control harness negative wire can be wrapped around the other regulator control wires, however, these are small gauge wires, typically 16 gauge.



Cables like this one, used for a radar installation, are equipped with shielded conductors, wires run inside a braided shield, as well as a separate braided ground conductor. Failure to properly connect these conductors can lead to poor radar performance, echoes, shadows and other anomalies.

The large gauge alternator output cable typically requires no such treatment other than keeping positive and negative cables from a producer or consumer as close as possible to each other. If high current consumer or producer cabling are run parallel to other wiring this can lead to inductive interference, which, as mentioned previously, is best avoided by separating these cables and wires.

Finally, as you mentioned, bonding all electrical equipment, particularly equipment whose manufacturers specifically call for this protocol, is a prerequisite in the battle against EM and RF interference. Because I've never encountered an instance where an alternator's suspected production of EMI caused damage to an engine's electronic control computer or related circuitry it's likely that, in your case, the problem was caused by the manner in which the gear was wired. Many new, electronically controlled diesel engines are equipped with high output alternators, often as an option from the engine manufacturer, with no noticeable or undesirable side effects.

Another especially common and insidious cause of interference for electronic engine control circuits involves the connection of ground and bonding wires to multiple locations on an engine block. This practice should be strictly avoided for at least two reasons. First, doing so can induce current to flow through the block, which in turn could create problems like the

one you experienced with your computerized engine management system. Second, if the engine's own large gauge ground cable becomes disconnected, loose, corroded or otherwise compromised, starter cranking and alternator output current may flow through other small gauge negative/bonding wiring that is connected to the block.



Coaxial cable terminals are frequently improperly installed. Both of the above examples are designed to be soldered at the center conductor and the shield, yet neither include any solder. The result is a poor, high resistance connection, which causes RF energy to be transmitted in ways it was not intended.

It's important to remember that current flows through these wires under normal circumstances as electricity will take all paths back to its source, not just those of least resistance. However, provided large gauge, low resistance cables are connected, they will safely carry the bulk of the current. If called upon to carry very high current, a starter commonly draws 300-500 or more amps, the smaller gauge wires will quickly overheat and burn, possibly igniting nearby flammable materials. To avoid both of these scenarios all bonding and ground cables should be connected to an engine block at a single point or via a single cable and then to a common ground bus bar. If it is somehow disconnected or experiences high resistance it's likely the engine won't start, which will alert the user to a problem and prevent additional damage from occurring.



Thus, it's clear to see that this often vexing problem can lead to a variety of cascading, frequently difficult to resolve problems. The discussion of EM and RF interference and its

prevention could easily fillentire article or book chapter.



Top: Solid copper ground plates are most effective when their edge distance is maximized, i.e. along rectangle or "ribbon" is more effective than a square. Edges should besharp, square and ideally a quarter inch thick.

Bottom: Ground studs found on electronics are often dismissed, even by professional installers, as optional or unnecessary. However, bonding of this gear is often mandated by equipment manufacturers, and is necessary for compliance with guidelines established by the National Marine Electronics Association (NMEA). You should insist upon it.

In short, however, followingrelatively simple EM and RF interference prevention protocols (in some casesthis involves no more than physical separation of equipment producinginterference from that which is being interfered with) during installation ormodification of a vessel's electrical and electronic equipment often goes along way toward preventing the occurrence of these phenomena from the outset.

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