



Noise filters: The two filters at the top are designed for alternator noise suppression. The two at the bottom are for electronic equipment, one for 10 amps (left) and one for 25 amps. Courtesy of Newmar

Electromagnetic Interference/Radio Frequency Interference (EMI/RFI)

Electromagnetic interference (EMI) is any unwanted signal which is either radiated or conducted to electronic equipment that interferes with the proper performance of the equipment. That's a pretty broad definition and rightly so because it's a pretty broad subject.

You've probably also heard the term "radio frequency interference" (RFI). Many people consider this to be synonymous with EMI. The purists will point out, however, that the RF range refers to a specific frequency band—10-kilohertz (kHz) to 300 megahertz (MHz)—while the electromagnetic spectrum is much broader. RFI is an older term and is used nowadays interchangeably with EMI, hence the commonly used "EMI/RFI" to describe such interference. Various types of circuits in all types of electronic equipment either emit or are susceptible to EMI or both.

Another form of EMI is the electromagnetic pulse (EMP). This is a high-intensity, short-duration burst of electrical energy. These pulses can occur in many ways, one of which is when there is a rapid change of voltage across an inductive load. A classical

When things go 'haywire'

Dealing with electronic interference

You just cleared the outer buoy, and you're about to settle down for a nice long run to your first waypoint. No course changes coming up for a while, nothing in sight or on the radar. Great! Time enough to go below and grab a quick lunch. You set up the autopilot and stay at the helm long enough to be sure that everything's working as it should. Satisfied that all is well, you go below, open a can of Dinty Moore's, empty it into a bowl, zap it in the microwave for a few minutes and settle back for lunch. Life is good; cruising offshore on a bright sunny summer day is good, even the stew tastes like gourmet fare. Finished, you go back up to the helm, and check your heading. You're off course! You look back to check your wake and see that you're beginning to make a large circle. You check the autopilot and see that it has tripped off. Puzzled, you press the resettable fuse switch and punch the ON button. The lights come up, the unit comes on—all seems normal.

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Or perhaps you're on a night passage when a little thunderstorm rolls in. It rains pretty heavy for a while and some lightning dances around the horizon but it's not very close. No big deal. You watch the show for a while and then glance over at the radar. Nothing! It's off! You reset the breaker—it's OK.

So what happened? Could be several things, a couple of which fall under the broad heading of electromagnetic interference. Some of the fixes discussed below are simple. Others are best done by a reputable marine electronics dealer. In either case, the discussion should help you better understand and describe the problem.



DC power conditioners provide supplemental voltage to sensitive electronics during engine start up. They contain a rechargeable battery and a relay that supply power to the electronics when the engines are being started. After the engines are running the internal battery recharges from the boat's DC system. Courtesy of Newmar

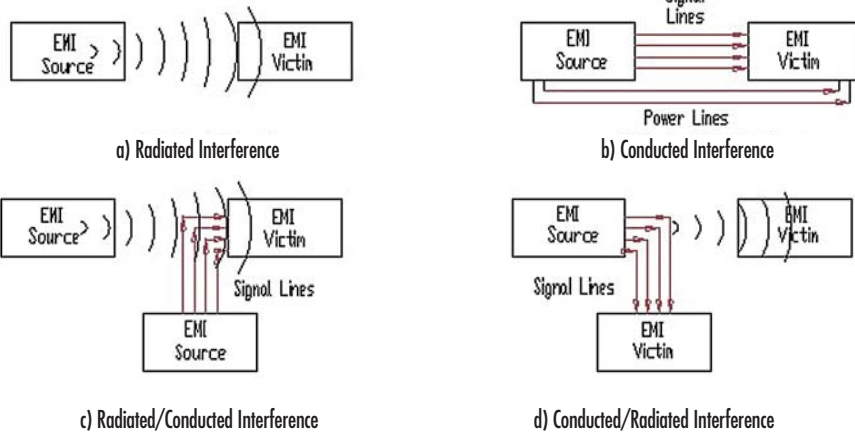


Fig. 1: EMI propagation: Radiated interference can occur directly or via conduction through wires, which act as receiving antennas. Conducted interference can be direct through wires or by radiation from unshielded wires, which act as transmitting antennas.

example is the high-intensity spark produced by the ignition coil in a gasoline-powered engine. Such pulses can also occur when an anchor windlass, winch or other electric motor is activated, or an electrical contact is made or broken. This is the type of EMI which could have been responsible for tripping out the electronic devices in our hypothetical scenarios above. EMPs are capable of causing considerable damage, especially in today's highly microminiaturized solid-state electronic equipment.

The effects of EMI can vary from static and other weird noises on VHF and SSB radios to malfunctioning of navigation electronics such as loran and radar, to incorrect readings on sounders, fishfinders, autopilots and fluxgate compasses. They can also cause all sorts of squeaks, squawks, whistles, crackling and popping in your entertainment electronics.

EMI may be radiated (Fig. 1a), or conducted (Fig. 1b), or both (Figs. 1c and 1d) and is corrected or suppressed by one of four methods: separation, shielding, filtering and/or grounding (bonding).

Radiated EMI is generated by voltages and currents in functioning electrical and/or electronic devices. It is received or transmitted by wire conductors carrying signals or by power supply conductors or both. It can also be caused by spurious voltage spikes caused by making and breaking electrical contacts. The first and best solution is to

identify the source device (culprit) and to correct the condition, e.g., worn or dirty motor brushes, loose connections, etc. that is causing the problem. If that's not possible, and often it's not, some devices are just electrically noisy, we must fall back on either separation—physically increasing the distance between the culprit and the victim—or shielding. (Figs. 2a and 2b). If shielding is necessary, it's a good idea to shield both the culprit and the victim, since shielding just one, leaves the other open to EMI from some other source.

Shielding means enclosing the offending and/or victim equipment in a metal enclosure which is then electrically connected to the boat's common ground. The radiated energy is absorbed by the shield and conducted to ground. If the equipment has a metal cabinet, the cabinet is simply grounded. Otherwise the equipment must be enclosed in metallic sheet, mesh, foil or a preformed purchased enclosure. In the case of wire radiators, the conductor may be replaced by shielded coaxial cable. If the problem cannot be resolved by shielding, we must resort to the use of filters. (Figs. 2c and 2d).

A filter is a circuit that allows some frequencies to pass while other frequencies are blocked or shunted to ground. A capacitor (C), for example, is a very simple filter since it is an open circuit to direct current (DC) but, depending on its capac-

What to look for

The effects of electromagnetic interference vary from static and other strange noises on radio receivers to malfunctioning of electronic navigation systems or incorrect readings on instruments. Some of the more commonly encountered symptoms are described here.

Autopilots

The boat may head off onto a different heading or begin to turn in circles. Probable causes are the alternator, voltage regulator or even possibly the SSB when transmitting, or just possibly a crewmember or guest unknowingly placed a portable radio or other source of magnetic interference too close to the autopilot's compass. If the autopilot trips off, the problem is most likely spurious voltage spikes (EMP) or supply voltage dips caused by the activation of heavy current draw devices such as the starting motor.

Loran

Signals may fade or disappear and the signal-to-noise meter on the loran will indicate poor signal reception when the engine is running. Engine ignition and charging systems are probable causes.

Radar

Bright flashing speckles appear at random on the screen and weak targets fade and disappear from the scope. Engine-related causes are likely.

VHF and SSB Transceivers

Buzzing, crackling, hissing, popping and other weird noises will interfere with genuine signals, possibly making them unintelligible. Most likely sources are the engine and engine-related systems (yours and other nearby boats), fluorescent lights, battery chargers, inverters, etc. Verify by shutting down the suspected source to see if the interference goes away.

What to look for

Entertainment Electronics

Stereos are particularly susceptible to EMI because of their often long audio speaker cables which act as very effective antennas. Popping or crackling noises may be engine-related. A constant pitch low-frequency noise may be caused by a television receiver. Electronic components do not pick up electromagnetic signals, wires do. Twisting the wires together and bundling them together may help or even possibly eliminate the problem. If not, you'll have to deal with it at the source.

Chart Plotters

Today's chart plotters are essentially LCD displays and, typically, are neither victims nor culprits of EMI/RFI. Older cathode ray tube chart plotters had the problems described in the main article for CRTs, i.e. they could emit electromagnetic energy. However, between the use of LCDs and improved design practices (internal shielding, filtering, etc.) EMI/RFI has not been a problem with chart plotters.

whistling in radio receivers. The whine will vary with the alternator's output current and the engine rpm and thus, the charging current to the batteries, going to zero when the batteries are fully charged or when the engine is shut down. You can verify that the alternator is the culprit by disconnecting the alternator's belt and starting the engine. If the noise is not there, the alternator is at fault. There are packaged filters specifically designed for alternators, as there are for most of the devices which are likely EMI sources of EMI. However, a 1.0 mfd, 200 VDC capacitor connected between the alternator's output terminal and ground will do just as well and is a lot cheaper. The positive (+) lead of the capacitor goes to the voltage regulator terminal, the negative lead to ground.

Voltage regulators will produce noise interference that sounds pretty much the same as that from the alternator except that it will vary in intensity only with alternator

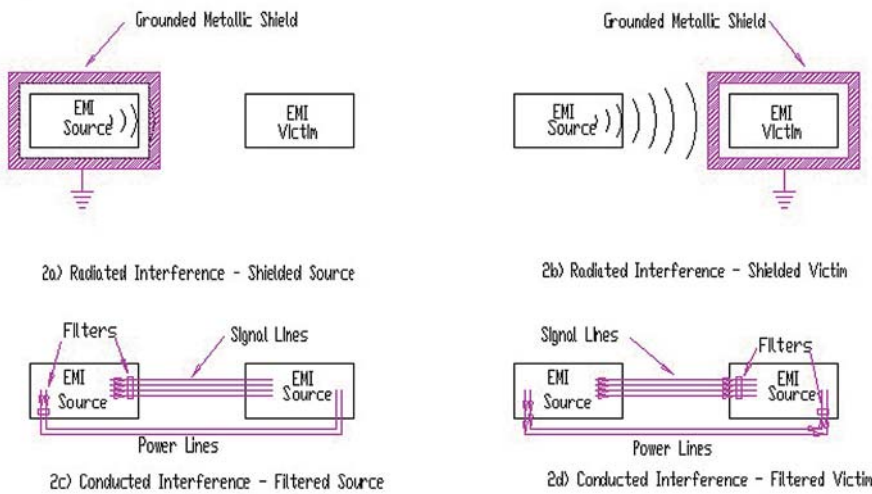


Fig. 2: Suppressing EMI: Shielding and filters can be effective, depending on the type of interference.

itance (in microfarads, mfd), will offer little or no resistance to alternating currents (AC). So, a capacitor of the right size can be placed in the circuit connected from the noise-carrying conductor to ground, and the interfering signal, which is alternating current, is shorted to ground and eliminated. A choke (inductance or coil, L) is the opposite of the capacitor; it offers insignificant resistance to direct current, but depending on its inductance (in henrys, h), can offer extremely high resistance to alternating currents. So, a choke of the proper size inserted in series with the noise carrying conductor, in effect, blocks the EMI. The most commonly used filter is the low-pass, pi-network filter consisting of both capacitors and an inductor (Fig. 3). Prepackaged combinations of LC filters designed for specific applications are available from you local marine electronics dealer for a variety of EMI conditions.

Causes and Cures

There are a number of potential sources of EMI on the boat. Electric motors with brushes or commutators, winches, windlasses, pumps—anything that can cause a spark such as switch contacts. All of which is not to mention sources external to the boat such as lightning, solar flares and nearby vessels. However, the major source by far, is the vessel's engine(s) and their auxiliary sys-

tems. So, how do you isolate the source of the EMI?

One of the simplest and most effective tools for tracking down and identifying the source of EMI is an ordinary, inexpensive pocket AM/FM radio with an ear-phone jack. Most EMI is broadband. To make an EMI detector (AM/FM pocket radio) more directionally sensitive, wrap the radio in aluminum foil (shielding), all except for the antenna. If your radio doesn't have an obvious telescoping antenna, you'll have to open it up and look inside to determine the antenna's location.

Tune the radio between stations, go down into the engine room and move your EMI detector around in close proximity to the suspected sources. The most likely sources are the alternator, voltage regulator, electronic tachometer, and for gasoline engines, the spark plug wires, ignition coil, distributor, etc. Starting motors are also a potential source. Have a crew member crank the engine over while you hold the detector close to the starter. Listen for crackling, popping, hissing, etc., that gets louder when you position the detector closer to the suspected component.

Alternators have diodes which cause a rapid change in current when they switch from the conducting to the non-conducting state. This shows up as a whining or

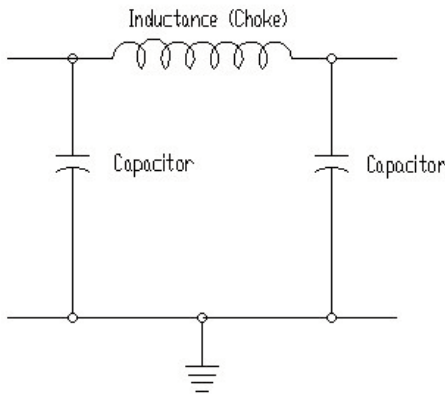


Fig.3: A filter like this is commonly used to block EMI in a conductor. It consists of capacitors and an inductor.

output, not with engine rpms. Here again, a 1.0 mfd, 200 VDC capacitor between the alternator's battery terminal and ground will eliminate the EMI from this source also.

Ignition circuits in gasoline engines are a common source of EMI. At low engine rpms it starts out as a slow ticking or popping sound that changes to a low-pitched whine as engine rpm increases. Likely suspects are the coil, distributor and/or spark plugs and plug wires.

If the coil is suspected, a low-pass filter rated at 5 amps or greater wired in series with the wire to the ignition switch is the recommended fix. Also, the high-tension wire from the coil to the distributor cap should be replaced with a suppression/resistance-type cable.

As far as the spark plugs are concerned, they and the plug wires should be of the suppression/resistance type to realize any EMI reduction benefit. However, if suppression type plugs and wires are used, it is important to keep all ignition components in good condition to avoid degradation in engine performance.

Electronic tachometers can pick up electrical pulses from the coil and radiate them as interference in the tach's display, disrupting the readout. First, the tach wires should be kept as far as possible from the boat's wiring harness, and if possible, shielded with noise suppression tape. Also, a low-pass resistance-capacitance (RC) tachometer filter should be installed at the coil in the lead to the tachometer.

Starting motors are another common source of EMI. These motors generate electrical pulses (EMPs) while they are cranking; these pulses are then picked up on the boat's wiring harness and conducted to the boat's electronics equipment. These voltage spikes can be very damaging to VHF radios, sounders, loran, GPS and other navigation equipment, wiping out waypoints, routes, coordinates and presets. Filters not specifically designed to withstand these high current and voltage pulses may fail. There are products specifically designed not only to protect the electronics, but also to maintain a stable source of DC voltage, preventing voltage dips on starting and preventing equipment crashes. These devices are not cheap, but neither is the failure of a crucial piece of electronics at a critical time.

DC electric motors are a major source of EMI as a result of poor contact between brushes and slip rings or commutator. This causes arcing, which in turn generates the EMI. The first, and in all probability the only necessary step, is proper maintenance: keep the brushes in good condition and the slip rings and commutator clean. If this doesn't solve the problem you'll have to resort to filtering. Again, the 1.0 mfd, 200 VDC capacitor connected from the motor's output lead to ground will usually eliminate the interference. A commercial filter specifically designed for this application is also available.

Cathode ray tubes (CRT), such as those used in some electronic equipment, emit EMI through their display screens. This can

be particularly upsetting to other electronic device in close proximity; loran is a good example. You can check for this by placing a metallic sheet—aluminum foil will work—up against the face of the CRT. If the problem goes away, that's it. Clear plastic sheets with transparent conductive films are available from shielding manufacturers specifically for this purpose. They do reduce screen brightness slightly and impart a slight tint, but they don't seriously impair visibility.

Other sources of electromagnetic interference that are more difficult to isolate and identify result from faulty—poorly made, dirty, loose or intermittent—grounding or bonding contacts. These can usually be found on metal cabinets, electric motor housings and other electrical device enclosures. The prop shaft is another likely source if the grounding brush contacts are dirty or worn. If the problem persists, a thorough check of the vessel's grounding and bonding systems is in order. The grounding and bonding wires should be at least as heavy as the power supply wiring for the equipment and preferably a size or two larger. They should be tinned copper stranded wire. The contacts must be clean, free of oil, grease or dirt, large area and tightly made up. Good grounding and bonding systems are essential to protect against damage from electromagnetic pulses. If there is any doubt, replace the conductor and/or remake the connection. **ME**

About the author

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