HF Radio Installation Procedure
For Marine Applications

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There have been numerous instances of RF grounding for HF/SSB installations as far back as Noah's Ark. Many great scientists have mathematical equations named after them. Einstein's Law of Relativity ($E=MC^2$), Newton's law of gravity, and Elijah's Law of Grounding (i.e., using 100 square feet of copper screen in the bilge of a vessel).

Elijah was the marine dock technician who installed the copper sheets in Noah's Ark. That was the right thing to do, for in those days there was always water sloshing around in the bilge which made good contact with the copper sheets. Times have changed, but unfortunately some installers still believe in that law.

This article will address these issues from both the theoretical viewpoint and actual use proven by many hundreds of hours of testing, retesting and more testing.

Radio

For operating an HF radio in a marine environment, the authors highly recommend the purchase of a "Marine Radio". Many owners look for the least expensive way out and try to modify a ham radio for marine applications. Bad decision! Marine radios are designed and manufactured with protection against salt water and sea air conditions. Marine radios are FCC Type accepted, and meet the requirements of frequency stability and RF radiation. Ham equipment does not need to meet these standards, and its use is prohibited by law on Marine bands.

When using Terminal Node Controllers (TNC) such as a Pactor modem, frequency stability and accuracy are critical. The further off frequency, the worse will be the reception. This limits the ability to connect and to transfer

data at the maximum rate for email. When tuning to a frequency, a marine radio has a highly stable Numerically Controlled Oscillator (NCO). This means it is EXACTLY on frequency. Ham radios use a Variable Frequency Oscillator (VFO) that does not have circuitry capable of automatic frequency compensation.

The radio should be connected directly to the batteries via a proper fusing system. Today's radios have fast-acting fuses that will react far more quickly than the circuit breakers on your panels. Many times the radio is connected to a breaker in the fuse panel marked "Radio". Usually the breaker is the same as the other breakers, i.e., 20 amps. Marine radios that transmit 150+ watts need at least 30-35 amp breakers. Install the radio by connecting it directly to the batteries or to the closest battery switch and install your fuses (yes, fuses, plural). Connect one on the hot side and the other on the ground side. In my experience most radios are lost by a power surge, lightning strike or corona hit to the ground side of the radio. Using fuses on each, should there be a high voltage surge the radio is protected on both positive and negative supply sides.

Not all fuses are the same. There are fuses made specifically for DC applications. The 110 volt fuses available at hardware stores and even some well-known Marine stores are not adequate. The correct DC fuse for a marine application is marked for 32 VDC or Volts D.C. When installing the fusing circuits to the radios, the authors prefer the new Plastic blade fuses that are specifically made for the auto industry. Not only are they designed for 12-volt use, but they are sealed to protect against poor environmental conditions. Glass fuses start to rust and corrode open causing problems because the fuse and fuse holder are made of dissimilar metals. The molecular difference in potential in the damp marine environment causes electrolysis. When the author was designing and overseeing the installs in Europe, he noticed the introduction of a new blade fuse that has a small red button on the top, a re-set button. This is the way to go: if the short is major, the fuse will melt and open, yielding a "blown fuse", but if it is a short transient surge, the fuse will trip, and it will only need to be reset.

Remember to calculate the distance from the radio to the battery source. Countless times when radios have low power output or modems that do not work, the cause is a wire size too small that is preventing the 12.6 volts from reaching the radio. To accurately measure the voltage, place the transmitter in the "FSK" mode and press the "PTT" button. Measure the voltage at the

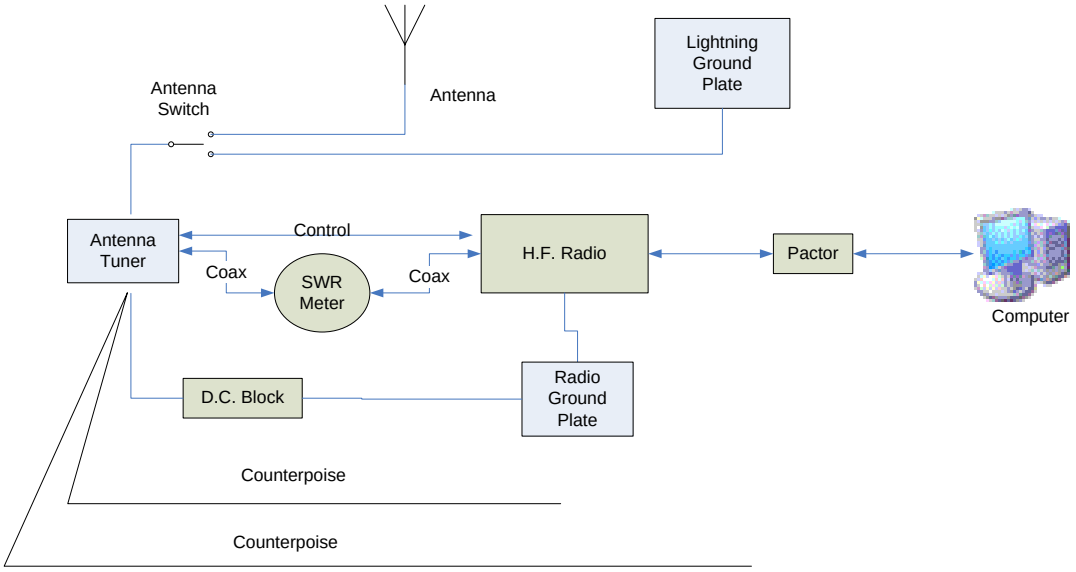
radio in the transmit mode, NOT just while it is in standby mode. This test is extremely important. It demonstrates why the radio panel goes dim, and the Pactors (TNCs) do not work. Antenna tuners will not work when they do not receive 12 VDC.

Another note: when operating in the marine bands, the radio MUST always be in the USB "Upper Side Band" position.

Last but extremely important is NOISE. What is excessive noise in the HF/SSB radio?

This is where the radio manufacturers have "missed the boat"! There is no signal strength meter on marine radios. Only the bars on the screen of the radio give an indication. When in the receive mode, if 4+ bars are shown on the radio, there is TOO much noise. (This has been independently verified by the author and a colleague who repairs most of the popular HF radios on the market.) The source of the noise may be on the vessel or simply nearby, such as welding machines or a faulty bleeder resistor on a power line pole near your location.

To verify the noise level, turn on all the DC panel breakers. Now slowly start turning them off, one at a time. Wait 15-20 seconds between breakers. Some electronics have high voltage capacitors and need time to bleed down. The bars on the radio will change with each breaker. As the bars decrease the amount of noise each circuit is contributing can be identified by the change in the bars displayed. Once the circuits which contribute the most noise are identified, investigation of the individual items on each circuit will reveal which are the sources of the noise. Major contributors are battery chargers, inverters, fluorescent lamps, some makes of halogen lamps, and certain DC fans.



Optimal System

Antenna Tuner

The next important device is the auto antenna tuner. This part covers almost all the auto-antenna tuners, and how they should be connected to the radio and the ground system.

The antenna tuner should be mounted within 5-7 feet of the ground plate, the closer, the better. For owners who do not want to use a ground plate, connecting the 2-3-4 bronze through holes together will work, but the green bonding wire needs to be disconnected and butted to bypass the through holes.

With 0.123 inch copper strap, a standard paper punch can be used to make holes for attaching to the tuner and the ground plate. Again remember to attach the copper strap to all the thru bolts from the ground plate. There are only two straps connected to the ground plate, one to the antenna tuner and the other to the radio.

Connect a copper strap (yes strap not wire) from the grounding lug on the antenna tuner neatly to the ground plate. If using a ground plate that has 4-5 bolts on the inside, then use the copper strap to bond all those bolts together; allowing maximum RF grounding to be transferred to the outside plate. The

RF resistance between the antenna tuner end of the ground strap and the ground plate should measure 4-12 ohms as measured with an RF ohm meter. The copper strap should be 1 to 1 ½ inches wide, and made of pure copper for minimum resistance.

There should be two cables from the radio to the antenna tuner, a coaxial and a control cable. Exception, there is an antenna auto tuner that only needs the coax cable and is powered by the DC fed down the RF coax line.

Almost all problems associated with systems working improperly are directly related to the PL-259 coax fittings. If there is a very fine wire from the shield, not touching but near the center conductor, when 150 watts of RF energy passes through the coax, it will arc to the center conductor and cause an RF short. To confirm a good connection, install a 52-ohm dummy-load on the coax at the antenna tuner end before you connect it to the antenna tuner. Check for 1.6:1 Standing Wave Ratio (SWR). Now remove the RF dummy load and connect to the antenna tuner.

Connecting to the antenna

Elijah's law and a California myth recommend using GTO-15 to run from the antenna tuner to the antenna and that the GTO-15 will protect from RF burns. Not true at all! GTO-15 was manufactured for neon signs like the type used inside diners. To ignite the neon signs, it takes high voltage, and GTO-15 was used because owners wanted to prevent a shock to their customers should they inadvertently brush against the sign. GTO-15 cable is not shielded and will radiate just as much RF as an open backstay or wire. The GTO-15 center diameter is no larger than the size of a hat pin. It is about the size of # 18-20 gage wire and provides high resistance.

The optimum design for antenna connection is copper tinned braid, like that used at broadcast stations. This braid will provide minimum resistance from the tuner to the antenna with very little RF lost. Cover the ¼ inch braid with high voltage blue-stripe-plastic auto-loom. It is available in ¼ diameters and easy to install. This braid will allow maximum transfer of RF energy to the antenna with very little resistance.

When attaching the RF feed line to the antenna, do not tie rap or tape it to the backstay. The RF line radiates and it will couple to the lower part of the

back stay which is grounded and that will reduce the output of your transmission.

The average length for the RF feed line should not exceed 5-7 feet in a mono-hull and should be much shorter in a CAT if the tuner is mounted a mid ship.

Counterpoise

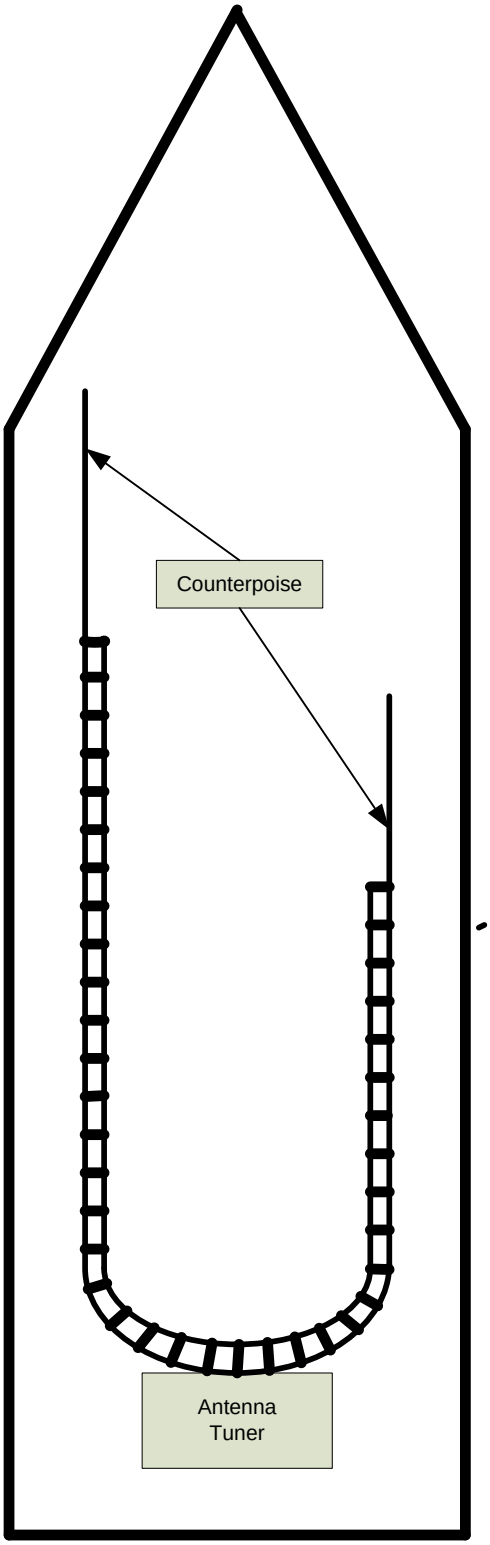
Definition: A system of wires "insulated" from the vessel's ground system and whose purpose is to be an artificial ground for the antenna. There are many different lengths which represent the primary operating frequencies. This subject is probably the most misinterpreted and misunderstood in the entire installation. It is by far the most important part of the system related to the antenna.

The counterpoise is the mirror image of the electrical side of your antenna. It can be minimized in length, as long it is resonant to the antenna.

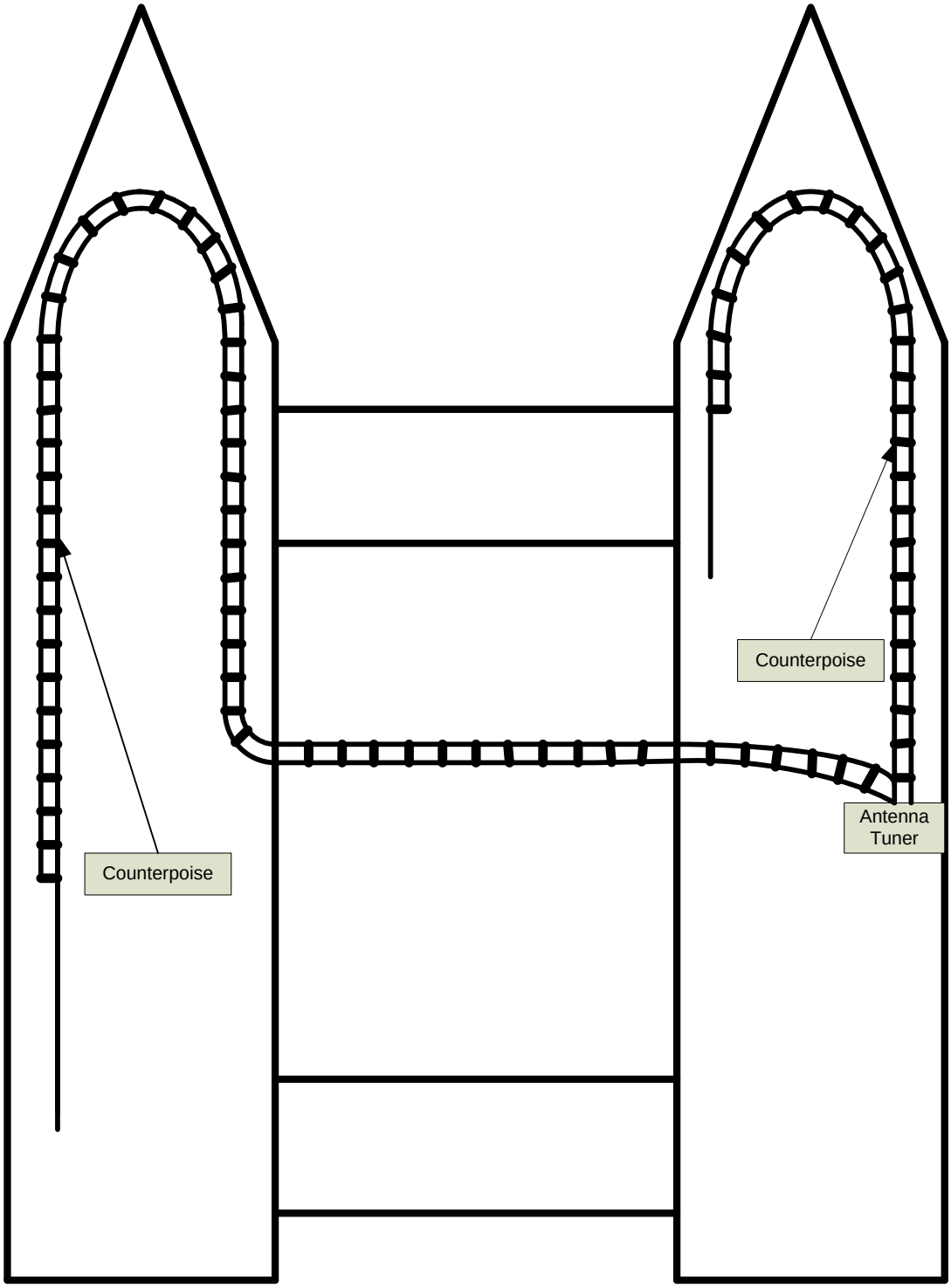
Remember that the antenna tuner wants to match the antenna and transfer as much RF energy to it as possible. Auto antenna tuners will match between 80 to 1200 ohms to the antenna at frequencies from 2.8 MHz to 22 MHz. It is important that this same RF impedance be established on the counterpoise ground side.

A few years ago the author introduced using 450 ohm ladder line for the counterpoise. When it is cut to the correct length, it has the same impedance (80 to 1200 ohms) to mirror the impedance to the auto tuner.

Also introduced was a counterpoise using two ladder lines, each connected to the same grounding lug of the antenna tuner, but one line running in the port side of the bilge and the other in the starboard side. The lines should be separated from each other throughout the entire length of the vessel and be at least 3 feet apart. (If they run together for a few feet it is acceptable.)



Monohull
Counterpoise



Counterpoise
Catamarian

When these counterpoises are built, signals of the desired frequencies are injected into the lines using a digital signal generator. The individual lines are then cut to resonate with the tuner and give the best performance. Interestingly, the impedance of the ladder lines is not always what is stated by the manufacturer. Consequently, the length cannot be copied from another vessel. By the design of these lines, the SWR match will be approximately 1.6:1 or better throughout all assigned frequencies.

Once again, the counterpoise is not the RF ground that gets connected to your systems DC ground and absolutely not bonded to the engine.

As you can see, the concept of 100 square feet of copper in the bilge has long ago been thrown out, although there are still those who believe in this ancient myth. Of course, if the vessel is a re-constructed Noah's Ark, then Elijah's law of Grounding just might work, because there will always be lots of water inside the hull!

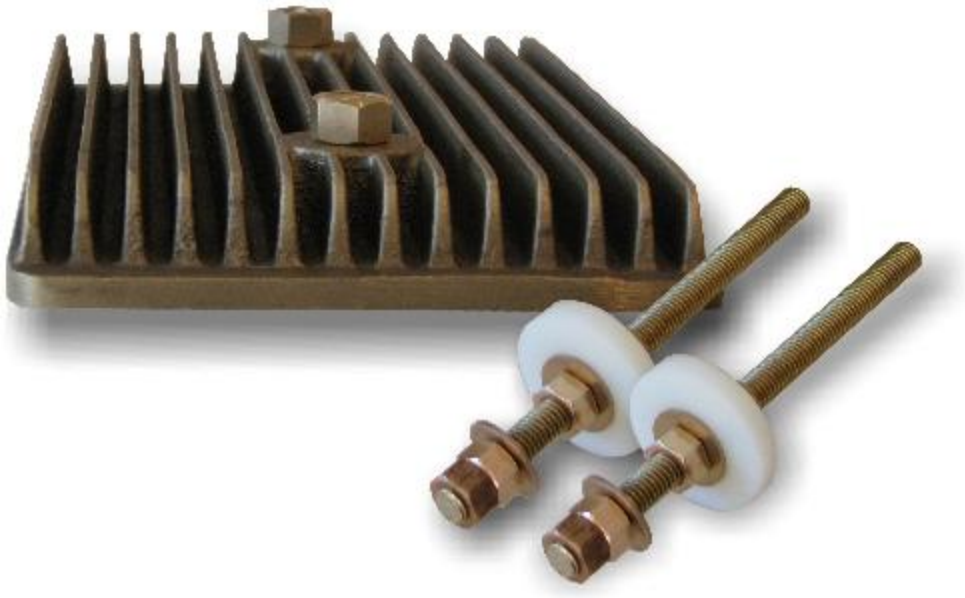
Counterpoise

Counterpoise in Bilge

RF Ground Plate

Ground plates are a very important part of a radio system, and also a major grounding connection for other important instruments on the vessel, e.g., the radar system. The RF resistance of the ground plate should be 4 to 12 ohms between the ground plate and the salt water and about the same for fresh water. The ground plate represents that copper or brass 8 foot stake that one would pound into the dirt to ground radio equipment on land.

The ground plate should be located about 5-7 feet from the antenna tuner, and deep enough under your vessel that when the vessel heels, the ground plate remains underwater. Now consider the surface area. There are some



Ground Plate

manufacturers who claim major surface areas by counting the dimples in their plates. From a technical standpoint the dimples do not do anything. In reality what counts is the total RF surface area. RF current does not look at each and every dimple on a ground plate; it looks at the surface area as a whole. For example, if a 4 x 18 inch plate is mounted solidly against the hull you cannot count the back as surface area.

Next consider the connection from the tuner and the radio to the ground plate. The average power is 65 watts using an Amateur radio or 150 watts using an authorized Marine Radio. The ground strap from the tuner and radio to the ground plate should be copper foil 0.123 to 2.0 mils thick and 1 to 1.5 inches wide. Anything more is a waste of time, money, and a painful exercise running the foil through those tiny scupper holes in the bilge.

The tuner has a “large” wing nut on a porcelain stand-off to attach the copper strap. Use the copper foil between it and the ground plate. If the plate has 4-5 through bolts, tie them all together with the copper strap. When making the connection, apply an anti-oxidant paste at the connection point only. This is because some copper foil is really only copper coated, and the molecular difference will start a small corrosion point. The author always uses Lanakote™. It is a grease that will last for a very long time in the bilge area.

A ground loop not only causes possible electrolysis to your radio, but also distortion of your radio signal that is most noticable in sending data such as emails. To prevent this from happening, a DC Block should be inserted by cutting the copper strap near either the tuner or the ground plate. This block will prevent a ground loop from your radio to the tuner and back to your radio.

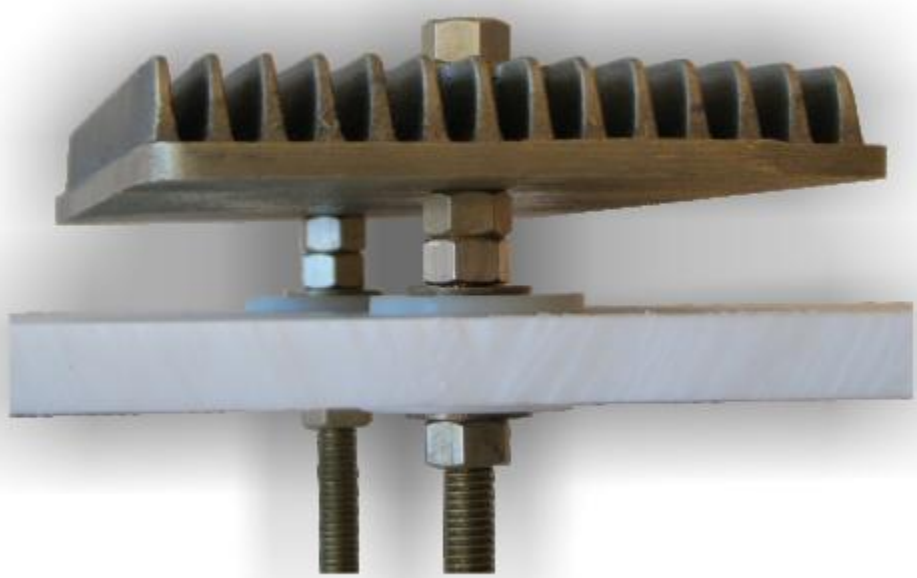
DC Block

At the radio side on most radios is an RF ground screw or lug that should also be connected to the RF Ground Plate. Cut another copper strap and run it from the radio to the same ground plate. If this is not possible, then connect the strap to 2-3 bronze through-hulls. If you have green 10-12 gauge bonding wire connected to the through-hulls, cut it away from and by-pass the through-hulls by terminating the connecting wire. Tie the 2-3 bronze fittings together with the copper strap, and clamp it with a "real" stainless steel hose clamp. Apply Lanakote™ and you are done.

Now to will address the mounting of the ground plate correctly to the hull. After extensive research, testing, measuring, and addressing some of the major rumors about grounding plates mounted on the hull of vessels, here are the facts. Review the diagram. It is the best way to have all the surface area that you need.

The ground plate should be off-set from the hull by 3/8 inch. Some years ago, a major vessel insurance company which shall remain nameless came to a false conclusion. They stated that vessels which had ground plates and were hit by lightning blew major holes not only in the fiberglass, but also in bronze through-holes. After an intense investigation the Department of Navy determined that this was not the case. There were improper connections to the ground plates. The 4-5 bolts that took the major portion of the direct hit from the lightning actually heated the through bolts so much, that it melted the fiberglass hull. After 6-7 months of exhaustive testing, it was found that by mounting the plate off-set by no more than 3/8 of an inch,

the water behind the plate not only provided additional RF surface area but also cooled the bolts sufficiently to prevent damage to the hull. This is also the reason to run an extra ground plate for lightning discharge. Remember that it is not just a lightning bolt hitting your mast, but the corona from lightning which can hit as far away as 18 miles and it can put enough electricity in the air to blow out all of the vessel's electronics, including it's radio. There is a good work-around to this problem which will be addressed in a future article. So remember, mount the plate, at least 3/8 of an inch off the hull and 5-7 feet from the antenna tuner.



Ground Plate through hull installation

Single Side Band Antennas

Single side band antennas are an extremely controversial subject. The authors have conducted tests on various antennas for the past 8-10 years. Numerous styles, makes and models of SSB antennas and their efficiency have been tested. The Rope Antenna was determined to be the most efficient, economical, and the simplest to install.

Rope Antenna

With any antenna, the installation of a good counterpoise provides the greatest efficiency and maximum output from the transmitter and the

antenna tuner (whether a manual or auto tuner). The transmission line to the antenna should not be running parallel to any rigging and should be spaced at least 2-3 feet away. This practice prevents the effects allowed by vessels that have poor filters in the power supply of refrigerators and inverters. The power supply of these devices oscillates into the grounding system which ties to the ground side of the battery. This pulsing oscillates at such a high level that it is coupled into the antenna system of the vessel. When listening to the HF radio, this noise sounds like someone sending Morse code. (If you turn off these appliances and equipment the noise will stop.

At the antenna tuner all that is needed is a flat copper ground strap 1 - 1.5 inches wide and no more than 0.130 thickness, going from the tuner to the Ground Plate. A DC Block should be inserted in the line from the antenna tuner to the ground plate. This stops the induced noise current from looping back through the antenna tuner to the radio, and reduces the noise caused by the loop.

Summary

For efficient and reliable H.F. communications it is extremely important to pay close attention to the details of the system installation. Equipment mentioned in this article may be obtained from www.ropeantenna.com and email service from www.cruiseemail.com. Both authors are available for design, installation, troubleshooting, and consulting.

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