



SSB/HF Radio Applications in Modern Sailing Vessels

Eric Steinberg, Farallon Electronics

So you're sailing across the ocean *and* you want to be able to call home while on the way. But most of all you want to be heard if you call for help from the middle of nowhere.

Communications on the open ocean has always presented a problem. The distances are vast and the transmitting platform is small, unstable and designed for a purpose other than being a radio station. If we exclude satellite technology, choices for the average mariner to communicate several thousand miles are about the same as they were 50 years ago. Marine Single Side Band (SSB) radio, also referred to as HF radio, is an "old standby" of voyaging vessels both small and large. It is called HF, or High Frequency, because of the frequency range used, 3 to 30 megahertz (Mhz). Medium Frequency (MF) is below at .3 to 3 Mhz and Very High Frequency (VHF) is above at 30 to 300 Mhz.

Commercially available marine SSB radios are pretty sophisticated machines. They range in price from \$1500 to \$10,000+ with many different configurations available. As with most electronics, from car stereos to computers, the price of equipment goes up with features and power capabilities. Output power, expressed in watts, of common marine SSB equipment is 150 to 400 watts with some shipboard equipment in the 1000+ watts range. Anything over a 150 watt radio is a big machine and for all but a few yachts too expensive and unnecessary.

Transmitting over the airwaves with a SSB radio is always free as long as you're not connected to a commercial service. It is for this reason that SSB is most often used for vessel to vessel communications when the 30 to 40 mile range of a VHF transceiver is insufficient to cover the distance between the two vessels. You can't beat it for things like "Hey Jim, how's the weather over there?" Current and upcoming satellite technology is better suited than SSB for making a connection to a landline phone, but the per minute air time charges are real, and so are the monthly service subscription fees (whether you use the phone or not). The average "Jim" will probably tire of you calling on the sat phone and costing both of you \$\$\$!

Sending Email and Data Over HF Radio

Sending data over a SSB using PACTOR mode modems has become a very popular method of communicating to people shore side or from boat to boat. PACTOR modems have created a new use for SSB and there are now numerous shore side service providers that transfer data via PACTOR. An in-depth discussion of modem installations justifies a separate article, however the demands a modem puts on a SSB are worth mentioning here. In normal operation, modems cause a radio to transmit at nearly 100% of the radios designed capacity. Deficiencies or problems with a SSB installation are accentuated when using a modem, which make the details of this article even more important. Modem installations require the radio have a proper DC supply and a good ground installation to the tuner. DC power and tuner grounding are discussed further in this article. Check with your electronics specialist as to the suitability of an existing SSB with a PACTOR modem.

Getting Started

With the help of your local marine electronics specialist you have selected a radio system that fits your needs and budget. You will be loaded up with a SSB radio, an automatic antenna tuner, copper strap, wire of different types and connectors. If you opt to do the installation yourself, the radio system will occupy at least one weekend for you and a best friend to install properly. Don't underestimate the difficulty of properly installing a SSB radio. It is not as technically difficult as it is laborious but as with anything on a boat, attention to the details will make the difference in performance.

For this discussion we will assume we are talking about an average 40' fiberglass or wood sloop with an inboard engine and an external keel with keel bolts. Steel and alloy boats will not have the same considerations for a ground system, ketch / yawl rigs have unique antenna problems and multihulls ground and antenna problems that need to be addressed individually.

A boat is a difficult radio platform and as most experienced boat owners know, a boat is always a compromise. With respect to a SSB radio on a boat the problem lies in that there is no earth ground plane or "counterpoise" for the antenna system, so one must be built. In a land based installation ground is usually easy. Pounding a 6' copper stake into the earth and / or grabbing onto the copper plumbing in a house can provide a sufficient ground plane. A good ground is vital, it is half of the antenna system and is often referred to as the springboard the signal uses to jump off the boat in to the atmosphere. To better understand "ground" you need to know the three different ground systems that can exist on a boat. One is your DC ground which is the negative post of the battery(s) that all of your DC powered items are ultimately common

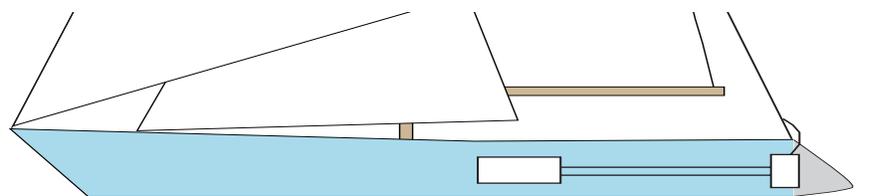


Figure 1a

Radio at nav station

Tuner close to antenna

with. The second is the bonding system that is intended to tie all of the metal items within the boat together that may be susceptible to electrolysis (galvanic corrosion). The third is your RF (radio frequency) ground for a SSB radio. An astute reader will note that all three ground systems are common to at least one point, the engine. In the case of the RF ground, the other ground systems are inconsequential and of no benefit to the RF system.

No Pain, No Gain. Think Metal Surface Area

RF ground installation are different for every boat, but the basics are the same. You want to attach all big metal items on the boat together with copper strap and end up with a minimum of 100 square feet of metal surface area. Starting with the Automatic Antenna Tuner, the tuner should be mounted close to the feed point for the antenna, which means it is usually mounted aft. From the tuner, copper strap will run forward and attach to the engine, any (and hopefully all) metal tanks and a keel bolt (any one will do). Getting the copper attached to metal toerails and the stern pushpit along with the lifelines can be of tremendous benefit. When incorporating the pushpit and lifelines, extra care must be taken with the route of the antenna feed wire.

Copper strap is commercially available from marine electronics shops and ranges from 2" to 4" wide and in thickness from .001" to .013". Two inch wide .001" (about as thick as an extra heavy aluminum foil) is easy to install around the boat but there is a trade-off when using the thin stuff. The issue is surface area and longevity. At HF frequencies electrical energy is no longer running through the copper conductor as it does at DC voltages, but rather it is traveling on the surface. Copper strap is used instead of a copper wire because the strap has much more surface area and offers less impedance (resistance at frequency) to the RF energy. Armed with this knowledge, we know that 4" strap is going to be more effective than 2" and that the wider material should be used whenever possible (some Volvo ocean racing boats are using 6+ inch wide copper). However it's an imperfect world especially when working on boats: sometimes 4" strap just will not go from point A to B. Four inch material

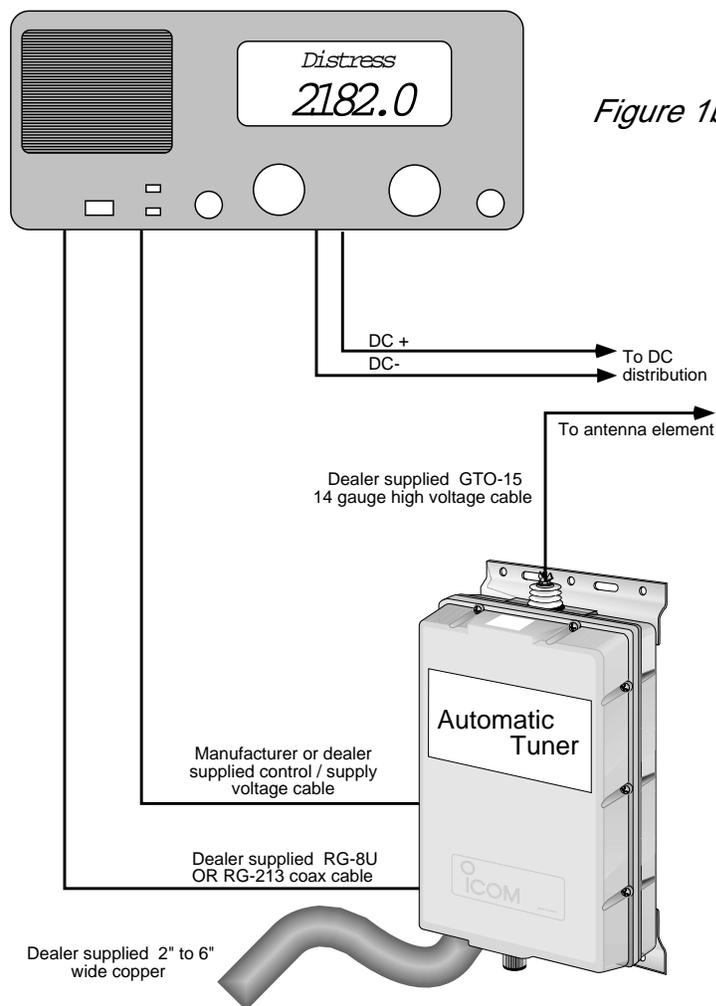


Figure 1b

folded in half is one solution and sometimes the ultra thin .001" x 2" copper is the only way to go, but make every effort to use bigger material. The life expectancy of .001 mil copper is shorter than thicker material because it rots from corrosion in the salt air much faster. Of course life of the copper is only an issue if it is a permanent installation . In a perfect world, the boat builder would have used copper screen and foil in the lay-up of the fiberglass during construction. This completely encapsulates the copper for long life. With an encapsulated ground installation, copper tabs exit the glass in appropriate locations to attach to the tuner and metal objects such as tanks and a keel bolt. Many boat builders now offer a SSB ground plane as an option for new construction jobs.

When attaching the copper to tanks, keel and engine try to do so in a way that achieves good metal-to-metal surface area contact. In the case of tanks, running to an inspection plate and attaching to a couple of the bolts with large washers works well or going to a fitting on the tank and attaching the copper to it with a hose clamp also works. The latter looks crude but is effective. Some tanks have cleats or clamps holding them in place that can be loosened allowing the copper to be sandwiched in between. At the engine, choose a bolt to sandwich the copper to the block . You should ask your mechanic about which bolt he would suggest using.

Why an Automatic Tuner? The antenna tuner is an essential component of the installation and an automatic tuner is required for most marine installations. The tuners function is to match the impedance of the antenna system (the combination of backstay or whip antenna and the ground plane) to the 50 ohm impedance of the final transmitter stage at the back of the radio. This is no small task as the impedance of the antenna system can change from a few ohms to hundreds of ohms depending on the frequency transmitted on. You say big deal? It is, only when the impedance is matched does the maximum transfer of power take place between the radio and the antenna system. Without a proper match, all of the radios energy doesn't make it past the tuner and in turn off the boat. Energy is reflected back towards the radio producing what is called a Standing Wave (SWR), a ratio between forward and reflected power before it goes through the tuner. An imperfect match between the radio and antenna is one of the reasons lights on your electrical panel will glow and meters will bounce around when transmitting on a SSB.

Out of the tuner comes the actual radiating high voltage. Naturally, you want to radiate off of the boat not into it, so the shorter the run from the output of the tuner to your insulated backstay or whip the better.

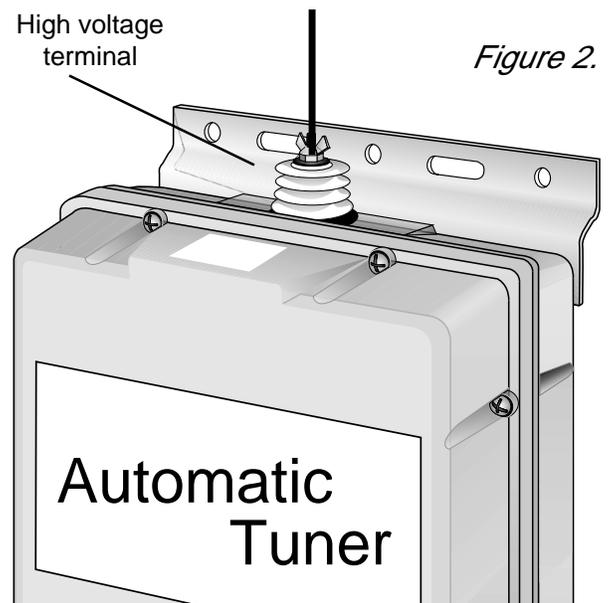


Figure 2.

A manual tuner will also do the job of tuning a whip or backstay, but a manual tuner needs to be mounted by the radio where it can be manipulated when the desired working frequency is changed. The problem with a manual tuner being by the radio is that the radio is usually a long way from the antenna element. The long run from the tuner output to the antenna element will not make an efficient antenna system and will result in a lot of RF energy being absorbed by the boat.

A word of caution about automatic antenna tuners Automatic tuners available today from major radio manufacturers use microprocessors and refined internal software to match the antenna to the transmitter. They are very good at their job, which can create a problem: auto tuners can tune what is effectively an inadequate antenna / ground system. It has been said by some professionals that all you need for a ground plane is to run a wire from your tuner to a metal thruhull and your system will operate. The tuner may indeed tune, but a majority of the energy from your radio is lost in the process and never escapes the boat. The difference manifests itself in being able to talk 1000 miles or the 6000+ miles you can achieve with a good installation. Here's the catch: for all practical purposes, a technician cannot put a "tester" on your system and tell you definitively how good your system is. A watt meter is a tool technicians use that can be put in between a radio and the tuner to give an indication of how well the tuner is operating, but the "business end" of the tuner is the high voltage terminal that hooks to the antenna element (backstay, whip, etc. Figure 2). An experienced

radio technician with the aid of a watt meter and knowledge of a good quality ground installation as outlined previously can make a educated call as to whether the system is working properly, but the real proof is whether you can make 3000+ mile radio contacts consistently. Apply the rules that have proven to be effective: 100 Square feet of ground surface area connected with wide copper foil and good metal to metal surface area contact when making ground and antenna connections. This is an ideal installation, and not every boat will allow these goals to be met, but do your best.

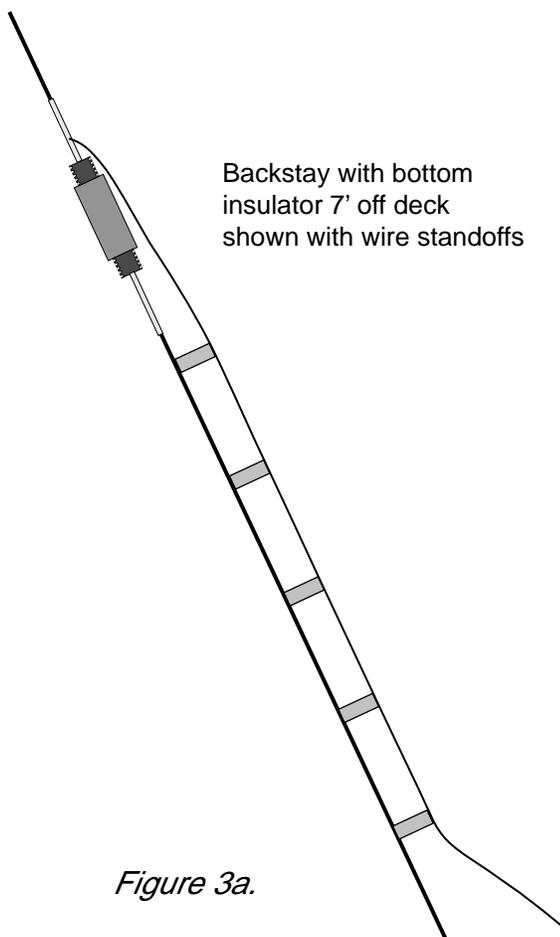


Figure 3a.

Primary Antennas Your primary antenna will usually be an insulated part of your rigging or a standing fiberglass whip antenna in the back of the boat. These are both "longwire" antennas, essentially a piece of wire held up in the air. An antenna could also be as simple as a piece of 14 gauge wire (back to that in a moment). The decision to insulate the rigging or use a whip is usually driven by cost and aesthetics as either

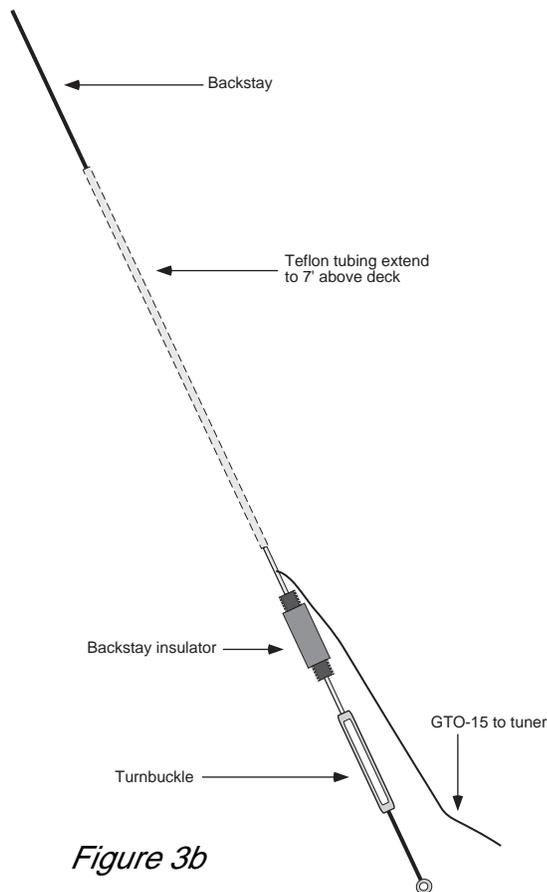


Figure 3b

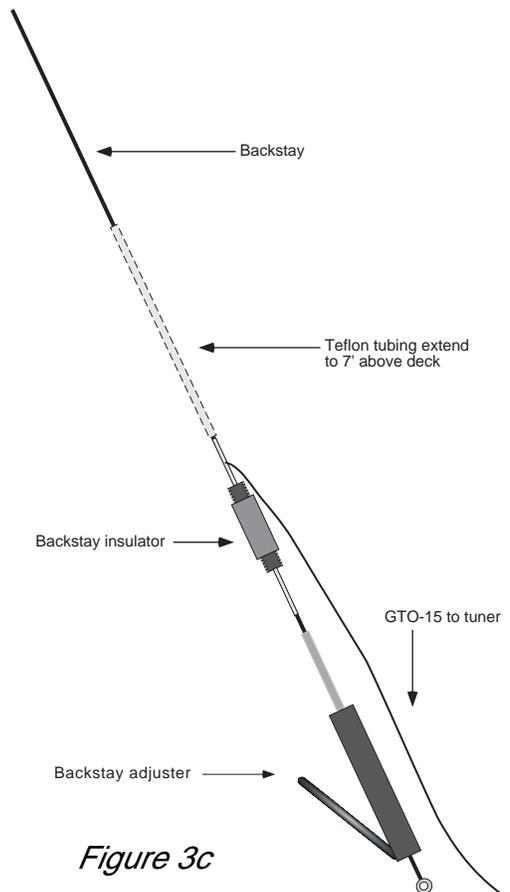


Figure 3c

will do a proper job. On a sailing yacht, insulating the backstay is common as it makes for a clean installation. The traditional guidelines for a backstay antenna are to have the bottom insulator 7' off the deck and 3' down from the masthead. Insulated sections of backstays longer than 35' are not required, however a longer antenna may perform better. The RF output from the tuner can be as high as 5000 volts at very low current and grabbing the uninsulated part of an antenna while the radio is being transmitted can cause a serious RF burn or could even be lethal! Therefore the bottom insulator is usually put 7' off the deck for safety reasons (Figure 3a).

There are other styles of fabricating a backstay antenna that offer better performance (Figure 3b, 3c). The bottom insulator can be mounted at deck level or may be completely unnecessary if the backstay chainplate terminates to fiberglass or wood construction, which acts as an insulator. With this type of installation, the backstay must be insulated from possible contact with crew by putting an insulating material over the backstay, turnbuckle, etc. The best material is Teflon tubing, which has very good insulating properties, however the tubing must be installed on the backstay when the backstay is being fabricated by your rigger. A distant second best material is white nylon "snap on" shroud cover products available in chandleries. Attention must be paid to disconnect items such as bonding system wires that may be attached to the backstay chainplate(s). Also note that a bottom insulator will have to be installed above a hydraulic adjuster (3c). You may wish to hire your marine electronics dealer to inspect your boat to make installation recommendations.

Insulating a backstay can be expensive depending on what type of rigging you have, wire rope, rod or as on some race boats Spectra, Kevlar or Technora. The initial cost of installing insulators sometimes leads people to consider using a standing whip antenna instead. The whip is tried and true and will do the job you require. There are whip antennas specifically made for SSB use and are 23' or longer.

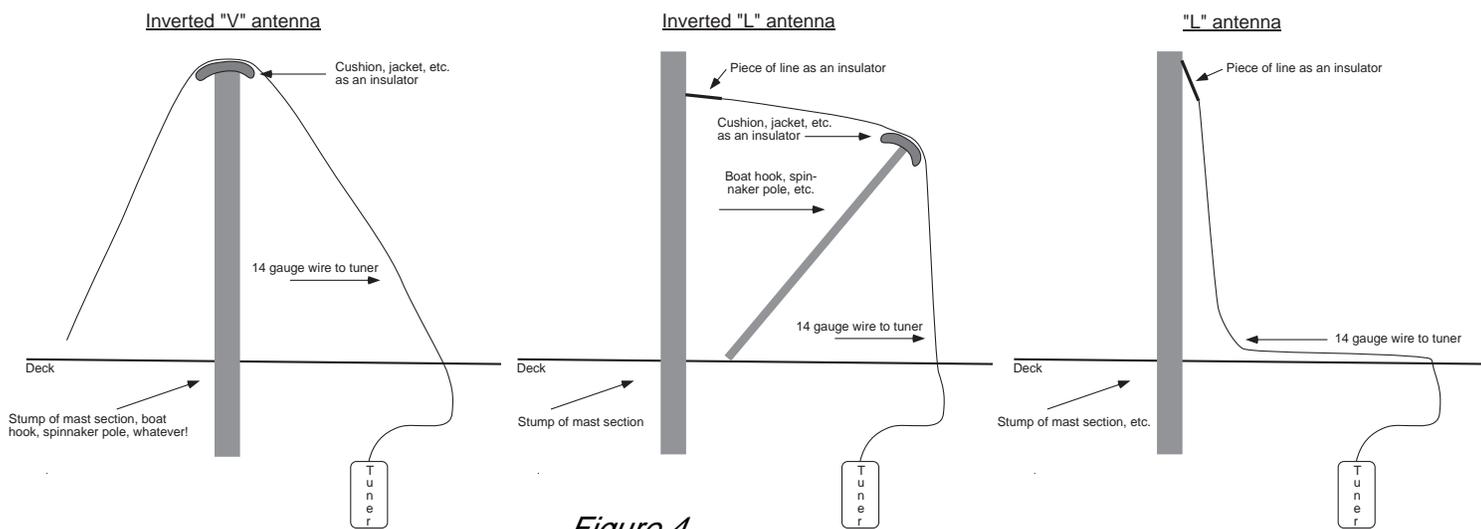


Figure 4

Emergency Antennas

Take what we know about a primary SSB antenna from the above text and an emergency antenna is pretty simple; a piece of wire, 14 gauge or larger, 23' or longer up into the air coming from the automatic antenna tuner. The automatic antenna tuner will tune almost anything attached to it. The \$5 emergency antenna solution is 40' of 14 gauge wire with a ring terminal soldered on to one end sized for the output stud on your tuner.

The emergency scenario is: you loose the rig and along with it your insulated backstay or transom mounted whip. “Lets tell everyone” being the second or third thing on your mind, disconnect what’s left of the wire that went from the tuner to the now missing antenna and attach your \$5 emergency antenna, stringing it up in the air by whatever means you have left on board (spinnaker pole, boat hook, etc.). If 40' is more wire than you are able to rig up, cut the new antenna as needed (no less than 20'). The antenna wire can be in an “inverted V”, as in up and over a pole or mast stump, an “L” and an “inverted L” or really whatever you can rig (Figure 4). Physically isolating the wire from the support pole with a piece of line or a cushion on top of the pole will improve performance. It’s really that simple because the high quality ground system that you installed at the beginning of this article is still in tact and the power of the computer inside your automatic tuner does the rest.

Wire, Connectors and Techniques The cost of high quality materials are a drop in the bucket when compared to the cost of the equipment you're installing. Marine specific materials do cost more, but the performance benefits over the long haul will be worth it. Tinned wire and connectors for corrosion protection, wire of the proper size, sealing tape to keep you connections dry and flat copper strap are essential parts of a good installation. The basic techniques are soldering connections, keep all connections bone dry and good electrical connection surface area contact.

There are usually two cables from the radio to the tuner, one for RF (coax) and one to supply operating voltage and/or control signals to the tuner. Follow your radio manufacturers recommendations for the control cable and consult your dealer. In most cases, the RF connection from the radio to the tuner should be made with RG-8U or RG-213 coax. This is the big 1/2" stuff and will offer the least resistance to the RF energy. RG-8X or "mini 8" may also be used with a slight reduction in performance but may be much easier to install. The antenna connectors are UHF type PL-259. They are tricky to make up the first couple of times and may require a professional hand. PL-259s are available in solder and crimp types. Purchase the solder type unless you have the professional \$100 UHF crimp tool for the crimp type connectors. If done correctly, the solder type connectors are better and should be your first choice.

From the tuner to the antenna element, use GTO-15 type single conductor wire. GTO-15 is a high voltage wire with a thicker jacket and an insulation material rated to 15,000 volts. Since a SSB antenna can develop much higher voltages than what standard boat cable is rated for, GTO-15 reduces signal loss and the risk of shock. The connection at the output of the tuner is a threaded stud. A properly sized ring terminal should be soldered to one end of the GTO-15 and affixed to the stud. Then the whole thing, stud, ring terminal and wire should be wrapped with a self-sealing waterproof tape such as 3M 2242. 2242 is a soft tape with a 200% stretch factor, and when applied with a little tension, it will make a watertight seal. As the GTO-15 leaves the tuner try not to run it close to other wires and metal objects. You will usually exit the hull with a watertight through deck gland of some type and then terminate the wire at the antenna element. If you are going to an insulated backstay, strip off 3" of the GTO-15 insulation, wrap the conductor around the upper swage several times and clamp with a small hose clamp. The last step is to wrap with a sealing tape (i.e. 3M 2242). **KEEP THE CONNECTION DRY** and it will last! If your backstay is wire rope, clamp on to the swage and not the wire rope. The fact that the swage is a smooth surface enables better surface area contact with the GTO-15 and it will provide for a better seal with the sealing tape.

To further reduce the amount of RF energy absorbed by the boat, standoffs can be fabricated to support the GTO-15 away from the backstay between the deck and the insulator (figure 3a). You can make your own standoffs with UV resistant tubing and electrical tie wraps.

HF Radios and Battery Voltage

When transmitting a SSB radio on a 12 volt DC system, the peak current draw can be 25 amps for an average 150 watt radio. This amount of current requires heavier gauge wire than other equipment on board. For the supply wire size you require, refer to the “wire size to % voltage drop” table from the ABYC or a similar table printed in the Ancor Marine Grade Products catalog.

HF radios are more sensitive to low voltage than other marine electronics. When voltage at the radio goes down, so does the RF output power. Extra attention needs to be paid to the DC supply of the radio to ensure optimum performance.

DC Wiring Techniques

The DC wire size, connections and the point where the wire is terminated are critical. Most SSBs sold come with a factory made two conductor power cable, which has a plug at one end and raw wires at the other. The supplied cable and its wire size are suitable for the length of the supplied cable only. If the supplied cable is long enough to connect from your radio to the DC distribution point (usually the DC breaker panel) you are in business. If the cable is too short, as is the case with many “remote head” style SSB installations, the supplied cable will need to be cut near the connector and a larger gauge spliced on. The preferred method for splicing is soldering and encapsulating the splice with marine grade heatshrink tubing, or using a properly sized “butt” splice crimp connector. Ancor Marine Products manufactures an excellent butt splice which incorporates heatshrink as part of the connector. As with all crimp type connectors mentioned in this article, use a crimp tool intended for non-insulated terminals that puts a dimple in the crimp for a superior mechanical connection.

Choosing the DC distribution point usually means finding a spare circuit breaker (or blank) in your DC panel and replacing it with a 30 amp breaker. In some cases all breaker positions are in use and an additional DC sub panel will need to be installed. Technically, an inline fuse does the same job of a circuit breaker, however a breaker is the superior method of DC distribution on a boat and should be used. A breaker or fuse **MUST** be at the supply end of the wire feeding the radio, even if the manufacturer supplied cable has fuses in it at the radio end. Although uncommon, some boats have been built with wire that is of too small a gauge to supply the existing DC distribution panel. This is a good item to have a professional look at for assessment. Corrosion or loose connections at the DC panel must be corrected as well.

When terminating the supply wire, select the correct size ring terminal for the wire gauge and the screw size that is going to go through the terminal. 30 amp breakers usually use a #10 screw. Soldering the wire to the terminal is highly recommended. Slip on some marine type heatshrink tubing around the terminal and wire for a professional finish that provides a strain relief and water protection for the wire.

Conclusion By following some basic guidelines and techniques a high performance Single Sideband radio installation can be achieved and with a little extra effort the system will last for years. Good quality materials improve performance and can greatly extend the life of the installation. The quality of the installation will impact your satisfaction with your radio purchase, not to mention the fun and piece of mind in being able to make long distance communications from anywhere on the globe.

This article assumes of the reader a basic knowledge of marine terminology, yacht construction methods and seamanship. If you don't understand concepts or specific details of the content herein, we strongly recommend you consult a marine radio professional for clarifications prior to making equipment purchases or attempting an installation. Do the job once and do it right the first time.

About the author Eric Steinberg is the owner of the marine electronics and consulting company Farallon Electronics, located in Sausalito, California. He is a FCC licensed Marine Electronics Technician specializing in electronic systems on performance yachts. His areas of expertise include SSB / satellite communications, navigation, weather systems and yacht racing instrumentation. He is a sought after racing yacht specialist with in-depth experience on performance boats from IMS Maxis to Melges 24s and was a member of the America True challenge for the Americas Cup 2000. Eric has been sailing since he was 5 years old and has many ocean miles to his credit.

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Materials, Manufacturers and Vendors

- 150 watt Marine SSB radio & tuners Icom, Furuno, SGC (electronics dealers)
- Copper ground strap Newmar, Farallon Electronics
- Copper braid, 1" tubular Farallon Electronics
- RG-8U, RG-213, RG-8X, GTO-15 Ancor Marine Products (electronics dealers & chandleries)
- Backstay insulators Navtec, Ronstan (rigging shops)
- Whip antennas Shakespeare, Glassmaster (electronics dealers & chandleries)
- Marine heatshrink tubing Ancor Marine Products (electronics dealers & chandleries)
- Ferrite chokes, type 31 material Farallon Electronics
- Crimp terminals Ancor Marine Products (electronics dealers & chandleries)
- UHF PL-259 connector Amphenol (electronics dealers & chandleries)
- 3M 2242 sealing tape Farallon Electronics
- UltraTorch pro soldering and heat tool Farallon Electronics
- Crimping tool for non-insulated terminals Klein Tool, tool supply stores, Home Depot

ABYC	http://www.abycinc.org/
Ancor Products	http://www.ancorproducts.com/
Farallon Electronics	http://www.farallon.us/
Navtec	http://www.navtec.net/home/index.cfm
Newmar	http://www.newmarpower.com/
Ronstan	http://www.ronstan.com/marine/
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