How To Adapt The 'New' 2.4gHz Gear To R/C Submarines

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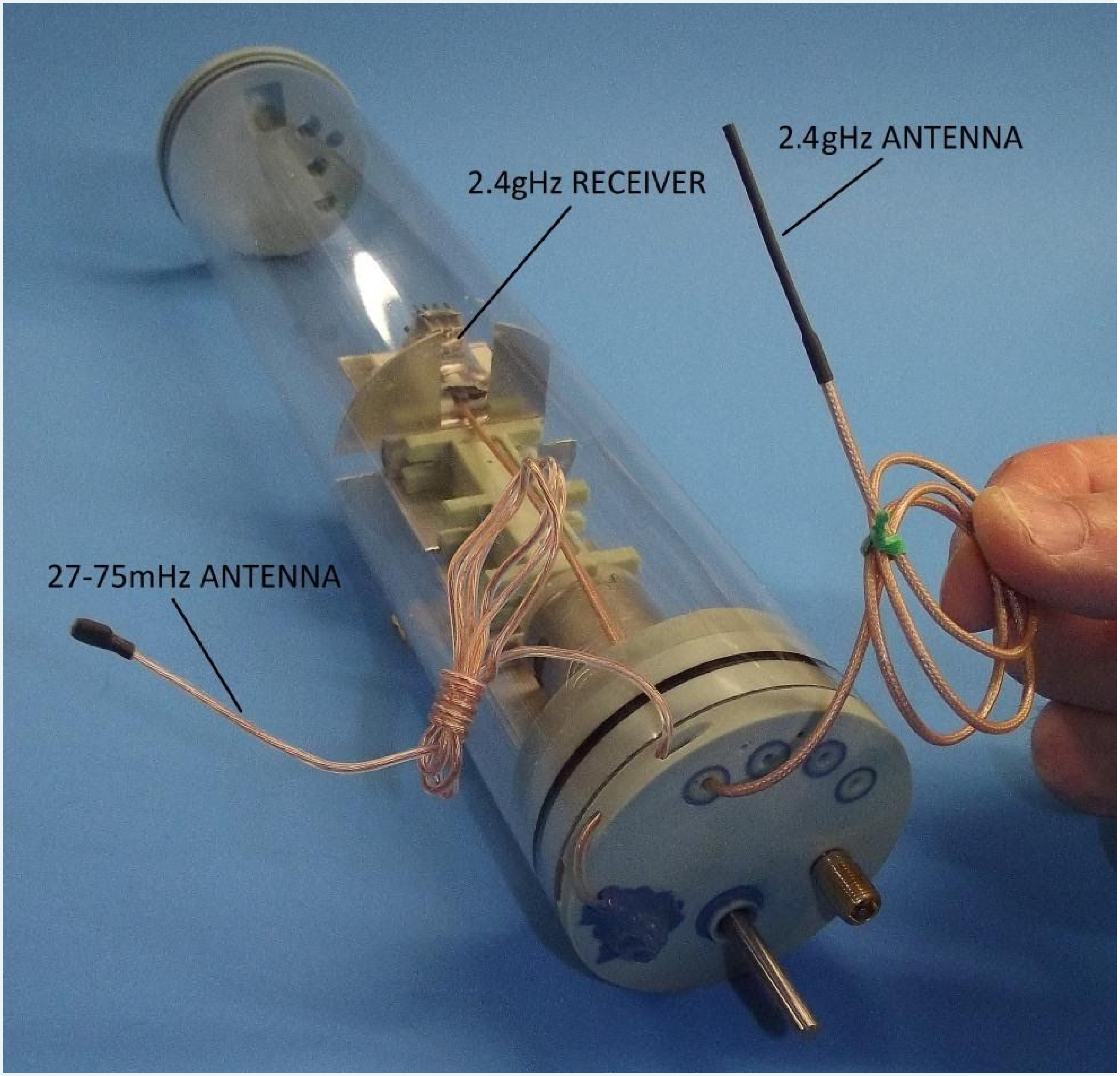


2.4-gigga-Hertz (2.4gHz) radio frequency -- the band at which all of today's commonly available radio control (r/c) systems operate -- does not penetrate water. In the past we r/c sub drivers enjoyed r/c systems that operated in the 27-75mHz bands -- radio frequencies (RF) well below the resonate frequency of fresh water. With that old gear we had the ability to operate the model submarine to considerable depths yet still maintaining complete control of the model -- the radio link between topside transmitter and submerged receiver was little atenuated by fresh water.

However, with the almost over-night switch within the r/c system industry from the lower frequency bands to the relatively high 2.4gHz band we r/c submarine drivers are now screwed! Using this new gear we denizens of the deep can no longer plunge our model submarines to great depths. Today, we are married to the surface, and if we are to be in control of our model submarine via radio control the receiver antenna must project up into the air. The goal of this instructional pamphlet is to demonstrate how to get the r/c system antenna off the receiver and up high atop the sail, resulting in the ability to at least operate your model submarine at 'periscope depth'. Not as good as it was with the old gear, but better than being a total surface-runner.

The objectives of this instructional pamphlet:

• establishment of how much coaxial cable is needed between receiver and topside antenna
• make up of coaxial cable conductor and shield to the receiver
• use of a packing gland to make a watertight passage of coax cable through the Sub-driver
• forming the 2.4gHz receiver antenna at the upper end of the coaxial cable
• working out a means of hiding the receiver antenna within a 'periscope'
• setting the receiver channel fail-safes to drive the model back up once the antenna dunks beneath the surface

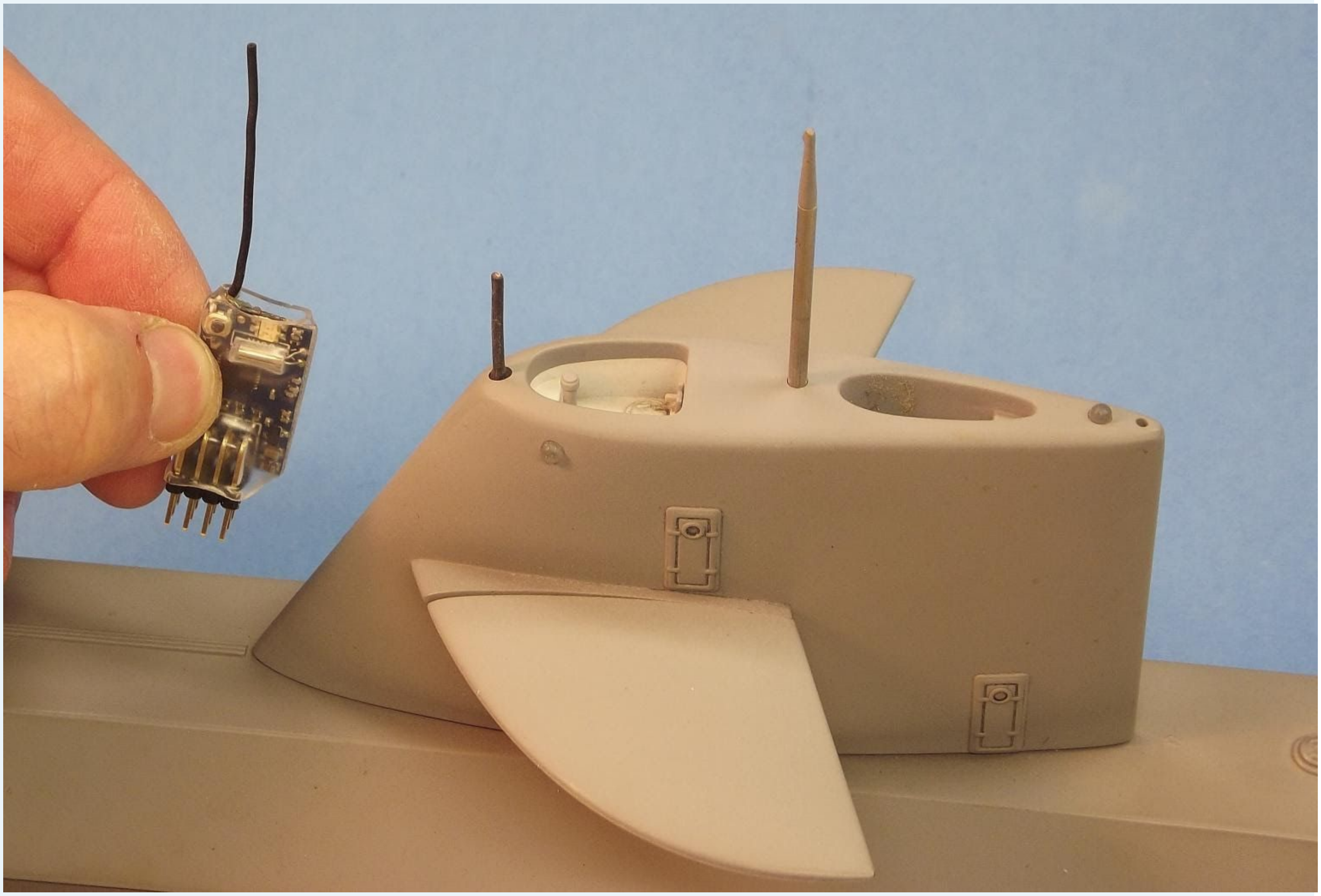
Before doing anything else you need to establish that the r/c system is working fine before proceeding with the receiver antenna modification.
Read and understand your r/c system set-up and receiver-transmitter binding instructions! First task is to get your transmitter talking to your receiver -- this is the initialization of receiver to transmitter.

2.4GHz RECEIVER AND THE 'ANTENNA PROBLEM' Unlike the lower frequency r/c systems, the exceptionally high frequency of 2.4gHz demands strict adherence of receiver antenna length and the need to maintain an unobstructed line-of-site orientation of the receivers antenna to that of the transmitters antenna. The very short wave form of the 2.4gHz signal demands the use of a very short, full-wave antenna -- this is why it is so easy to block the signal between transmitter and receiver: should not a sizable fraction of the wave impinge the antenna, very little signal gets to the receiver and drop-out will occur. Hence the need to get the antenna out of the WTC/Sub-driver and positioned up high atop the sail. The agent of receiver antenna relocation is the thin gauge RG-178 coaxial cable provided.

I would be negligent not to credit the early pioneers of r/c submarining. Guys like Mike Dorey. Guys who, forced by location, where only salt water was available to them, had to devise means to run their receiver antennas up high into the sail of the model submarine. To sail in salt water, which blocks even the 27-75mHz RF signal. These guys showed how to extend the antenna out from the watertight enclosure and up where at least some fraction of the antenna projected above or even with the raised periscope. This was a relatively easy task with the 27-75mHz r/c systems as those receiver antennas were of fractional lengths of the systems full wave form, so there was a lot of latitude as to how much signal got to the antenna, i.e. even a 1/4" of such an antenna above salt water was enough to ensure detection by the receiver even out to a two-hundred foot cross-range.

However, the critical operating perimeter of the 2.4gHz system is the fact that the 1.25" long antenna is a full-wave antenna -- it either gets the full wave form or the signal is not likely to be detected by the receiver. Extending the antenna length by anything other than a shielded cable will result in de-tuning of the receiver detector circuit and the system won't work.

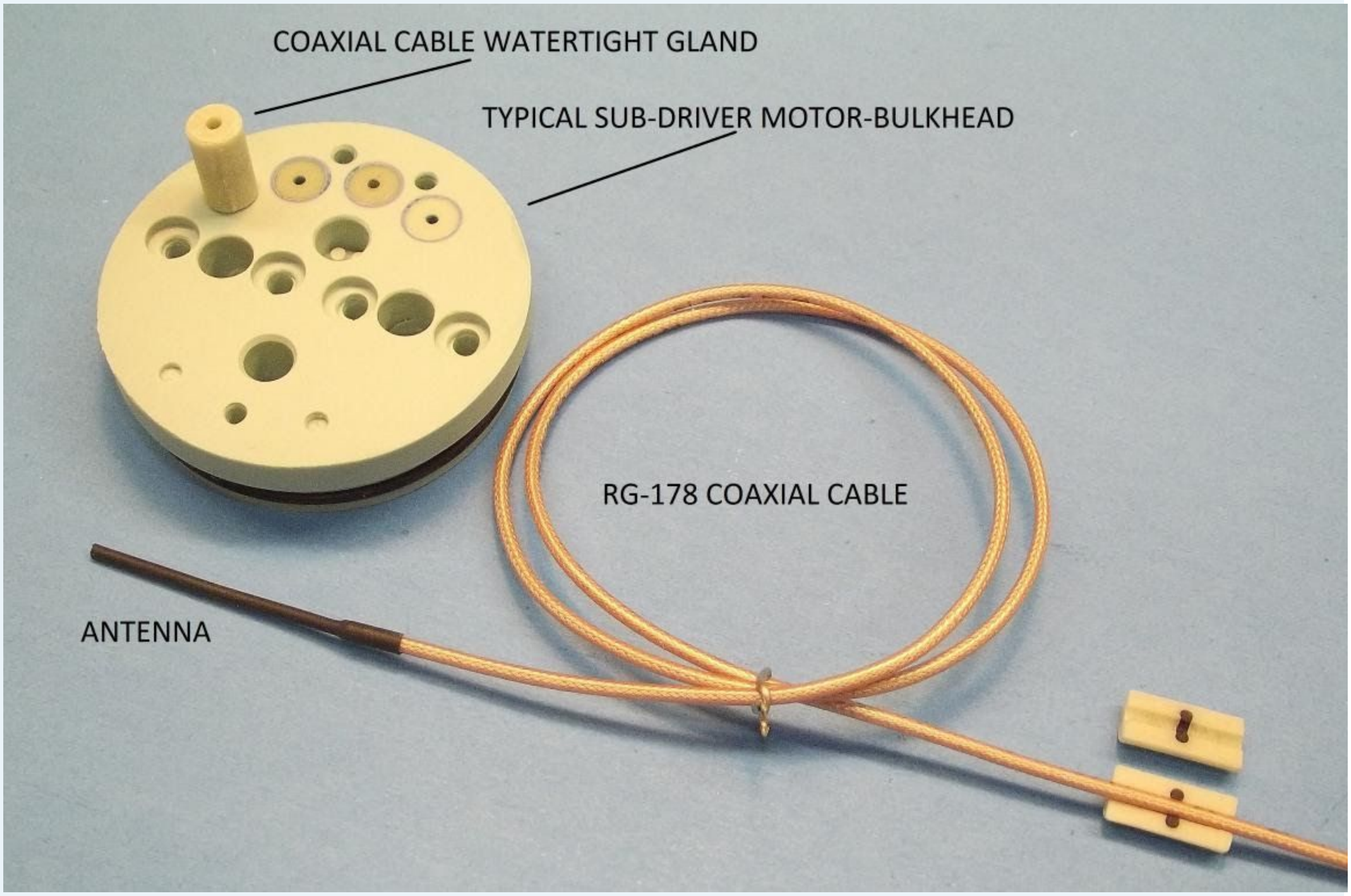
So, to get the 2.4gHz r/c system to work with the model submerged we have to get the antenna off the receiver printed circuit board, and place it to a point atop the sail. And doing so while keeping the antenna geometry to the critical 1.25" length. And insuring an unobstructed (by water or other RF blocking structure) line-of-sight between transmitter and receiver antenna. This repositioning is done by splicing in a length of coaxial cable between receiver and receiver antenna.



Coax is a special type of conductor designed to carry high frequency signals without outside EMF getting to the conductor or permitting RF within the conductor from getting out. Coax typically has a single conductor at its center which is wrapped in a thin insulation; surrounding this insulated conductor is a braded metal shield -- This shield, at ground (typically electrical negative) potential, prevents induction to or from the inner conductor, such induction would change the effective length of the antenna. The short length (1.25") of coaxial cable with the shield pulled away becoming the receivers antenna.

ESTABLISHING LENGTH OF COAX CABLE The length of coaxial cable needed between the Sub-driver/WTC and antenna is of course driven by the scale and model submarine subject. Two-feet of RG-187, .071" diameter coaxial cable has been provided -- more than enough for most model submarine subjects. You will determine the length of coaxial cable you need by a dry-fit of the cable -- one end (dry side) runs into the SD to a position where the receiver will go, and the other (wet side) end of coax sized to run up into the models sail and up into a suitably modified scope tube or mast to place the antenna, atop the coaxial cable, as high as possible. You also must account for the slack in the coaxial cable required to permit easy access the models interior as you lift its upper hull off and set it aside next to the lower hull.
Once the length is established, the excess coaxial cable is cut away and you can proceed with make-up of the dry-side of coaxial cable to the models receiver.

The gland is made up to the coaxial cable after you have soldered the shield and conductor to the receiver pads and mounted the receiver within the SD. Run the bare end of the coax through the dry side open hole in the motor-bulkhead, then install the motor-bulkhead onto the after end of the SD's cylinder. Lightly coat the coax cable with Vaseline, then slide the gland down on it till the gland is about an inch away from the motor-bulkhead hole. Mount the system into the lower hull of the model submarine.



You have already worked out where the antenna atop the coax will reside within or atop the sail and have made provision to pass the coax through the upper hull and sail. Pass the coax up through the upper hull and sail as you place them atop the lower hull. Pull out the slack (easily, this is not a tug-of-war contest!). Push about two-inches of coax down and into the model. The end of the coax is standing vertical where is will sit during operation. Cut off the excess coax. The next step will outline how you strip back the insulation and shield to convert that last inch-and-a-half into the required 2.4gHz antenna

MAKING UP THE COAXIAL CABLE TO THE RECEIVER Once you cut the coaxial cable to the required length, the next step is to remove the receivers factory installed antenna/coaxial cable and make up the dry-side of your coaxial cable.

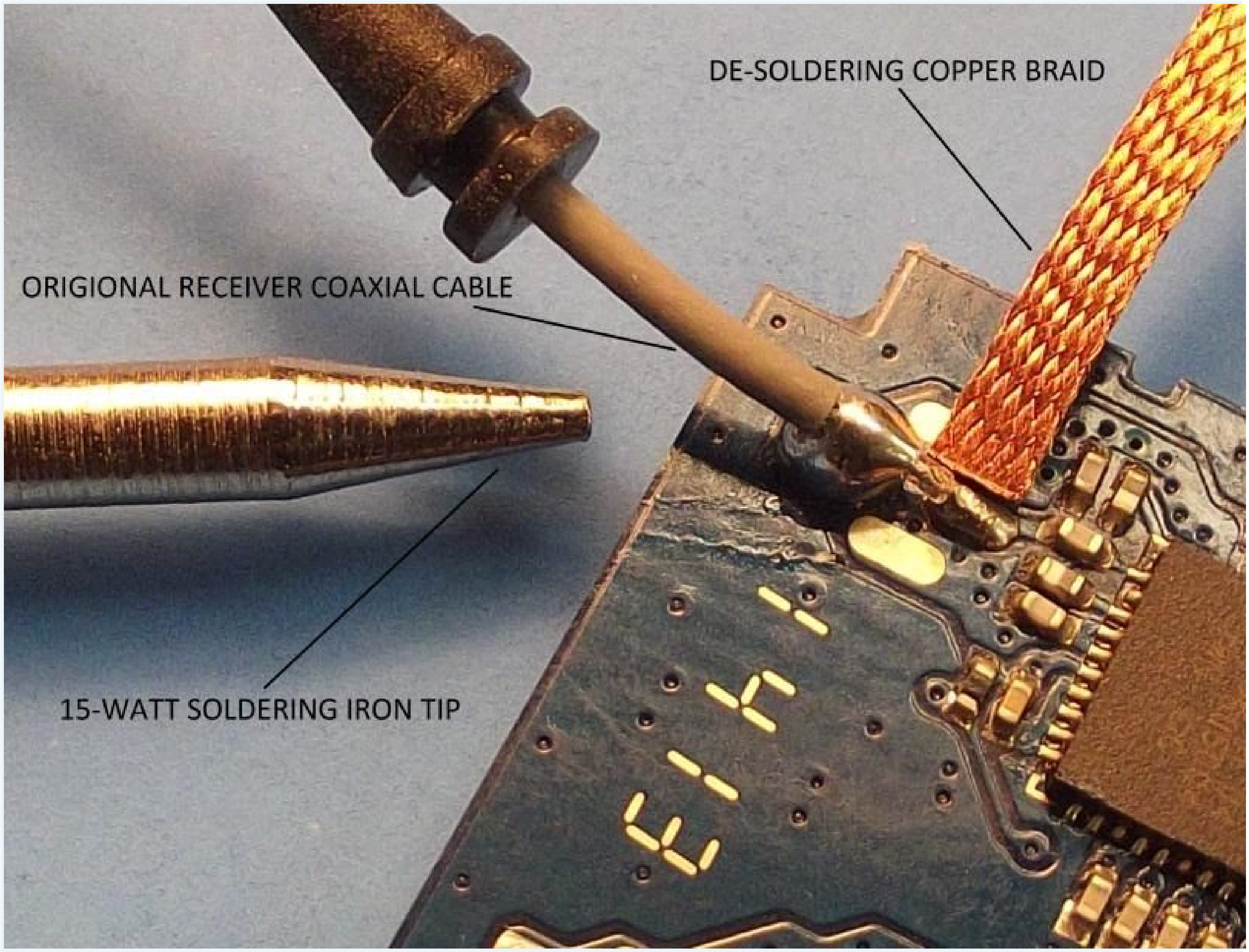
2.4gHz receivers, for the sake of this discussion, are of two types: those with one antenna, and those with two antenna. Why two antennas on some of these receivers? Well, that's because such receivers have two detector circuits on a common board, each with its own antenna -- this two-in-one packaging permits selection of the detector possessing the 'cleanest' data stream; should detector circuit not generate the proper pulse chain, then it's output is shunted, and the detector with the best signal has its output sent on for decoding and use by the models on-board devices. The two-detector receiver is expensive and usually has at least eight-channels. The cheapie four-channel receiver usually has only one detector, hence one antenna

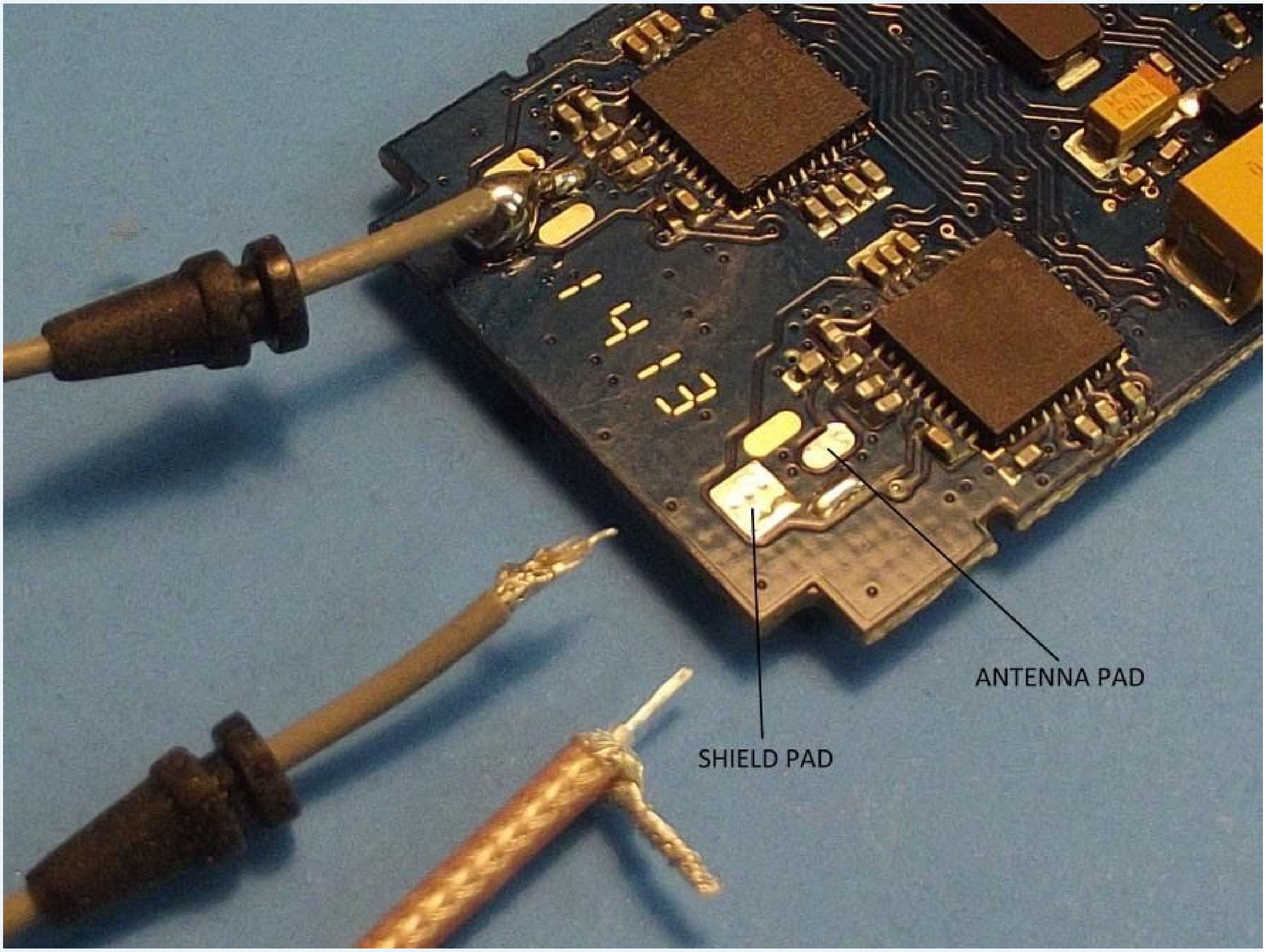
Some receivers have the 1.25" long antenna directly soldered to a pad on the receiver printed circuit board (PCB). Other type receivers, extend their antenna a few inches clear of the PCB through a length of very small gauge coaxial cable. The type receiver with the antenna directly attached to the PCB present a special problem -- the lack of a dedicated grounded solder-pad for our coax cables shield; we are compelled to run a jumper wire from the coax cable shield to the nearest grounded point we can find on the receiver board (or, as illustrated the negative side of the pin-connector bus).

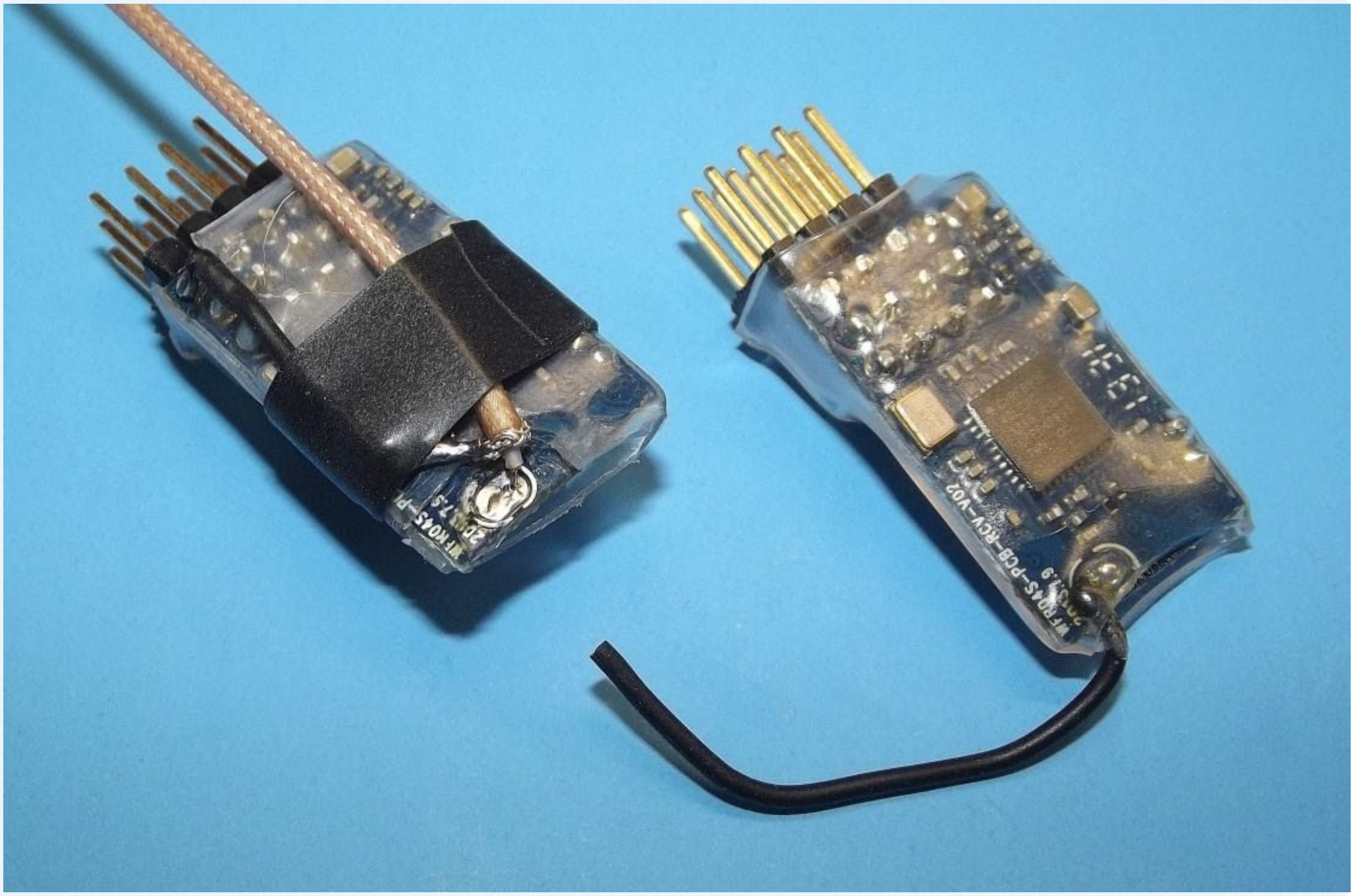
Caution: after exposing the receiver PCB, make sure you hold the receiver by the edges of the PCB and don't touch any of the exposed conductors on the face of the PCB -- the microprocessors are sensitive to electro-static current, and you can cream the entire receiver if you're not careful. Once work is done either protect the conductors with heat-shrink tubing or insert the receiver back into its original case.

Regardless of receiver type, the objective here is to move the receiver antenna (or one of the two receiver antennas) off the receiver board and move it a considerable distance from the SD housed receiver, to a position up high in the model submarines sail, were it will be in the air as the model cruises submerged at 'periscope depth'. Placed between the receiver and the relocated antenna is a length of small-gauge coaxial cable (coax).

OK, enough background -- now, on to how to solder the receiver end of the coax to the antenna and ground pads:


DE-SOLDERING COPPER BRAID
ORIGIONAL RECEIVER COAXIAL CABLE
15-WATT SOLDERING IRON TIP


ANTENNA PAD
SHIELD PAD



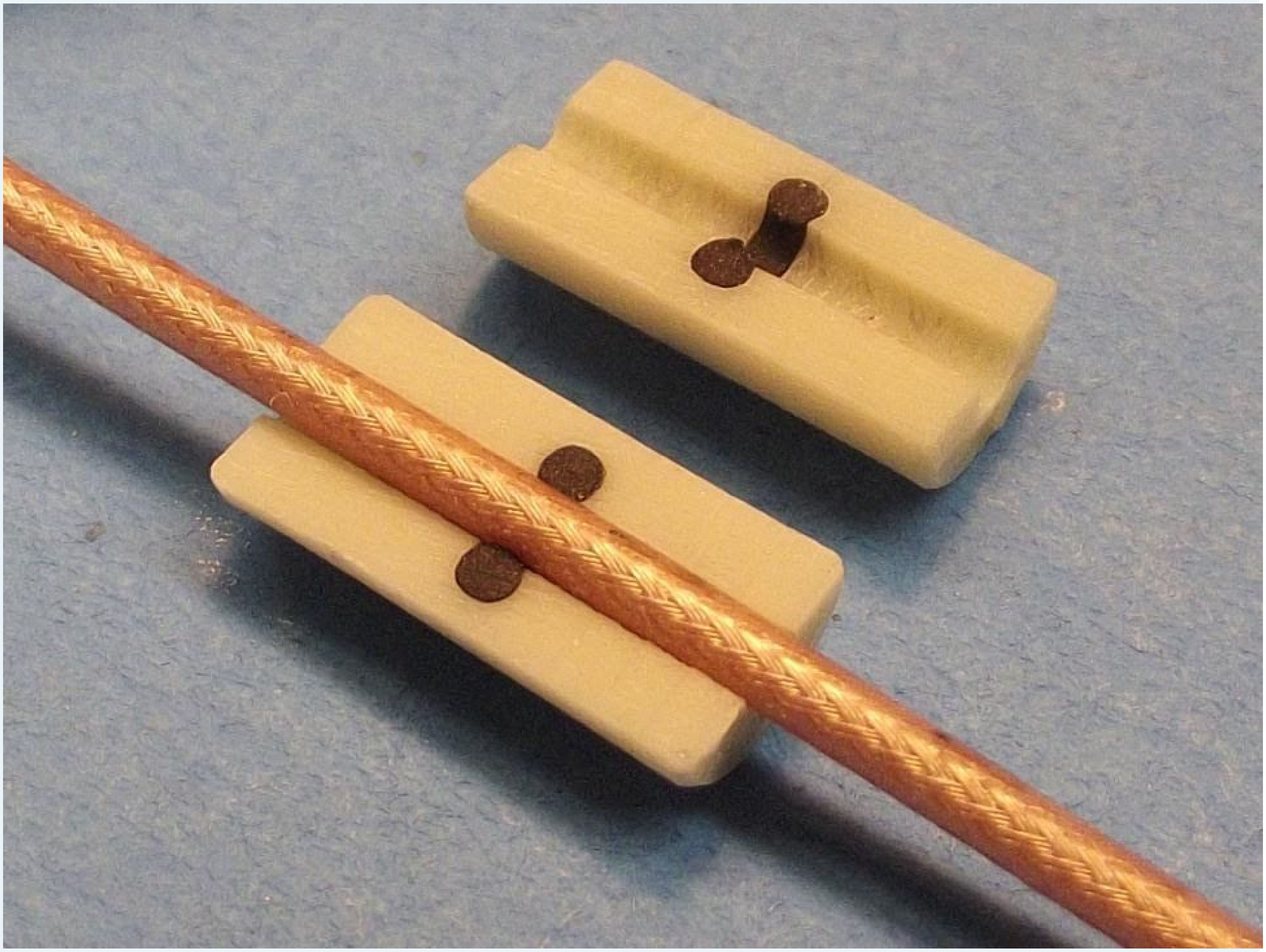
1. De-solder the existing receiver antenna or coaxial cable unions at the receiver PCB. This is done by heating the solder and either wicking it away through capillary action or use of a molten 'slurp gun. One the binding solder has been removed from between the receiver antenna and shield pad, the antenna/coax is pulled away. At this point the crystallized rosin (an artifact of the original soldering job) has made a mess on the face of the PCB -- this is easily removed with a stiff lacquer thinner drenched acid-brush and a low pressure air blow-down.

2. At the dry-side of your coaxial cable remove 1/4" of outer insulation, pull back the shield and roll it between your fingers for form a lug you can solder too. 1/16 from the shield, strip the insulation away from the conductor. Tin (pre solder) the shield lug and conductor. It's vital to keep the distance between conductor and shield as short as possible -- if you can remove more conductor and insulation after the tinning and still achieve a good solder joint at the receiver antenna pad, do so! Solder the coaxial cables conductor to the receivers antenna pad. If the receiver has a ground pad, then make use of it and solder the coaxial cables shield to it. If there is no defined shield ground pad on the receivers PCB, then run a jumper from the coaxial cables shield and make it up to a clearly defined portion of the receivers negative bus. Strive to make the jumper wire as short as possible. Where possible provide some form of strain-relief -- this to immobilize the coaxial cable from flexing at the receiver PCB solder pads.

3. The coaxial cable watertight glad is prepared within the motor bulkhead, and the receiver installed to its assigned position within the Sub-driver. The wet end of the coaxial cable is lightly greased and run through the gland, leaving about 1/2" of slack between the forward face of the motor-bulkhead and receiver

4. The receiver is either returned to its factory case or wrapped in heat-shrink tubing to protect the exposed conductors from shorting out against the Sub-driver device shelf

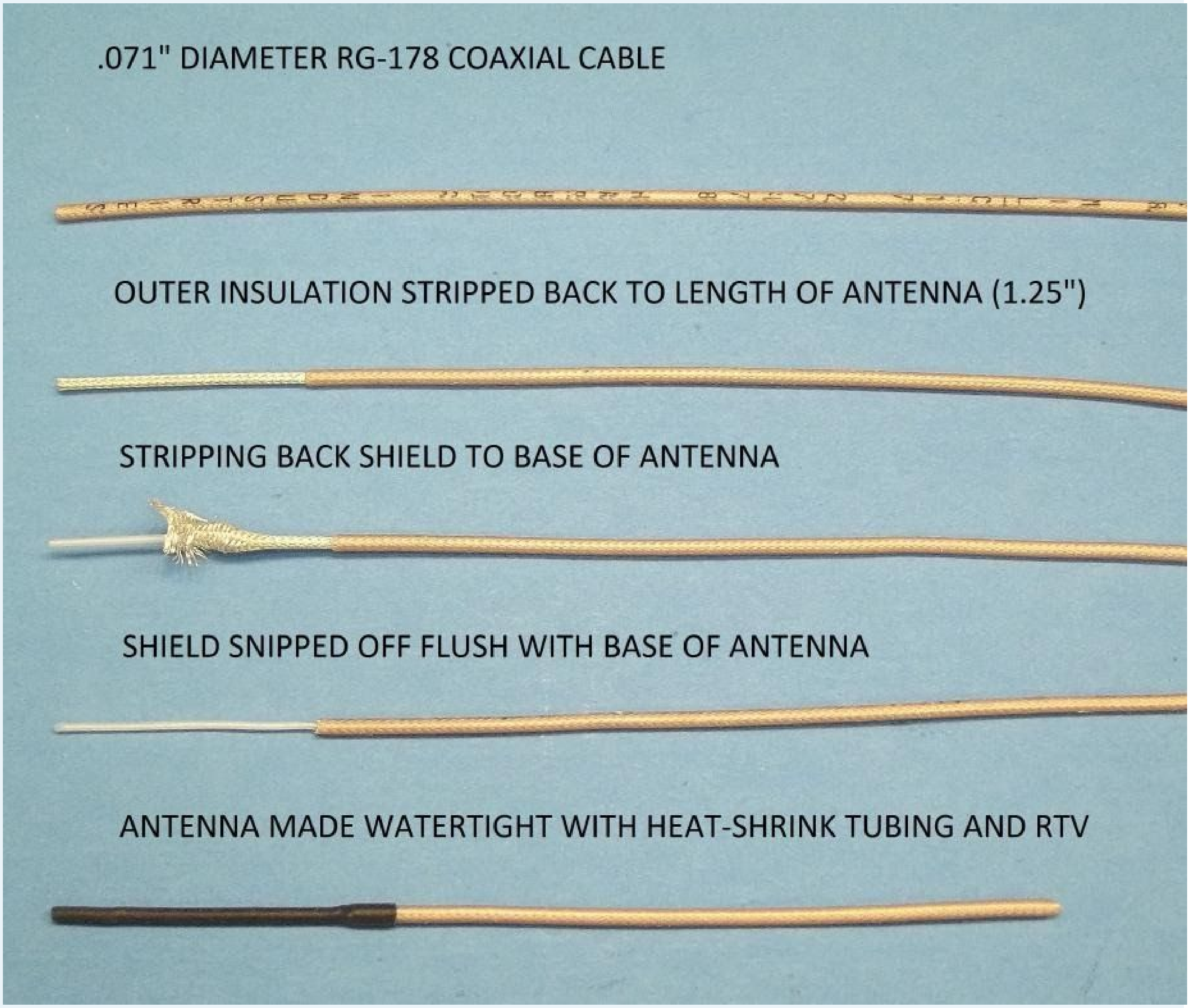
THE COAXIAL CABLE SUB-DRIVER WATERTIGHT GLAND Looking very much like our standard 1/16" (.062") pushrod seal, the coaxial cable gland is in fact the same device, bored out to receive the .071" diameter of the coaxial cable. It's the function of the gland to make watertight the passage of the coax into the SD. The provided coaxial cable watertight gland is inserted into an unused 1/4" pushrod seal body hole in the motor bulkhead.



An alternative -- if you are presented with the situation where you have more 1/16" pushrod seals set into the motor-bulkhead than your model requires pushrods: Identify the 'unused' pushrod seal and enlarge the bore by drilling through it with a 3/32" bit. This will not damage the rubber sealing element within. However, the larger bore of the converted pushrod seal will now permit passage of the coaxial cable.

FORMING THE ANTENNA FROM THE COAXIAL CABLE CONDUCTOR OK, you've made up the dry side of the coaxial cable to the receiver; you've run the wet side of the coaxial cable through the motor-bulkhead watertight gland; and you've worked out where the eventual receiver antenna will be situated up atop the sail -- either sitting up high or hidden within an RF transparent structure such as a periscope tube, periscope head, or mast fairing.

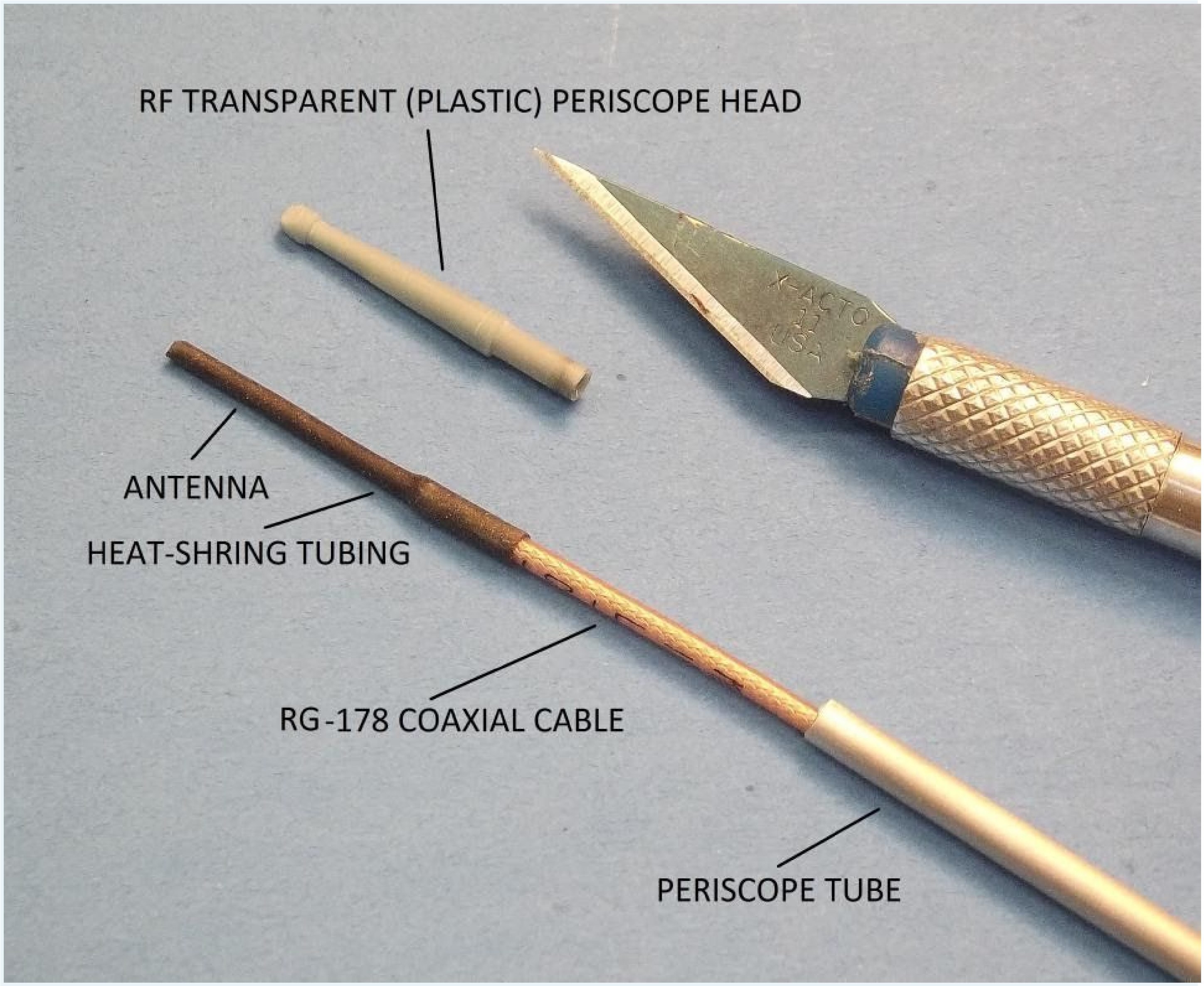
Right now there is no antenna, just coaxial cable -- the grounded shield prevents any RF energy from inducing a signal to the internal conductor. However, if you strip away the outer insulation and shield to expose the correct length of center conductor, now you have an antenna. An antenna of the correct length for the frequency, and well removed from the receiver, safe within its watertight Sub-driver.

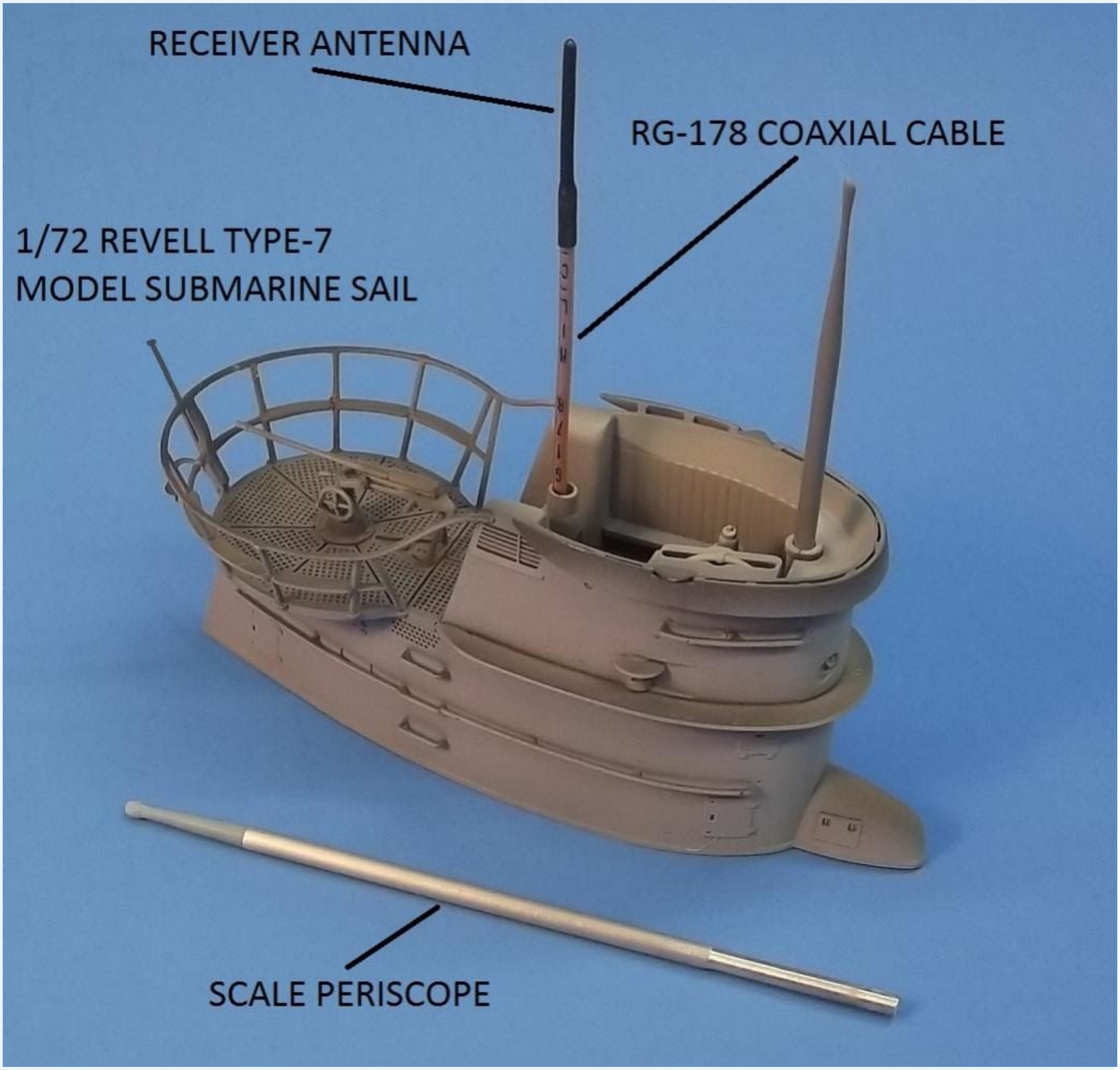


The photo shows the steps taken to produce the antenna. Note that once the antenna is exposed a short length of heat-shrink tube, which will form a protective sheath, is placed over the antenna; this sheath extending down 1/4" over the un-stripped coaxial cable. Heat is applied to tighten up this protective sheath and once cool the tip if filled with RTV sealant and the bottom of the sheath rubbed with the RTV -- this step to insure no water gets at the antenna conductor or shield. The last thing you want is water working its way down to the receiver PCB ... ain't that right, Gene!?

The completed antenna can be situated atop the model submarines sail alone or hidden within any mast, scope head, or shear large enough to accommodate the diameter of the sheaths bulge at the base of the antenna.

HIDING THE ANTENNA ATOP THE MODELS SAIL Most of us drive scale model submarines, and want to hide the receiver antenna as best we can. A sometimes difficult task on model submarines representing subjects in scales smaller than 1/96. The obvious answer is to run the coaxial cable, topped by the receiver antenna up a hollow tube -- that tube representing either a periscope tube or other retractable mast unique to the submarine in question. Metal tubes would attenuate the signal to the antenna, so that portion of scope or mast must be of an RF transparent material (no metal, no carbon) which is pretty much transparent to RF energy in this band.


RF TRANSPARENT (PLASTIC) PERISCOPE HEAD
X-ACTO
11
USA
ANTENNA
HEAT-SHRING TUBING
RG-178 COAXIAL CABLE
PERISCOPE TUBE



As illustrated here, you can employ a metal scope tube, to run the coaxial cable, but provide the upper portion (scope head) within which the antenna resides, as a plastic, RF transparent material. This arrangement puts the scope head above water -- and coincidently, the antenna -- when operating the model submerged, at 'periscope depth'.

Your average real-world periscope tube is between seven and ten inches in diameter, that scales out to around 5/64" diameter for a 1/72 scale model submarine. Study the photo of this 1/72 Revell Type-7C model and how I replaced the number-2 scope provided in the kit with an aluminum tube topped with a hollowed out scope head: the coaxial cable running up the tube, terminating in the antenna that sits within the RF transparent plastic scope head. Obviously, the larger the scale, the easier the task of hiding the receiver antenna.

If you are operating smaller scale model submarines, then the periscope option is not viable -- you will have to hide your antenna within a mast of thicker proportions, such as the snorkel induction mast, or radar mast. Whatever mast you chose, it must be plastic and robust enough to survive handling and minor collisions.

SETTING-UP YOUR RECEIVER FAIL-SAFE POINTS The receiver fail-safe settings work to direct your submerged submarine upward when the antenna dunks under the water's surface. Almost all of the new r/c gear has the fail-safe feature -- the ability of the receiver to generate commands to position the devices it controls to pre-set positions upon loss-of-signal. Positions that will, in our case, work to raise the model in the water. As a loss-of-signal condition would most likely be the result of the antenna dipping beneath the water's surface, it's desirable to have the model submarine seek the surface once loss-of-signal occures ... we want that antenna back up into the air ASAP! These autonomous commands, along with the slightly buoyant submarine (submerged trim will place the waterline an inch or so below the top of the conning tower/sail) should broach the antenna in short order and you can sail along, in control, as before.

When the receiver antenna goes underwater, the receiver looses the signal and, switching to fail-safe mode (the loss-of-signal settings you programmed into the receiver) commands the ESC, control surface servos, and ballast sub-system servo/solenoid/pump controller to work to reduce the depth of your model submarine.

During the set-up of your r/c system you not only 'bind' your receiver to your transmitter, you also configured the receiver fail-safe signals (originating from the receivers memory, not the transmitter) to the devices it controls. When properly set, the receiver, when it loses the transmitted signal, directs the devices to push the model to the surface, to broach the antenna so it can once again deliver the transmitted signals to the receiver, putting you back into the control loop.

channel type control device action fail-safe action

1 servo rudder position center rudder(s)
2 servo bow plane or stern plane full rise
3 electronic speed controller propulsion all-stop
4 servo/pump/solenoid manage ballast water blow/pump out water
5 servo bow plane retract n/a
6 servo stern plane full rise

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