Ditch the glitch

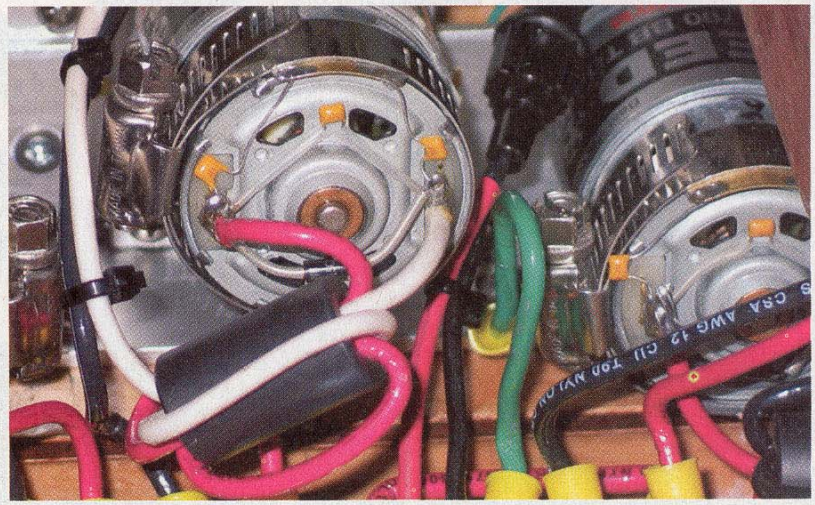
Eliminate radio frequency interference

by David Harrison
Photography—David Harrison

If you've ever lost control of a boat for no apparent reason, or experienced intermittent control or just plain poor radio range, this article is for you. I explain radio frequency interference (RFI), where it comes from, and how we can minimize it to get the most out of our radios. RFI means glitching, and as we all know, in RC boating, a single glitch can lead to disaster.

The source

Brushed electric motors for model boats are notorious generators of RFI. In contrast, brushless motors do not produce RFI, but brushless speed controls can generate RFI and cause glitching if they aren't well separated from receiver antennas. Brushed motors generate RFI in two ways: first, when the commutator switches current to the armature windings, it creates sharp current spikes in the supply wires. The short current spikes contain many high-frequency energy signals that can extend into the hundreds of MHz. The current spikes will cause voltage spikes at the battery and at any point along the length of the wire because of the wire's resistance. The receiver wires can send the voltage spikes right back to the radio. Second, the commutator arcing radiates RFI directly through the air. The supply wires themselves will act as antennas and radiate RFI back to the receiver.

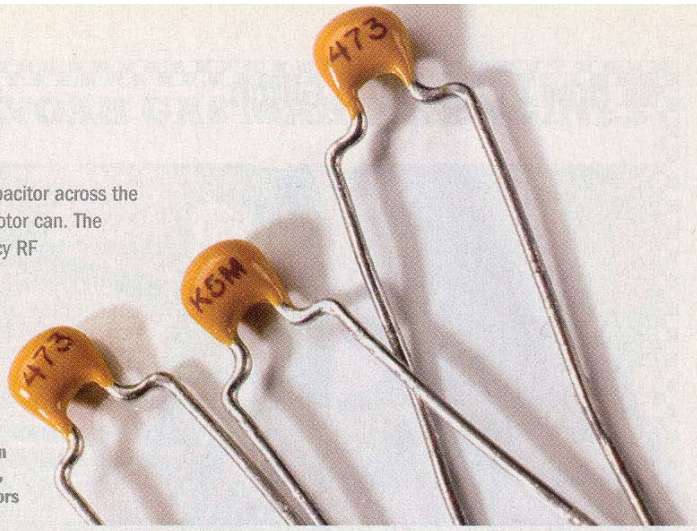


Motors are the main source of glitch-inducing RFI. To fight glitching, this motor is well set up with capacitors, ferrite beads and a transient suppressor.

REDUCING RFI

Supression Capacitors

Suppression capacitors on brushed motors are a must. Solder a 0.1µF capacitor across the motor terminals and a 0.1µF capacitor from each motor terminal to the motor can. The capacitors create low impedance, i.e., AC "resistance" to the high-frequency RF signals but no DC resistance. Do not use capacitors much larger than 0.1µF because their charging and discharging currents put an extra load on the speed control. Be sure to use high-frequency capacitors such as those made of ceramic. Never use electrolytic or tantalum capacitors because they do not have good high-frequency characteristics, and they are polarized (they have positive and negative leads and can only be connected one direction). Keep the capacitor leads as short as possible, and put the capacitors that go from the terminal to the motor's can as close to the terminal as possible.



Capacitors come in all shapes in sizes, but 0.1µF capacitors work best for RC.

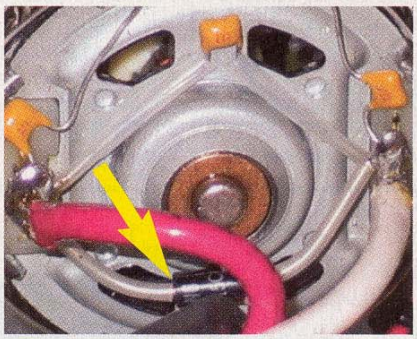
Ferrite beads wrap around electrical wires and suppress RFI.

Ferrite beads

Ferrite beads on the motor wires also help to reduce RFI. Ferrite is a nonmetallic, iron-based compound that greatly increases the magnetism around it. If you place them on the supply wires, they increase their impedance, which acts as a choke to the RFI signals in the wire. Both supply wires should go through one bead as close to the motor as possible. If the beads are large enough, it is even better to wind both supply leads through and around the bead once to make a kind of elementary transformer. If you do this, the current spikes in one wire will cancel out the current spikes in the other wire because the currents will go in opposite directions. Ferrite beads are often hard to find, especially in sizes large enough to accommodate the heavy wire gauges necessary for fast-electric motors. Electronic surplus stores are typically the best sources of them. They are very cheap (about $1 each). The large bulges in computer monitor cables near the monitor end also contain ferrite beads, so if you have a useless monitor, cut the cable open, and see what you find.

Transient voltage suppressors

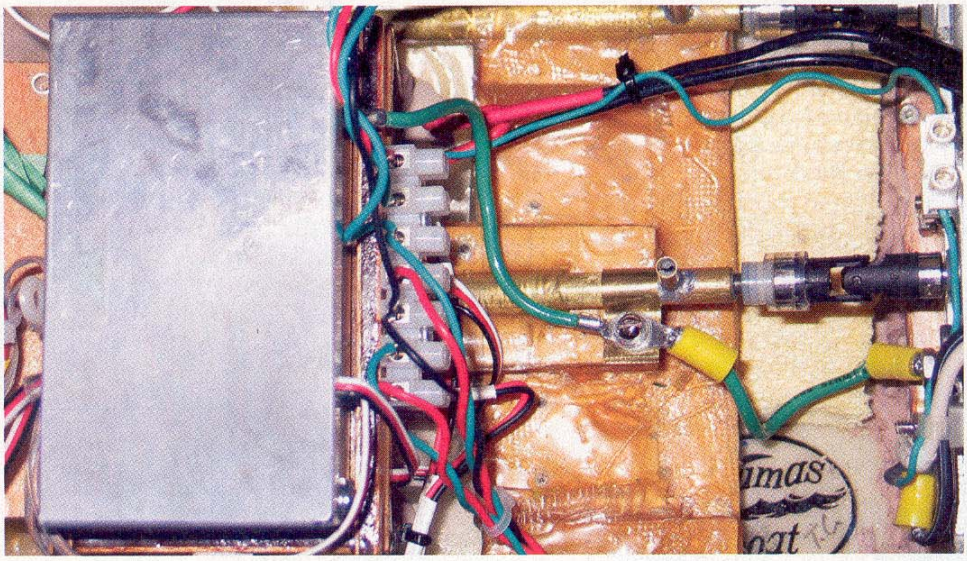
Transient voltage suppressors (also known as transorbs) are bidirectional and will clamp voltage transients to their rated voltage, e.g., 15 volts. They can effectively reduce RFI if you connect them across the motor terminals (with very short leads) in addition to the capacitors. They are available in a variety of voltage and power ratings. The voltage rating should be just a little above your maximum battery voltage (taking into account potential over-charging); thus, for a 12V gel battery (which can get up to about 14 volts when fully charged), a 15V rating is appropriate. If you run 7.2V batteries, a rating of 9 volts is OK, and for a 6V system, use 7.5 volts.



Transorbs (arrow) effectively reduce RFI and work best connected across motor terminals.

SHARED GROUND & POWER WIRING

Shared ground and power wiring involves two or more connections made to the battery terminals at different locations along the supply wires. Also, a conducting loop can be formed easily if there are multiple return paths in the wiring. If any part of the shared wire or loop carries high motor currents, the resistance of the wire can create small spiky voltage drops. If that same wire is shared by your radio, the radio supply voltage becomes spiky as well. Ideally, you would make all connections to the battery in a "star" configuration so that wires are not shared between motors and electronics. In practice, this is difficult to achieve, especially when the typical battery eliminator circuit (BEC) in the speed control is used to supply the receiver power.



Grounding

Ground the motor cans by connecting them to your propeller-shaft stuffing box. Make sure that the propeller end of the stuffing box has a small, unpainted area to make contact with the pond water. Although the pond is not a great electrical conductor, it does act as a weak ground plane and dissipates motor-can RFI signals to ground.

The thick, green wire attached to the aluminum receiver box is a ground. It is attached to the stuffing tube.

Mounting electronics

You can reduce radiated RFI by keeping all possible radiating antennas (motor supply leads, ground leads, etc.) as short as possible. This also helps reduce voltage loss caused by wire resistance. You should also try to keep the sensitive electronics (receiver, servos, speed controls) as far away from the motors and their supply leads as possible. Obviously, speed controls cannot be kept too far away, otherwise, the supply leads will be too long and act as antennas. Just keep the speed control away from the receiver. I mount my receiver in a grounded aluminum box to minimize RFI that radiates directly into the receiver. Be sure to keep the receiver antenna wire far from the motors, their wires and the speed control. For the best possible function, most of the antenna wire should be vertical to get a better signal. This may present a problem in some scale models, but you can use a mast, a scale antenna, a crane jib, etc. Ideally, you won't have to cut the receiver antenna wire, but if you do, disguise it, and then make sure that the remaining conductor is exactly the same length as the piece of wire cut off. Never coil or fold the antenna wire on itself. Also, a longer antenna wire is just as bad as a shorter one; the length has been adjusted carefully at the factory to match the radio band it was designed for.

To reduce your electronics' susceptibility to glitches, install the components carefully and thoughtfully. Make sure that the antenna is as isolated as possible.

All model electronics should be mounted with a degree of vibration isolation. Model boats, especially fast ones, have considerable mechanical vibration inside the hull. Over long periods, this vibration can weaken soft soldered joints and make them unreliable. In the receiver box, mount your receiver in a bed of rubber or polyurethane foam. Always use the rubber grommets or pads supplied with your servos for their mounting, and prevent the servo bodies from touching adjacent surfaces.

For receiver box and speed-control mounting, I use self-adhesive Velcro®. This may sound crude, but it provides a bit of vibration isolation, andtypically, the adhesive on the Velcro® strips is quite aggressive and provides a strong attachment. ⚓

Parts sources

If you're having trouble locating the items mentioned in this article, contact Digi-Key and ask for the following item numbers.

Ferrite beads—item no. 240-2080-ND

Transient voltage suppressors— P6KE15CALFCT-ND (for a 15V 600W application) If you choose a different suppressor, make sure that it's bidirectional and not unidirectional.

Digi-Key; digikey.com