

***Beat RFI!***

An article on

Radio Frequency Interference Suppression  
In Model Boats

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## **Beat RFI!**

Ever lose control of a fast electric boat for no apparent reason? Got intermittent control or just plain poor radio range? Then this article is for you.

David Harrison, of the [Rideau Nautical Modellers](#), Ottawa, Canada, tells us about Radio Frequency Interference (RFI), where it comes from, and how we can minimize it to get the most out of our radios. This sometimes "black art" is explained in an easy to understand way.

In fast electric boats, the largest source of RFI is the main electric propulsion motor(s). Other less important sources are the ESC microcontroller and the movement of metal surfaces (especially different metals) across each other at high speed. Methods to reduce RFI must attack both the sources, and their propagation.

### ***Motor Generated RFI***

Brushed electric motors used for model boats and submarines are notorious generators of RFI. Brushless motors do not suffer from the same sources, although brushless ESC's are complex digital electronic devices and, as such, can also generate RFI if not well separated from the receiver antenna.

Brushed motors generate RFI by two mechanisms. When the commutator switches current to the armature windings, sharp current spikes in the supply wires are created, and also the commutator arcing radiates RFI directly through the air. The current spikes, being of very short duration, contain many high frequency energy signals that can extend into the hundreds of MHz.

The current spikes can find their way back into your radio by two mechanisms.

- The current spikes will cause voltage spikes at the battery, and at any point along the length of the wire due to the resistance of the wire. These voltage spikes can find their way directly back into the radio by the receiver supply wires.
- The supply wires themselves will act as antennas radiating RFI back to the receiver through the air.

### ***Reducing RFI in the motor wires***

#### ***Suppression Capacitors***

Suppression capacitors on brushed motors are a **MUST**. Solder a 0.1 $\mu$ F capacitor across the motor terminals and a 0.1 $\mu$ F capacitor from each motor terminal to the motor can. The motor can will probably not heat up well enough with a regular soldering iron to take the solder well, so some other means of attaching the capacitor wires must be found, e.g. a hose clamp. The capacitors create a low impedance (i.e. AC "resistance") to the high frequency RF signals, but no DC resistance. Do not use capacitors much larger than 0.1 $\mu$ F since their charging and discharging currents put an extra load on the ESC. Be sure to use good high frequency capacitors such as ceramic. Never use electrolytic or tantalum capacitors as these do not have good high frequency characteristics and they are polarised (they have + and - leads and can only be connected one way round).

Quite often these capacitors are installed by modelers, but they overlook some important factors.

- Keep the capacitor leads as short as possible. If you have to compromise between short motor can side versus brush connector side, always keep the brush connector side as short as possible.
- Always ground the motor cans by connecting them to your propeller shaft stuffing box. If they are not connected to anything other than the suppression capacitors, they will act as big fat antennas radiating the RFI coupled into them by the capacitors! Exactly the opposite of what you want! Also ground the negative battery supply lead so that you have ONE 0V or ground reference point.

Make sure the propeller end of the stuffing box has a small area without paint to make contact with the pond water. Although the pond is not a great electrical conductor, it does act as a weak ground plane, dissipating the motor can RFI signals to ground.

- When making the negative battery or ground connections, keep the wires as short as possible otherwise they may act as antennas themselves. Try to have **ONE** central grounding point that all the ground wires and the -ve battery lead go to. This can be the stuffing box clamp, or a central point in a power distribution terminal block.
- It is advisable to use axial leaded capacitors (with the leads coming out on the axis of the body) instead of radial leaded ones. Radial leaded capacitors generally need their leads bent very close to their body, increasing stress at that point which can lead to premature failure.

### ***Ferrite Beads***

Ferrite beads on the motor wires also help to reduce RFI. Ferrite is a non-metallic iron based compound that greatly increases the magnetism around it. The effect of placing them on the supply wires is to 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, since the current will be going in the opposite direction.

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 store are usually the best source for these. They are very cheap – about a buck 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***

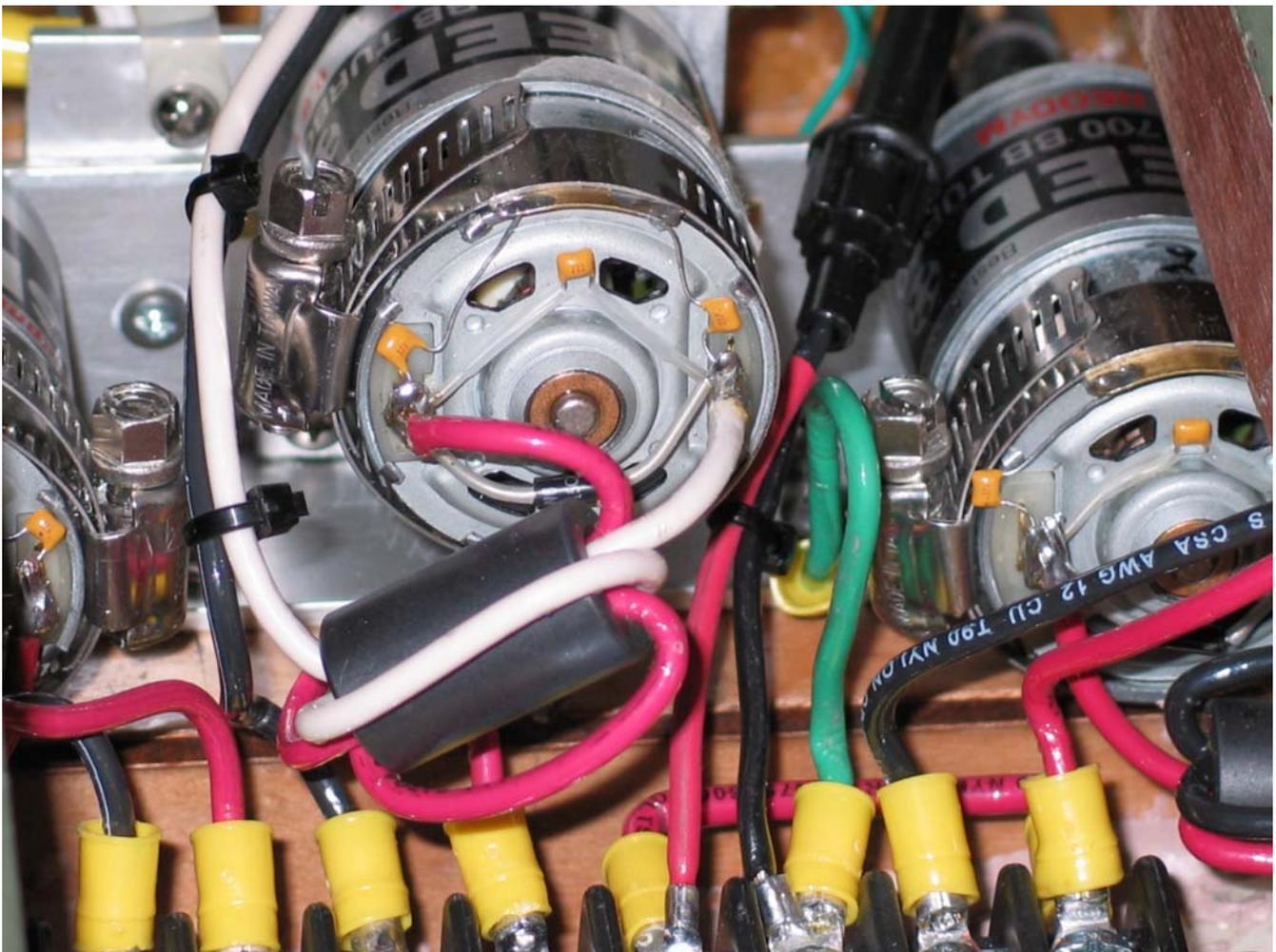
Transient voltage suppressors (also known as transorbs) are like two series back to back zener diodes. They are bi-directional and will clamp voltage transients to their rated voltage, e.g. 15V. They can be very effective in reducing RFI by connecting them across the motor terminals (again with very short leads) in addition to the capacitors. They are available in a variety of voltage and power ratings. The voltage rating should be chosen to be just a little above your maximum possible battery voltage (taking into account possible overcharging). Thus for a 12V gel battery which can get up to about 14V when fully charged, a 15V rating is appropriate. If you are running 7.2V batteries, a rating of 9V is OK and for a 6V system use 7.5V.

### ***Shared Ground and Power Wiring***

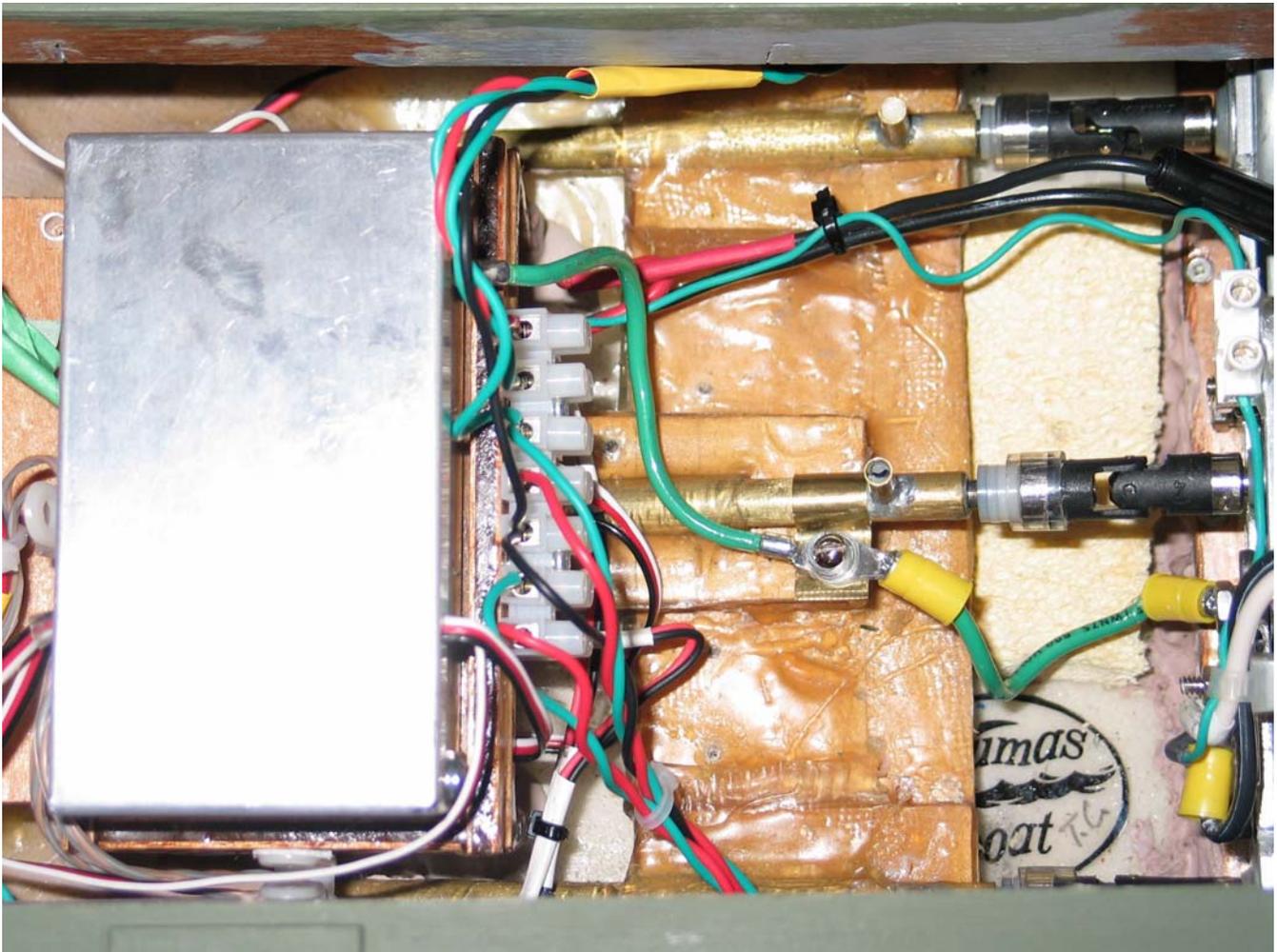
Shared ground and power wiring is when two or more connections are made to the battery terminals at different locations along the supply wires. Also a conducting loop can easily be formed if there are multiple return paths in the wiring. If any part of the shared wire or loop carries high motor currents, the resistance of the wire can create small spiky voltage drops. If that same wire is shared by your radio, then the radio supply voltage becomes spiky as well. Ideally, all connections to the battery should be made 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 BEC (Battery Eliminator Circuit) in the speed controller is used to supply the receiver power.

### ***Example Photos***

**Photo 1 – Motor connections - capacitors, ferrite bead and transient suppressor (just below the motor end bearing).**



**Photo 2 – Ground connections - aluminum receiver box and ground wires.**



### ***Reducing the effects of radiated RFI***

Radiated RFI can be reduced by keeping all possible radiating antennas, i.e. motor supply leads, ground leads, as short as possible. This also helps to reduce the voltage loss due to wire resistance.

The other obvious method is to keep the sensitive electronics (receiver, servos, speed controllers) as far away from the motors and their supply leads as possible. Obviously, in the case of the ESCs, these cannot be kept too far away, otherwise the supply leads will act as longer antennas. Generally keep the ESCs away from the receiver (in the opposite direction away from the motors).

I choose to mount my receiver in a grounded aluminum box to reduce RFI radiating directly into the receiver.

Also keep the receiver antenna wire as far away as possible from the motors, their wires and the ESCs. If your motors are heavy duty types, then the majority of the antenna wire should be vertical to get a better signal/noise ratio. This may present a problem in some scale models, but you can use a mast, a scale antenna, crane jib etc. Preferably, the receiver antenna wire should never be cut, but if you have to, to disguise it, then make sure 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 frequency it was designed for.

### ***Model Submarines***

RFI reduction obviously pertains to model submarines even more so, since space is usually very limited and the effects of loss of control can be much more dramatic!. Thus submariners should pay particular attention to all the above techniques for RFI reduction.

### ***Mounting Electronics***

All model electronics should be mounted with a degree of vibration isolation. Model boats, especially fast ones, have a considerable amount of mechanical vibration inside the hull. Over a long period of time, this vibration can weaken soft soldered joints, making them unreliable and even open circuit.

Mount your receiver in a bed of rubber or polyurethane foam inside your receiver box. Always use the rubber grommets or pads supplied with your servos for their mounting and keep the servo bodies from touching adjacent surfaces. For receiver box and ESC mounting I use self adhesive Velcro. This may sound crude, but it provides a bit of vibration isolation and usually the adhesive on the Velcro strips is quite aggressive, providing a strong attachment.

### ***Sources of parts.***

Ferrite beads and Transient voltage suppressors can be purchased from Model Solutions of Canada ([www.modelsolutions.ca](http://www.modelsolutions.ca)).

### ***Sidebar – About the Author’s Boat***

The photos in this article are from the author’s boat, a 48” 1/20 scale model of PT109. The model is powered by three Graupner Speed 700 Ball Bearing Turbo Neodymium magnet motors. The power supply is a 12V 7AH gel battery. Despite the heavy boat and battery, the boat planes beautifully, and is very realistic at speed. All navigation lights work, the search light works, the rear Oerlikon 20mm cannon rotates under servo control. The twin Browning machine guns and the 20mm Oerlikon cannon have light bulbs in the ends of the barrels. These are hooked up to a custom, self designed sound effects module, which also flashes the guns in sync. with machine gun or cannon bursts. Engine sounds synchronized to motor speed, guns, general quarters klaxon and fog horn sounds are all on this boat.

Next projects on this boat include working 1/20 scale electric torpedoes with counter-rotating propellers and all four working compressed air torpedo launch tubes.

**Photo 3 – The Author’s PT109**

