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Excellent, Easy, Cheap Common-Mode Chokes

"I don't have RFI," you're thinking, "so I don't need chokes."

Bzzzzt! Wrong! You're an HF contester. You need to work stations, especially mults, and, "You can't work 'em if you can't hear 'em." You'll hear more stations, if you choke your antenna feed line(s), because your received noise level will drop.

"I might need common-mode chokes if I were hearing noise generated in my own house, but all I hear is featureless, white, stationary, 'Gaussian' noise. That comes from the atmosphere, the sun or the galaxy, right?"

Not necessarily. The noise made by the switching-mode power supply in the Verizon FiOS terminal box in my basement sounds perfectly "natural" to me. But, when that terminal was powered up, my received noise levels rose on all HF bands.

"I tried a common-mode choke, and it didn't help."

Did that choke have enough impedance? If you don't know, then it probably didn't. Also, the noise you hear may be conducted to your antenna by various paths. Your choke may have blocked one path but not all that mattered. Noise from switching power supplies and digital electronics in your shack, for example, travels to your tribander not only via the common mode (on the outside of the shield) of your coaxial feed line, but via the common mode of your rotator cable and via any *other* cable that goes to your tower. Noise from sources elsewhere in your house travels to your radios via ac power cables, computer network cables and other conductors — and from there to your antenna.

"I can't choke everything. Chokes are expensive. And, anyway, you say a choke may not have enough impedance. This is hopeless."

No, it's not. I'll show you how to make chokes that have enough impedance and are cheap. Choking the most important paths to your antenna won't cost much and may reduce your noise level *a lot*. Typically the most important path is the coax from your shack to the feed point of your antenna. The second most important path is the ac power line to your radio and any devices connected to your radio. At my station and at most of my friends' stations, a handful of chokes reduced the noise by more than 10 dB and sometimes by more than 20 dB.

"That 'handful of chokes' can be pretty expensive, right?"

No, unless you consider $50 to $100 too much to clean up your noise issues. You can make an excellent, high impedance choke for less than $20. Packaging it for outdoor use will cost a few additional dollars.

"I run high power. Don't I need a big choke, of thick coax wound on $50 worth of ferrite?"

No. My "excellent" choke can handle high power.

Doubling Down on the "Pretty Good Choke"

To make an "excellent" choke, we'll construct two "pretty good chokes" (PGCs), as I'll describe, and insert them in a cable 1 foot apart. Two PGCs separated by 1 foot work better than a single choke, no matter how good, because even a perfect (infinite-impedance) choke would be bypassed by capacitance between the coax on its opposite sides.

To fabricate an excellent choke in 50 Ω coax, you will need 4 feet of coaxial cable, either RG-303 ($10.40) or RG-142 ($14.40) and four ferrite "cable beads" Fair-Rite Products, p/n 2631102002 ($6.50).

Either RG-303 or RG-142 coax is good for high power at HF. Each has solid (not foam) PTFE (Teflon®) dielectric, a silver-plated center-conductor and a silver-plated shield. RG-303 has one braid shield and its outside diameter is 0.170 inch. RG-142 has two braid shields and its outside diameter is 0.195 inch. If you transmit high power, do *not* substitute polyethylene-dielectric coax.

This same approach works to choke any flexible, insulated, multiconductor cable of less than 0.25 inch diameter, such as a rotator, control or data cable. If the connector is molded onto the end of the cable, I usually cut the cable, thread it through the beads, and then splice the cable back together. Splicing is tedious, but I use heat-shrinkable tubing, and the result looks okay. Sometimes I cut one molded connector off, throw it away, and replace it with a new connector, or I leave the connectors in place and use electrically equivalent, split, "snap-on" (Snap-it™) beads. If you use split, snap-on beads, it is important to tighten a *strong* cable tie around the middle of each bead to keep it closed. In time, the plastic cases of these beads relax; and a microscopic (or wider) air gap opens between the halves of the ferrite bead. Even a 0.001 inch gap increases the reluctance of the magnetic circuit enough to destroy the usefulness of the bead and the choke.

Be sure to observe customary voltage, current and environmental limits.

Four feet of cable allows for a 5 inch lead ahead of the first PGC, 13 inches wound into the first PGC, 12 inches between the PGCs, 13 inches wound into the second PGC, and a 5 inch tail at the opposite end.

If this choke will be indoors, it won't need an enclosure, but outdoors it will. The enclosure may be fitted with SO-239 or other suitable connectors, or with strain-relieving bushings. See Table 1 for a list of components and suppliers.

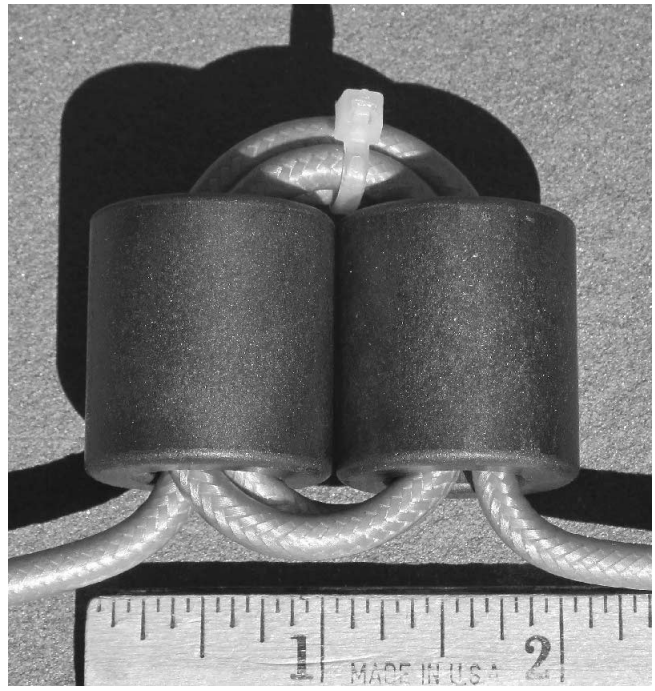

Figure 1 — The "pretty good choke" (PGC) comprises two ferrite beads, each a Fair-Rite Products p/n 2631102002, wound with RG-142 coax. The cable passes through each bead three times. The winding has no excess length and is kept tight by a nylon tie. The scale is in inches.

Table 1

A list of parts and sources to fabricate and enclose one "excellent choke"

4 feet of coaxial cable, either RG-142 or RG-303 (**www.radio-ware.com/** and other suppliers)
4 ferrite "cable beads" (Fair-Rite p/n 2631102002, available from Newark and other suppliers)
2 feet of 2 inch PVC schedule 40 pipe
2 PVC schedule 40 pipe caps for above
PVC pipe primer and solvent cement
2 SO-239 (or other suitable) bulkhead connectors)
Screws, nuts, lock washers, solder lugs (check junk box)

Note: Google "2631102002" to find vendors of this ferrite bead. Shop around because prices vary. In lots of 10, Newark's unit price is $1.57. I always buy a larger quantity to get a lower unit price, then use what I need and sell the rest to friends at cost. The price of RG-303 and RG-142 has risen considerably in recent months, so try googling these cable types for the best deal on short pieces.

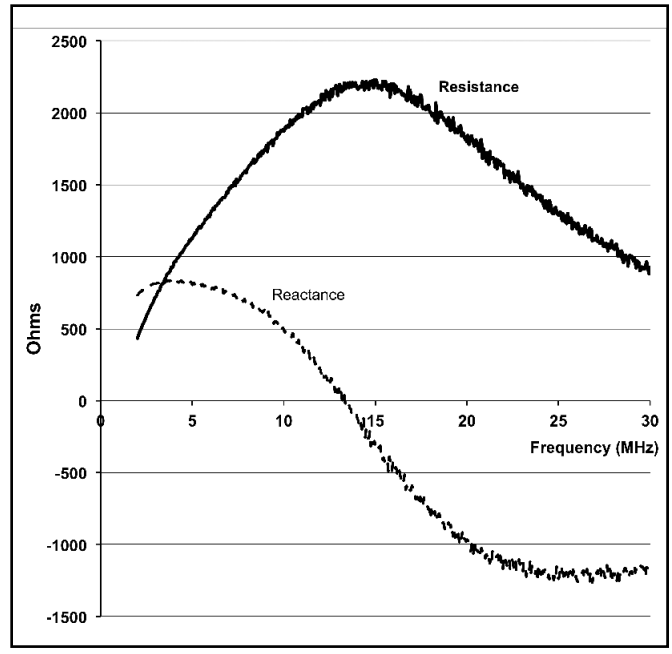

Figure 2 — A graph of the complex impedance of a pretty good choke (PGC), as a function of frequency. The choke was fabricated using RG-142 and measured with an AIM 4170. The choke was isolated from surroundings, including the instrument itself, to minimize stray capacitance. The measured resistance (real part of the impedance) is the solid line. The reactance (imaginary part of the impedance) is the broken line.

Building the Choke

A pretty good choke (see Figure 1) takes less than a minute to make. The coax passes through each bead three times (no more!). Don't leave excess length in the winding. Excess length adds capacitance that bypasses the choke.

Make two PGCs in a single 4 foot length of coax, leaving 1 foot between them. This separation reduces capacitance between the PGCs and between the coax on opposite sides of them. Do not put the PGCs closer together, and keep the coax at one end away from the coax at the other end. I have measured the capacitive effects of proximity, and they are not trivial.

Enclosing the Choke

Cut and deburr a 2 foot length of 2 inch schedule 40 PVC pipe. Install an SO-239 or other connector in each of the two pipe caps in Table 1. Solder one end of the coax to one connector. *Just one!* Leave the other end loose for now.

With two PGCs inserted 12 inches apart and with a 5 inch lead at each end, the assembly will be slightly longer than 24 inches from end to end, if it's stretched out gently. Slip the free end of the choked coax through the 2 foot pipe and fit the cap to which the coax is attached onto the end of the pipe. *Do not cement the cap yet!* Within the pipe, the cylindrical axes of the ferrite beads should be perpendicular to the axis of the pipe. The beads will not contact the inside surface of the pipe, but the coax emerging from the boreholes of the beads will.

Check that there's enough slack in the coax to solder the free end to the connector in the second end cap before you install that cap. If there's not enough slack, you can cut the pipe slightly shorter, but first make sure you didn't insert one of the PGCs backward. I suggest applying globs of RTV adhesive to the coax near the ends of the beads, so the PGCs will not rattle around if the pipe is shaken or dropped. Once everything fits, solder the coax to the second SO-239 and cement both caps onto the pipe.

One more thing, and this is important: The enclosure must not be completely sealed. It must have a drain (or "weep hole") at its lowest point, so that water condensing inside can escape. After you install the choke in its outdoor location, drill the weep hole at the choke's lowest point (eg, at one end). When drilling, be *extremely* careful not to damage the coax inside. A good place to drill is near one of the connectors. Drill a second hole to serve as a vent, provided this second hole will not be in a position to admit water. To keep spiders and insects from entering, plug the hole(s) with pieces of synthetic (eg, Dacron) rope. Air and water will pass through the plug, and bugs won't eat it.

Choke Impedance

To be effective, a common-mode choke must insert a series impedance into the common-mode transmission path that is much greater than the impedance of the common-mode wave incident on the choke. In the common mode, as in the usual transmission line or differential mode of a line, standing waves may occur, and impedance may vary radically with distance along the line. At a current node, impedance is high; at a voltage node, impedance is low. On average, one sees the characteristic impedance of the line. For the common mode of a coaxial cable, current flows and charge (with associated voltage) appears on the outside of the shield. The characteristic impedance of this mode is of the order of 300 Ω, depending on the proximity of the "ground" return path. Therefore, to be effective, a common-mode choke should have impedance greater than 1000 Ω and preferably more than 3000 Ω (see Figure 2).

Impedance is a complex quantity having a real part representing resistance and an

imaginary part representing reactance. For a common-mode choke, the resistance is more important, because it cannot be canceled by reactance of opposite sign that the choke may see looking into the common mode of the line in which it is inserted. The resistance of an excellent choke comprising two PGCs 1 foot apart is about 900 Ω at 2 MHz, about 4400 Ω at 14 MHz, and about 2000 Ω at 28 MHz.

Installing the Choke

The first place to install a common-mode choke is in your antenna's feed line close to the antenna's feed point. Hang it in the air directly below the feed point of a horizontal antenna using Dacron rope, not the coax, to protect the coax from wearing through or fatiguing as the choke swings in the breeze. It's important to separate the choke from conductors that could bypass the choke through capacitive or inductive coupling to the coax. With this in mind, do not tape the choke to a metal boom or a metal tower. If another cable runs parallel to the cable you're choking, then you must choke the *other* cable, too. All parallel cables must be choked at the same place (ie, in the same perpendicular plane. An un-choked cable will carry RF (in common mode) past the choke in an adjacent cable. All cables that run down a metal tower must be choked after they leave the tower, typically near ground level. All cables in a conduit must be choked before they enter and after they exit the conduit. All cables entering your shack must be choked before they come into your shack *and* before they connect to anything. It may be helpful to think of cables as charged to a high voltage (say, 100 kV), and to think of a choke as a high-voltage insulator.

Power Line Noise

The ac power wiring within a house typically is extremely noisy. Noise conducted by these cables to your radio (not only your transceiver, but also your amp, computer, and other digital devices connected to your transceiver) can be conducted via your feed line to your antenna. Power line noise can be so intense that choking your feed line is not enough.

It helps to choke the ac power cable(s) to your radios and connected devices. Plug multiple devices into a multi-outlet strip, and choke the strip's line cord. This line cord is usually a cable of three AWG 14 or AWG 16 conductors with an overall diameter of about 0.4 inch — too thick to pass more than once through a cable bead. To get enough impedance, you must string at least 25 of these beads on the line cord. I usually cut the molded plug off, throw it away and install a new plug. You can choke 15 A (3 × AWG 14) or 20 A (3 × AWG 12) Romex cable the same way.

More Information

The ARRL Handbook for Radio Communications and my draft article, "Common Mode Chokes" (**www.yccc.org/Articles/W1HIS/CommonModeChokesW1HIS2006Apr06.pdf**) offer more information on this topic.

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