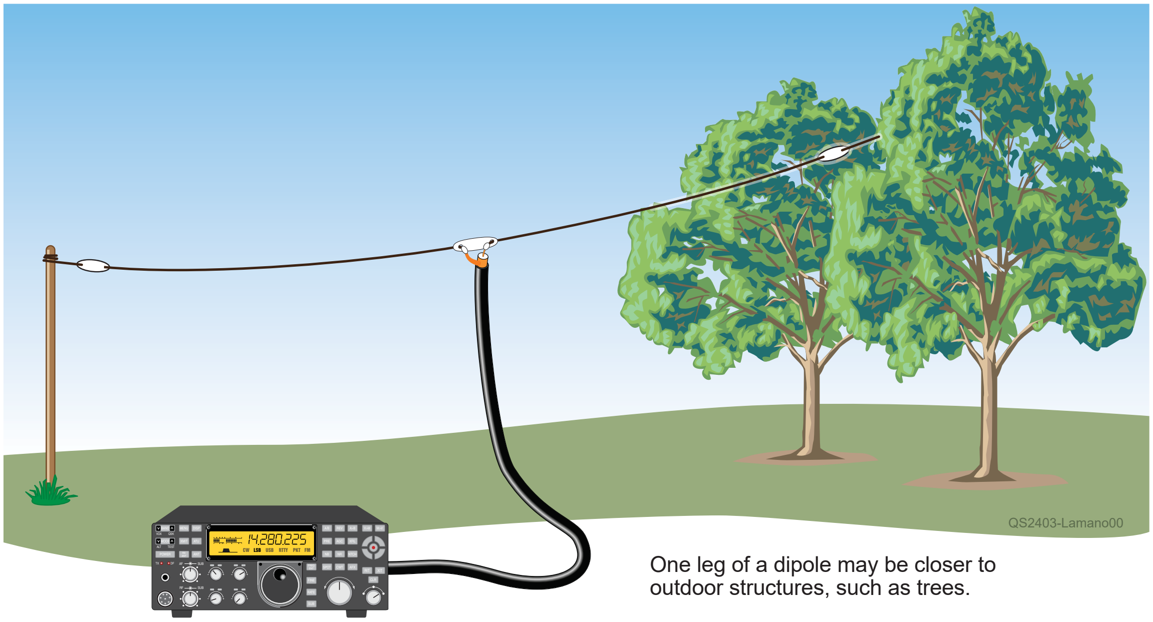

One leg of a dipole may be closer to outdoor structures, such as trees.

Common-Mode Current and Common-Mode Chokes

An overview of CM current, and what hams can do to correct it.

Larry Lamano, WAØQZY

When it comes to HF antennas, regardless of the type of feed line, one dipole leg may be closer to things like the ground, a tree, or a building (see the lead image). Coax-fed HF antennas are also inherently unbalanced because one side of the antenna goes to the coaxial braid or shield, and the other goes to the coaxial center. These factors unbalance the currents flowing in the legs of the antenna and the feed line. In this article, I will use the coax-fed antenna as an example to illustrate this concept. When current in the shield and the center conductor of the coax is not balanced, the difference is referred to as *common-mode* (CM) current. Radiation from balanced currents cancels outside of the coax, but the unbalanced CM current flowing between the antenna and the transmitter produces radiation. The coax effectively becomes an antenna that can cause interference to nearby electronics — and in severe cases, RF bites. Adding a grounding strap to where the coax enters your shack may not help, as it becomes another part of the unwanted antenna.

CM current changes the radiation pattern of the antenna. It can also detune the antenna, change the standing wave ratio, and add noise.

Minimizing current requires increasing the impedance in the current's path. In amateur radio antennas, we reduce current by placing a CM current choke or current balun in the CM current path; this tends to force equal currents in both halves of the

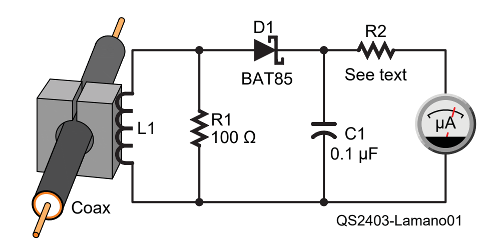

Figure 1 — A CM current meter. The clamp-on ferrite has 10 turns of small wire (L1) wound through it. When clamped on the coax, it becomes a high-ratio current transformer. The CM current reads on the meter after being rectified by D1. R2 sets the meter's sensitivity.

antenna. If these currents are equal, there will be no unwanted current flowing in the coaxial shield. Chokes are placed at the antenna's feed point for optimal efficiency.

There is debate about how much CM impedance is necessary to attenuate the CM current. Some say 500 Ω is enough, but the actual value depends on how much CM current there is to begin with. A Yagi on a tower may have much less current than an off-center-fed antenna near the ground. It's best to have the highest impedance reasonable to implement. In the examples that follow, we will use 2000 Ω to define the usable bandwidth of a choke.

Measuring CM Current

The first step in deciding what kind of choke you need is to measure the CM current at your chosen frequencies. Figure 1 shows an easy, inexpensive way to build a CM current meter, and further details with additional choke design references are provided at **www.arrl.org/qst-in-depth**. Securely clamp the split ferrite over your coaxial feed line. While transmitting and watching the meter, slide it across a half wavelength of the cable. The current will have a peak and null over that length. If you see nothing on the meter, you probably don't need a CM choke, but a half-scale reading indicating about 50 mA or more should be dealt with. After you install a choke, retest to see if the current has declined to an acceptable value.

Constructing an Effective CM Choke

There are many ways to create a CM choke. The most common choke type is a simple coil of coax at the antenna's feed point. It is a reactive choke, as it relies on the inductive reactance of the coil to present an impedance to the CM current. The coiled coax acts as an inductor, and its inductive reactance will choke the CM current without affecting the desired currents inside the coax.

It is often erroneously stated that if you wind the coil with sufficient choking impedance at 160 meters, it will work better at any higher frequency because the inductive reactance increases. However, it actually creates a parallel resonant circuit with an impedance characteristic shown in Figure 2. There is capacitance between the turns of a coil that forms a parallel resonant circuit with the coil's inductance. Every inductor has a self-resonant frequency (SRF).

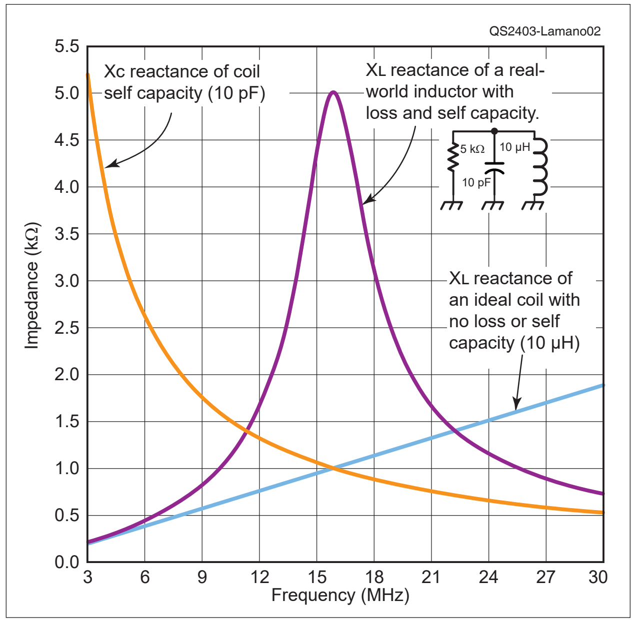

Figure 2 — A pure inductor of 10 µH would have the impedance depicted by the blue line. However, a real inductor could have 10 pF of self capacity, as shown by the orange curve. These are in parallel, and there is loss in the coil represented by the 5K resistor in parallel. The purple curve shows the actual impedance of the coil versus frequency. The impedance is high at resonance, but it drops on either side.

At that frequency, the currents through the inductance and the capacitance cancel, leaving only the resistive losses. Above the SRF, more current will flow through the coil's self capacitance and lower the overall impedance, as shown in Figure 2. That means that on 160 meters, a good choke with many turns and a high self capacitance will generally be a poor choke on 10 meters. Reactive chokes can be excellent near their resonant frequency because the impedance of a parallel LC circuit at resonance is high, but there is a relatively narrow band around resonance, where the impedance is high. A coil's SRF can vary by several MHz depending on what kind of coax is used and how it is wound. Simply stating, "Wind five turns with a 4-inch diameter," does not guarantee a choke's performance on a given frequency. Air core chokes are typically scramble-wound or solenoid-wound. It is difficult to get repeatable results with scramble winding, and solenoid-wound chokes have fairly repeatable results, but they require a form to wind.

You can measure the choking impedance of a coil versus frequency with an instrument like the

See the Digital Edition of *QST* for More!

Check out this article in the digital edition of *QST* (**www.arrl.org/qst**) to see a video of a friendly choke-building competition among ARRL staff members who have different levels of experience. The goal was to increase the technical confidence of newer licensees by letting them each build a basic choke. Contestants included ARRL Foundation Development Associate Mimi Guerrat, KC1TJW (center); W1AW Station Manager Joe Carcia, NJ1Q (right); ARRL Acquisitions Editor Mark Derks, KC1RVQ (rear center), and ARRL Book Editor Makenzie Ozycz (left). The ARRL Lab served as the judge, measuring the effectiveness of the chokes at 20 meters. Watch the video to see who won.

ARRL Book Editor Makenzie Ozycz (right), who is currently studying for her Technician-class exam, holds the form as ARRL Foundation Development Associate Mimi Guerrat, KC1TJW (left), winds a choke.

ARRL Lab Digital RF Engineer John McAuliffe, KD2ZWN, explains the test rig he will use to judge the effectiveness of the chokes.

ARRL Acquisitions Editor Mark Derks, KC1RVQ (left), a General-class ham, builds a choke with binocular-shaped ferrite cores, with advice from ARRL Lab Digital RF Engineer John McAuliffe, KD2ZWN (right).

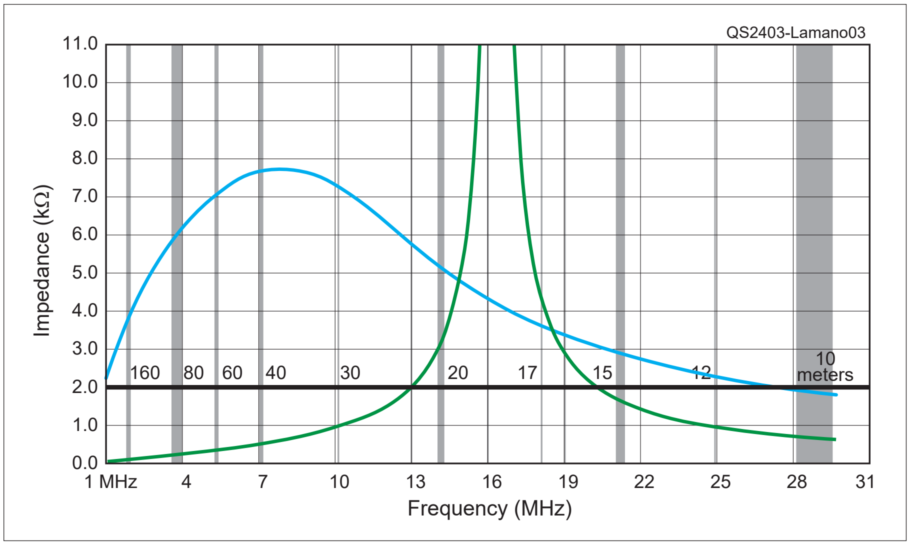

Figure 3 — The total impedance of an air-wound (green curve) and a ferrite toroid-wound (blue curve) choke balun. The black line at 2000 Ω shows the target impedance for effective CM current choking. The vertical gray bars show the limits of the amateur bands.

NanoVNA. Doing so allows you to determine the resonant frequency and bandwidth of the choke. For the measurements shown in Figure 3, I used a NanoVNA-F v3.1 with firmware v1.0.5 along with the free *NanoVNA Saver* v0.4.0 software. Set your NanoVNA to S21 Through mode to measure the impedance of what is connected between the two ports. In *NanoVNA Saver*, set the display to **S21 |Z| SERIES**. Connect the shield at each end of the choke to the NanoVNA ports, thereby placing the choke between the two ports. For each port, use a short piece of wire terminated in an alligator clip. There is no need to connect the ground sides of the NanoVNA ports.

The green curve in Figure 3 represents the measured choking impedance of a scramble-wound air core choke, and the horizontal line represents our target impedance of 2000 Ω. This reactive choke consists of six turns of LMR-240 coax with a diameter of approximately 6 inches. The choking impedance declines rapidly on either side of resonance. The high-frequency performance worsens the closer the turns are to each other, as this increases the interwinding capacitance. It's clear that it isn't only an inductor, but a parallel resonant circuit with a narrow bandwidth. At 2000 Ω, this choke would be adequate only on the 20- and 17-meter bands. Reactive chokes can work well as single-band or sometimes as adjacent-band chokes, but they are inductive below resonance and capacitive above resonance. As such, they can increase CM current if — at some frequencies — their impedance is of opposite polarity to what is seen looking back down the coax. A document discusses this concept further at **www.arrl.org/qst-in-depth**. If you desire a wideband choke, resistance is needed because resistance is independent of frequency. In practice, this means passing the coax through a lossy ferrite core instead of an air core. The most common ferrite mixes for the HF bands are types 31 and 43. Their resistances allow chokes to have much broader frequency ranges. The blue curve in Figure 3 shows the same coax used in the previous measurements, but passed through a Fair-Rite 2631626202 core, and with the turns spread apart to lower the interwinding capacitance. The peak impedance is less than that of the reactive chokes, but there is a much wider band (160 – 12 meters) where the impedance is more than 2000 Ω. Even at 10 meters, the impedance may be acceptable.

See *QST* in Depth for More!

Visit www.arrl.org/qst-in-depth for the following supplementary materials and updates:

- ✓ Additional details about building a CM current meter, with references on choke design
- ✓ An explanation of how a choke can worsen CM current

Larry Lamano, WAØQZY, an IEEE Senior Life Member, was first licensed in 1966. He earned a BSEE and an MSEE from the University of Missouri at Rolla in 1973 and 1975, respectively, with emphases on communication systems, transmission lines, and antenna theory. Larry's first job was with Collins Radio, and his last one was with Apple. Since leaving Apple in 2001, he has been doing analog and digital consulting. Larry has always enjoyed designing and building things with the goal of understanding underlying theories. He can be reached at **wa0qzy@gmail.com**.

For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.