Balun Basics: Common Mode vs. Differential Mode

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Most of us are familiar with the term “RF in the shack.” Severe problems have obvious symptoms. We might get an RF burn when we touch a panel or knob. There may be odd equipment behavior such as distortion, equipment lock-up, or erratic CW keying. Lesser problems, on the other hand, are often not very obvious. Unwanted coupling can carry noise back to the antenna, and we might assume the noise is normal and unavoidable. Unwanted RF currents also waste power that otherwise would be transmitted as a useful signal, and we probably wouldn’t know the extent to which it is actually occurring.

Antenna space limitations can force us to install antennas close to the operating position. When antennas and the operating position are less than 1/2 wave length apart, normal antenna fields can couple large amounts of energy directly into station wiring. Other than moving the antenna or operating position, the only cure might be tying equipment and wiring grounds together with the shortest leads possible and using an artificial (counterpoise) ground system at or near the operating position.

In other cases antenna design might create a problem. One example is an antenna intentionally worked against a poor ground, such as a long wire or vertical with a small radial system. RF exiting the antenna might be finding a ground path through the feedline to station equipment and wiring. Once the unwanted RF current gets into the station equipment, it can cause voltage differences between equipment and other things in the room. This can cause severe RFI and even RF burns. These are the cases where properly installed antenna isolators (also called choke or current baluns) are beneficial.

Current baluns, isolators, and choke baluns are all interchangeable names for the same basic device. We use “choke balun” because the device tries to “choke off” unwanted currents. The same basic device might be called a “current balun” since each output terminal tries to supply equal and opposite currents to each output terminal regardless of load characteristics. Recently, the name “isolator” has appeared. The current or choke balun “isolates” common mode paths along a feedline. These descriptions are interchangeable; the same basic device works in all three applications. Effective choke baluns, current baluns, and isolators are completely interchangeable.

Differential Mode Current

Transmission lines are designed and advertised with a certain characteristic impedance value. This impedance is established by the ratio of distributed inductance and capacitance in the transmission line. This impedance, if applied as a resistance across the line at the far end, would make voltage and current uniform along the line (except for the small normal power loss with distance). Because this impedance relates directly to opposite flowing currents in each conductor, it is called the differential mode. It deals with the "across" or between conductors characteristics.

A conventional two-conductor transmission line, even if one conductor is called the "shield," must have exactly equal and opposite flowing currents into each conductor at each end. Without equal and opposite (differential mode) currents flowing at every point in a transmission line, it will radiate and receive signals. A transmission line with purely differential mode operation would never radiate unwanted energy. It also would not respond to outside radiation or signals.

Common Mode Current

Transmission lines may have another mode, conducting currents known as parallel or common mode currents. Common mode current is the portion of conductor currents not matched by exactly opposite and equal magnitude currents. This is the portion of total current responsible for a feedline behaving like a single wire line. Common mode current is most commonly caused by improper feedline installation or antenna design. The feedline, in effect, behaves like two very different transmission lines connected to the antenna and equipment at the same time.

As with differential mode's impedance across the feedline conductors, parallel or common mode operation has impedance to "ground" to other objects around the feedline, and to other points in the system. It is often useful to consider this the system impedance when fed like a long wire. Common mode voltage differences along the line cause current to flow, and the common mode impedance determines current flowing in that mode. The voltage that causes common mode current almost always appears at the antenna, since that is where major balanced to unbalanced transitions occur.

Measuring Common Mode Current

Another myth is equal conductor currents mean a feedline is balanced. Equal conductor currents do not prove correct balance; they merely indicate balance is possible. Conventional meters do not measure or account for phase, they simply indicate current. The same is true for light bulbs, which only indicate the relative amount of voltage and current and not the direction or phase of current or voltage. Current levels can be equal, and all of the current can be common mode. The line could also be perfectly balanced; we wouldn't know without considering phase.

A clamp-on RF current meter will allow accurate reliable balance measurements. The current sensing clamp must be placed over both feedline conductors at the same time in a balanced line, or around the outer shield of coaxial line. When the current sensor is clamped over the entire cross-section of feedline, a clamp-on meter will read common mode current of any style transmission line. To confirm proper operation all along the line, the line should be checked at two or more points 1/8 wavelength apart. This test will not work reliably with rod-type meters.

Reducing Unwanted Common Mode Current

A properly designed choke or current balun inserts a large amount of common mode impedance in series with the feedline without causing unwanted changes to differential mode operation. When common mode impedance substantially increases, common mode current on feedline will be greatly decreased. The combination of proper grounding and high common mode balun impedance can reduce unwanted currents to immeasurable or unnoticeable values.

To be most effective the balun or isolator must be located outside the station, before unwanted currents get near station wiring. There must be no other significant path or coupling into the station. A balun and grounding will not be as effective when a troublesome feedline parallels another conductor for any distance. Current will simply be induced in the other conductor, and give us one more conductor to worry about.

A commonly repeated rule-of-thumb suggests a five, or ten-to-one common mode balun impedance. Using this guideline, 500 ohm common mode impedance is enough for 50 ohm transmission lines. Unfortunately this rule isn't always correct. The balun choking impedance requirement can be nearly any value, depending on the system. Isolation or choking impedance is not tied to transmission line impedance or SWR, but rather the voltage exciting the feedline and system common mode impedance.

In most cases we want to have the highest possible common mode impedance. DX Engineering baluns have much higher common mode impedance than competing baluns, and maintain high impedance over very wide frequency ranges.