Microvolt

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Transmission lines

A *transmission line* is a conductor that's used as a path for electrical energy. To an electrician or a commercial utility worker, it's a wire that carries electricity to our homes and businesses over long distances. In the circle of amateur radio, our discussions about transmission lines usually surround the pair of conductors that carry a radio signal from the transceiver to the antenna and back. In this issue, let's explore how understanding those conductors can be meaningful to us beyond being a simple pair of wires.

Cover – Transmission lines

In the RF (radio frequency) world, transmission line pairs carrying electrical signals are much more than just wires. Their physical characteristics have been studied extensively, but due in part to their deeply technical nature with respect to radio signal behavior, they've been the subject of a large amount of myths and misunderstanding.

Because we use a transmission line to "feed" RF electrical signals to an antenna, we call it a ***feed line***. In today's amateur radio world, the feed line of choice is overwhelmingly ***coax*** (coaxial cable), because of its low cost and high immunity to noise, although others are available.

Impedance is the opposition to current flow, is frequency-dependent, and its value is expressed as a complex number, with the units *ohms*. Each transmission line pair possesses a ***characteristic impedance***, which is a property that's derived from the wire material, geometry, and insulation that separates the conductors. The characteristic impedance of most coax used in amateur radio is 50 ohms.

If you were to measure the resistance between the conductors of a coax cable alone, the meter will likely read infinite, or like an open circuit, because the two conductors are not electrically in contact with each other. Properly measuring transmission line properties requires a VNA (vector network analyzer), although many antenna analyzers can perform the measurement.

The transmission line characteristic impedance is important because it's the value that must be presented by the load at the end of the line, to provide for the most signal power transferred by the line to the load. In our case, the applicable load is the antenna, so to allow for *maximum power transfer*, the antenna must also ***match*** the feed line characteristic impedance by presenting an impedance of 50 ohms itself. When an RF signal traveling on a feed line reaches the load and the load impedance does not match that of the feed line, a portion of the signal is ***reflected*** by the load onto the feed line back toward its source, the transceiver.

A common misconception about feed line reflections is that the reflected signal is lost. It's true that, reflected or not, some of the signal is lost as heat as it travels in the transmission line, and a tiny bit in other things (tuner, meter, connectors) that are connected in between. But the signal that's reflected back from the antenna and reaches the transceiver is not lost, but is re-reflected by the transceiver and sent back to the antenna. Hence, the term "return loss" referenced by some is a misleading misnomer.

The signal losses in the transmission line can therefore be reduced if the signal does not need to travel down the line more than once. Again, to achieve this "single-trip" operation requires an antenna whose feed point impedance matches that of the transmission line. Unfortunately, even the most carefully crafted antenna often does not exhibit a 50-ohm impedance at the antenna ***feed point***, the location where the feed line meets the antenna.

Antenna makers often take steps to correct, or at least minimize the mis-match between the antenna and the feed line by applying some sort of circuit that will transform the antenna impedance into something close to the feed line impedance. One way is through a passive matching network, and another popular way is by an active (requires power to perform its function) device called a ***tuner***.

Finally, unique to coax is the fact that a completely balanced RF signal will travel on the outside of the center conductor and inside the braid or outer conductor through the skin effect. However, if an RF signal returns to the coax in an unbalanced fashion, such as from an off-center-fed or end-fed antenna, some of the return signal will also flow on the outside of the braid, an undesirable condition known as ***common-mode current***, which can be reduced by an RF choke or isolator.

So, an otherwise innocent-looking pair of wires can perform like a very complex device, and that's the nature of transmission lines.

Microvolt editorial staff