# Loads of fun with quarter-wave sections and pads

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Everyday magic in RF often relies on two little tricks—the unusual characteristics of quarter-wave line sections, and the universal healing qualities of attenuator pads. "Don't leave home without them."

First of all, the pad. Put one at the input of an amplifier, and it improves the headroom. Put one at the output of an amplifier, and it reduces the "turn-around gain" and helps get rid of intermodulation. Put one in between two amplifiers, and it improves the impedance match seen by both. Placed between an amplifier and antenna, it helps protect the amp from VSWR damage.

And no matter where you put them, they'll help keep the RF shack warm and inviting on cold winter nights. Sometimes it seems as if almost anything could be improved by sliding a few pads into the system. The only real improvement left to consider is the pad with gain, the so-called negative-attenuator, but we'll reserve that special case for a future column.

The quarter-wave section is the original RF transformer. Use it to change impedances, to split RF power and to join it up again. It's also the main component in cavity filters and traps, including the traplexer used by television transmitters. The magic tee and switchless combiner both rely on quarter-wave sections. At lower frequencies, a pi- or a tee-section can look like a quarter-wave of transmission line.

There are only three things you need to remember about quarter-wave sections: (1) If the output of a quarter-wave section is left open, the input sees a short; (2) if the output is shorted, the input sees an open; and (3) any two impedances can be matched by joining them together with a quarter-wave section that has a characteristic impedance that's their geometric mean. For those of you that haven't already fallen asleep, I have handy examples of all three.

1. is a bandpass or reject cavity in a can, say for an STL filter or a module of an FM combiner. Inside the can is a quarter-wave stub, shorted to the can at the top, and open at the bottom. The input connector attaches to a (broadband) coupling coil that couples RF energy magnetically to the stub. At the quarter-wave frequency, the open at the end of the stub looks like a short at the coupling end, and maximum energy is coupled to the stub. If it's a bandpass can, there's a second coupler on the other side of the stub that will pick up maximum energy when the stub is resonated.
2. is a harmonic trap at an FM transmitter output. (Not a so-called harmonic filter, which is really nothing of the kind—it's really a low-pass LC filter consisting of series inductors and shunt capacitors to attenuate all low frequencies.) The true harmonic trap is a tee in the output line, with one leg having a sliding trombone contact for the centre conductor, and ending in an open. At the harmonic frequency, that open looks like a short at the centre of the tee, and so that harmonic energy is shunted to ground.
3. is one of those two-bay educational FM antennas that use a simple tee N connector for a power divider. If the two antenna elements are 50 ohms each, how can that work? Well, if the tee connector is placed between the bays, and a quarter-wave line section is on each side of the tee going to a bay, and the coaxial cable used for each section is 75 ohms characteristic impedance (probably RG-11/U), then the 50-ohm termination of each element is transformed to 100 ohms at the tee. And the two 100-ohm loads in parallel makes for a 50-ohm impedance, as seen by the transmitter. (The geometric mean of 50 and 100 is 70.7 actually, but for our purposes 75 ohms is pretty close). So that 50-ohm transmitter matches up just fine into two bays of 50-ohm antenna. You can do the same thing for two STL receivers at 950 MHz, working off a single STL antenna (a tip of the hat to Al Pippin for mentioning this one): split the antenna line with a normal N tee adapter, and run quarter-wave 75-ohm line sections to each receiver. It makes a handy, low-cost, properly matched power divider out of everyday materials.

That's all for this time!