Open-Wire Line – A Novel Approach

Quantitative tests reveal an easy home-brew method
to gain the advantage of low-loss 450 Ohm window
line, in places you may have never considered

by John Portune W6NBC

Coax became popular with the growth of radio in WWII. Hams quickly forgot open-wire line. Yet ladder-type open line has a big advantage over coax – low loss. It is several times better. Why then do so many hams overlook this benefit today?

Mostly, I suspect it's because of ham chit-chat. "Open line" we've all been cautioned, "can't be used near solid objects, especially metal." Or you shouldn't run it through a stucco wall, or over a metal window frame. And don't even dream of laying it right on the ground, in a flower bed or on a metal roof.

It may come as a big surprise, but the tests I present in this article strongly suggest that these "no-nos" are largely untrue. You'll also see an easy home-brew method for using open line in adverse situations you may have never even considered.

I began investigating this topic while prototyping an all-band HF flagpole vertical. (See end of article.) It wasn't even close to 50 Ohms. Had I fed it with coax, I would have incurred serious line losses. Could I instead feed it with open-wire line? Was it sheer foolishness to even consider laying open-wire line right on the ground or in a flower bed? But that's where my flagpole's feed line has to run to get to the feed point.

Instead of just baldly accepting ham hearsay that my idea was ridiculous, I began searching the internet and the literature for actual loss figures for open line in other than in open air. Guess what? There are no hard figures, only unsupported opinions. I wanted real answers, so I decided to run quantitative tests of my own. Was I "barking up a hollow coax?" Figure 1 shows the adverse situations that I chose. (One is in open air, for comparison.)

Figure 1: Adverse, non-open-air, situations for 450 Ohm window line: (1) on dry concrete, (2) lying on wet garden soil (3) directly on an aluminum patio roof, (4) in the open (comparison reference)

Let me be very clear, though, I never intended my tests to be a laboratory-standard study. I only meant them to be simple ham-level tests, sufficient to broadly test my basic idea. Later in this article, for readers interested in the validity of the tests, I show my methods in more detail. But again, at the beginning, all I wanted to know was, does the performance of open-wire line fall apart badly near other objects, as my ham buddies were presuming? In the end, I was pleased to discover that it doesn't. Further, in the process, I was led to a simple home-brew method to deploy open line other than in open air, such as lying in my flower bed.

The Test Conditions

I chose 450 Ohm window line. 300 Ohm TV twin-lead is not viable; it has nearly as much loss as coax. 600 Ohm line has a bit less loss then 450 Ohm line but is considerably more difficult to use for my deployment method.

As you can see in Figures 1 and 2, the method is really very simple: encase the open line in the inexpensive gray polyethylene foam tubing sold at hardware stores for insulating ¾ in. hot water pipe.

Figure 2: 450 Ohm window line encased in the polyethylene foam tubing for insulating ¾ in. pipe

The line easily slips through the tubing, which now takes over the role of stand-off insulators. Further, the foam protects the line from moisture, a potential enemy of open line. The bubbles in the foam are closed. In its "comfy little shroud" open-wire line can now be deployed much like coax. It can "go where no open line has gone before," heaven forbid, even on the ground in a flower bed. As an added bonus, foamed window line is much less "neighbor sensitive." You can even paint it to match your house.

In practice, you only need to encase the line for those portions of the run that lie directly on the ground or right against an object. Where the line can run in the open, use it as is. Where rigidity or mechanical protection is important, give the foam-encased line additional enclosure in 2 in. ABS DWV pipe. We'll later see, it can even be put inside EMT metal conduit.

The tubing is inexpensive and widely available in 6 ft. lengths at local hardware stores. Three wraps of 2 in. waterproof tape, also sold at hardware stores, join the segments. Long lengths of pipe insulation can be purchased in coils from industrial/building suppliers.

Test Results

Figure 3 is a graph from my data. To insure consistency I made four separate test runs, repositioning the lines each time, but always in the same adverse conditions. As I expected, there was variation between runs. Soil and the concrete caused the most. But notice that the variations are small, 15% at the most – certainly not the giant jumps ham chit chat might predict.

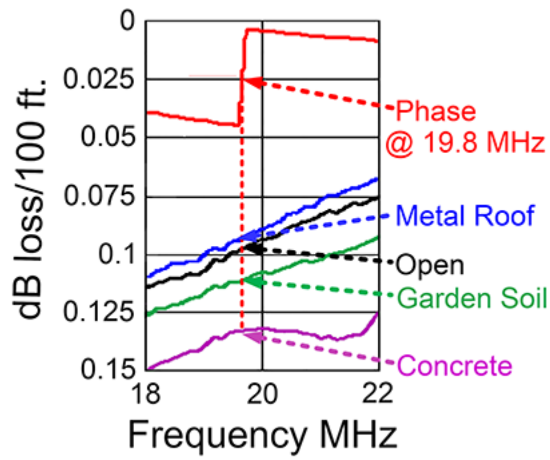

Figure 3: My Loss figures in dB per 100 ft., at 19.8 MHz
(See test methods below for this choice of frequency.)

I suspect the reason the small change in a variety of adverse situations may be because the bulk of line's field does not extend more than an inch or so from the line. Most of the field exists between the conductors. This may explain the small amount of variation.

I was especially surprised at the results for open line on a metal roof. Had you told me this before my tests, I would never have believed you. But, amazingly, there was actually less loss on metal, for all four runs. I have nothing but a guess why, but it at least suggests that metal window frames, chicken wire in stucco house walls, or even a hole through the metal skin of an RV or mobile home aren't nearly as much of a concern as many hams think.

A Later Surprise

Some time after my initial tests above, I decided to be truly bold. I put the foam-encased line inside of 2 in. EMT metal electrical conduit. "Never in a million years" would I have previously expected open wire line to fare well inside metal conduit. But surprise, surprise, it does, and it also physically fits nicely. It truly amazed me that it has less loss than in open air. It was then that I recalled Twinax, a 100 Ohm two-wire coaxial transmission line developed some years ago for the computer industry. 450 Ohm line in conduit is simply a lower-loss version of the same concept. This then clearly points to successfully burying open-wire line. Who'd have thought?

How I Measured Line Loss

In the radio community, a common technique for measuring transmission line loss is to run an S11 dB return loss measurement sweep (in dB) with a vector network analyzer. I used an SDR Kits VNWA-3e set for 2-30 MHz. I included a phase measurement of the reflected signal as well. Figure 3 shows the curves from 18 to 22 MHz for the four situations. We'll see in a moment why I zeroed in on this smaller range.

One makes return loss measurement from one end of a line with the other end open. The resulting infinite mismatch at the open end forces the test signal to totally reflect and to make two passes of the line. The loss then is half the measured total.

But why did I select 19.8 MHz? It is because of the sudden 180 degree jump you can see in the phase trace in Figure 3. It indicates the lowest half-wavelength resonance of my test line. And why is this important? At other frequencies the loss measurement is a complex number. It is a combination of real loss (what we're interested in) and reactive (mismatch) loss. Only near the λ/2 frequency do we measure only real loss. The slope of the curves is caused by the reactive components.

You can make similar measurements with an MFJ-259B antenna analyzer (on the coax-loss setting) by manually recording the loss one frequency at a time. The lowest λ/2 frequency is found by sweeping the frequency upward to locate the first major SWR dip.

Impedance Matching

An impedance-matching balun between the VNA and the line was also required for my tests. You can see it in Figure 1. VNAs are commonly 50 Ohm instruments; window line is 450 Ohms. I built a 9:1 (450 Ohm to 50

Ohm) Guanella current balun, Figure 4. Instructions for making ferrite baluns are readily available on the internet.

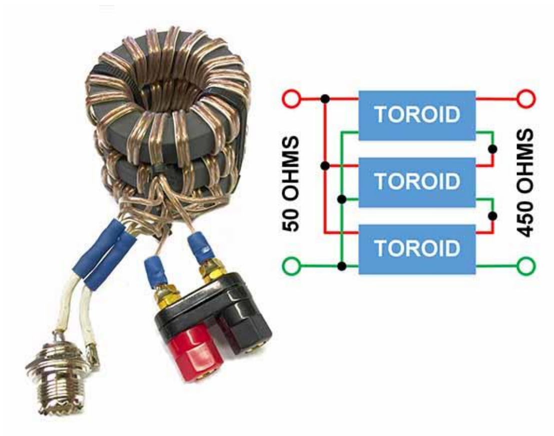

Figure 4: My 9:1 testing balun, using three FT-240-61 toroids, each with 17 turns of dual (bifilar) AWG 18 speaker cable, connected as shown.

A Practical Example

As I mentioned earlier, I ran these tests while building a neighbor-proof, 20 ft., off-center-fed, coaxial, half-wavelength, no-radial, all-HF band aluminum flagpole antenna, Figure 5. My CC&R-toting neighbors have no idea that it is an antenna. There are no visible loading coils, tuning stubs or capacity hats. It’s just a plain 2 in. aluminum pole with fiberglass insulators at the base and the off-center feed point, and of course a flag and a brass eagle (very patriotic).

Figure 5: My stealthy 20 ft. HF HF flagpole fed with foam-encased open-wire line lying right on the ground

Again, had I fed this non-50 Ohm plain pole directly with coax, especially on 80m and 40m the losses would have been considerable. But now with a short run of foam-protected 450 Ohm window line lying right on the ground next to my house, and a tuner nearby in my shack, I get out well. I had originally been expecting to have to use an expensive remote auto tuner at the base.

Other Possibilities

Another practical application for foam-encased line is to feed a beam antenna with the foam-encased line tie-wrapped directly to the leg of a fixed tower, or suspended for a crank-up tower. Then, if you ever want to use a tuner in your shack to move your beam to a band for which it was not designed, the loss will be much less.

Other antennas that can profit from this approach are Windoms, Zepps, end-fed long wires and OCF dipoles. Also, you 43 ft. vertical aficionados take note. All these are naturally non-50 Ohm antennas. Low-loss open line, an impedance-matching current balun and a tuner in the shack are a very acceptable choice. This approach for an OCF dipole is much less lossy than running coax to a balun at the feed point.

Lastly, how do you feed an antenna with 450 Ohm line that was designed by the manufacture to be fed with 50 Ohm coax? Using two 9:1 baluns, back-to-back, one at each end of the 450 Ohm line, is an obvious way. A more efficient way it to modify the antenna for direct 450 Ohm feed. Antennas do not care how you feed them as long as the feed point is matched. Gain and directivity remain essentially the same. You will still need a current balun at the rig. The balancing baluns found in many tuners are unsatisfactory; they are commonly Ruthroff voltage baluns.

A beam, for example, can be re-fitted with a 450 Ohm delta or a gamma match. Other antenna designs, like the Hy-Gain R-series, may already have a matching balun at the base, which can be replaced with one for 450 Ohms. The benefit, especially when you want to work off frequency, is noteworthy, however.

So don't dismiss open-wire line, as many hams summarily did in 1945. The simple ham-level tests here have shown me that there are many practical possibilities for deploying open-wire line in situations where coax was once thought to be the only player. Perhaps I should write a novel, "Ladder-line – Splendor in the Grass" – hi, hi.

The author will be pleased to correspond: jportune@aol.com or w6nbc@arrl.net, 519 W Taylor St, Unit 111, Santa Maria, CA, or through w6nbc.com.