Let's Build a Coaxial Collinear antenna – for 2M or 440

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25 Nov. 2017

Snohomish County Hams Club

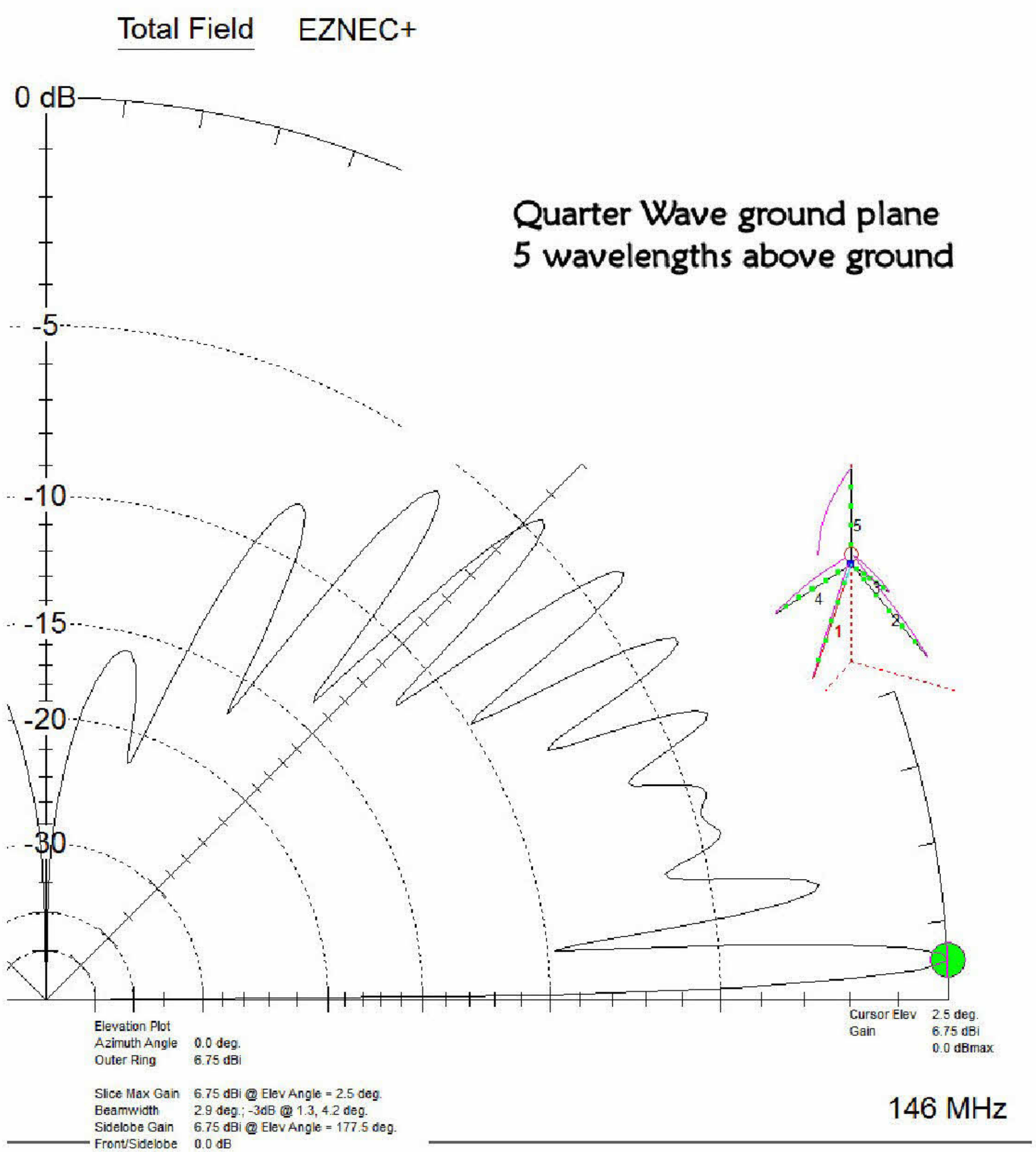
How did I get into this, anyhow?

…

Are antennas magic?

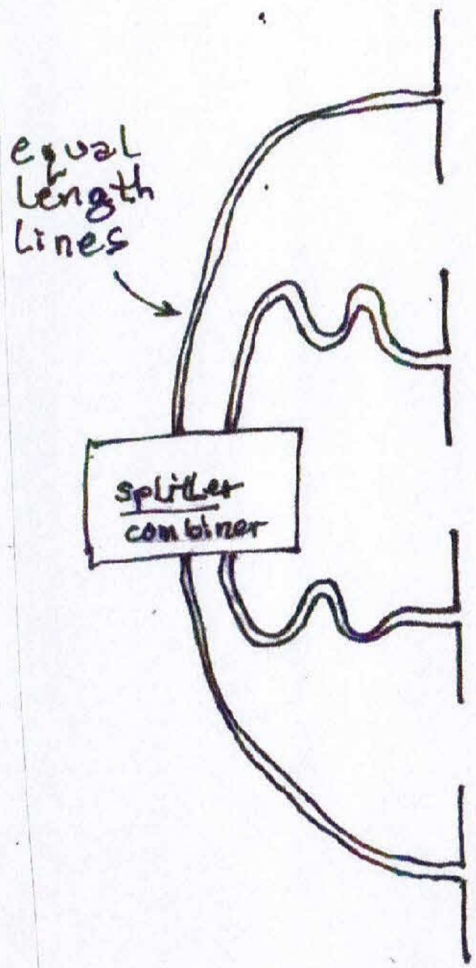
Some antennas hams use on 2M and 440 for local point-to-point and repeater operation:

- ¼ wave ground plane
- Vertical ½ wave dipole
- 5/8 wave ground plane
- J-pole
- Collinear array of ½ wave dipoles

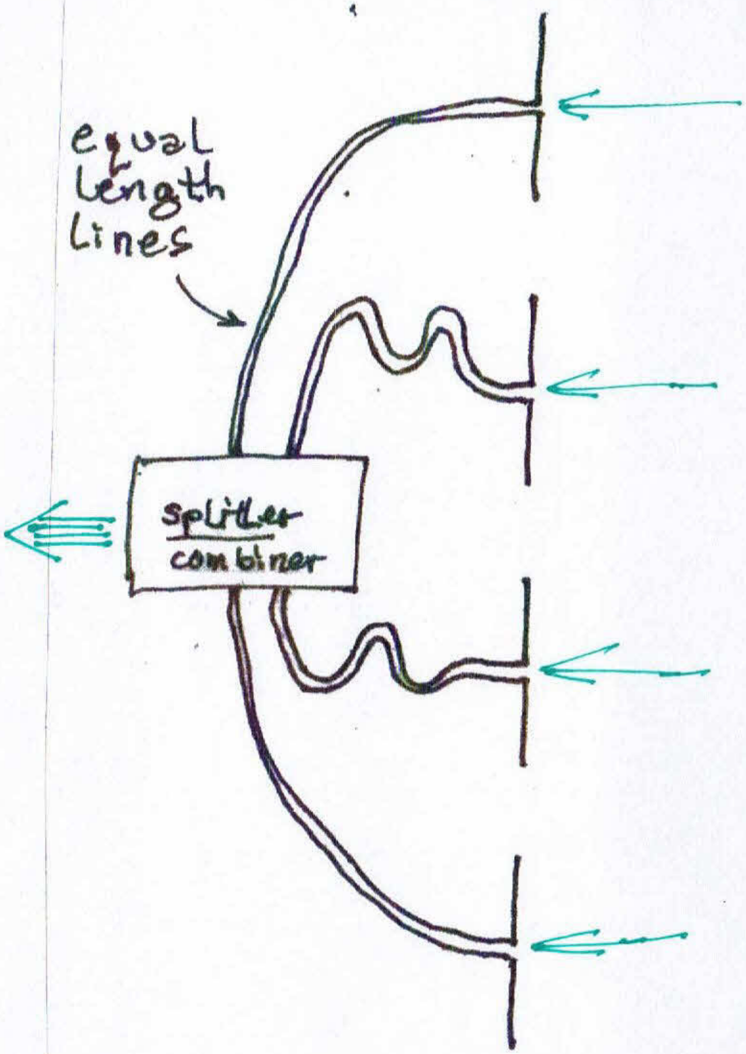


The pattern of real antennas over ground is much more complicated than the freespace pattern. This simple antenna, in this configuration, has 6.75dBi gain.

Four ½ wave dipoles
spaced ¾ wave center-to-center

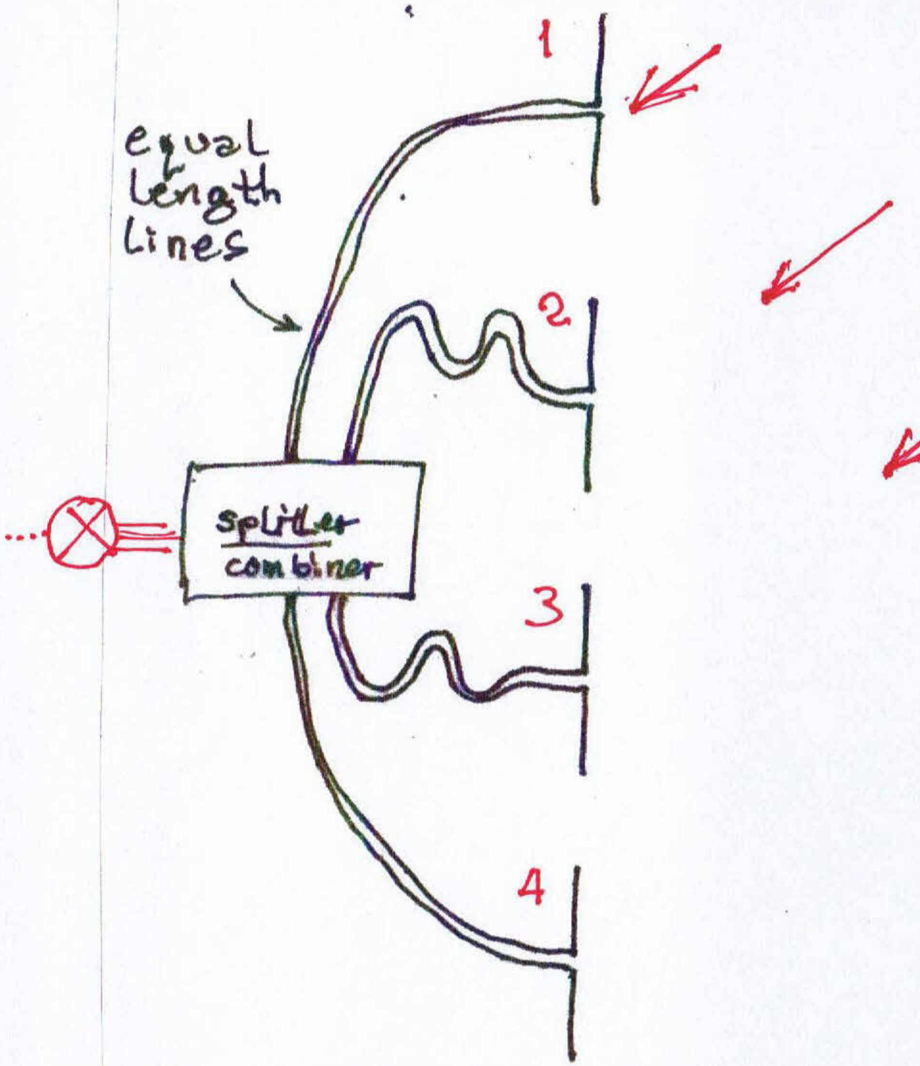


Four ½ wave dipoles
spaced ¾ wave center-to-center



For a signal coming in horizontally, waves arrive at each antenna at the same time, and the combiner adds them together – you get about four times the power as you would from just one ½ wave dipole.

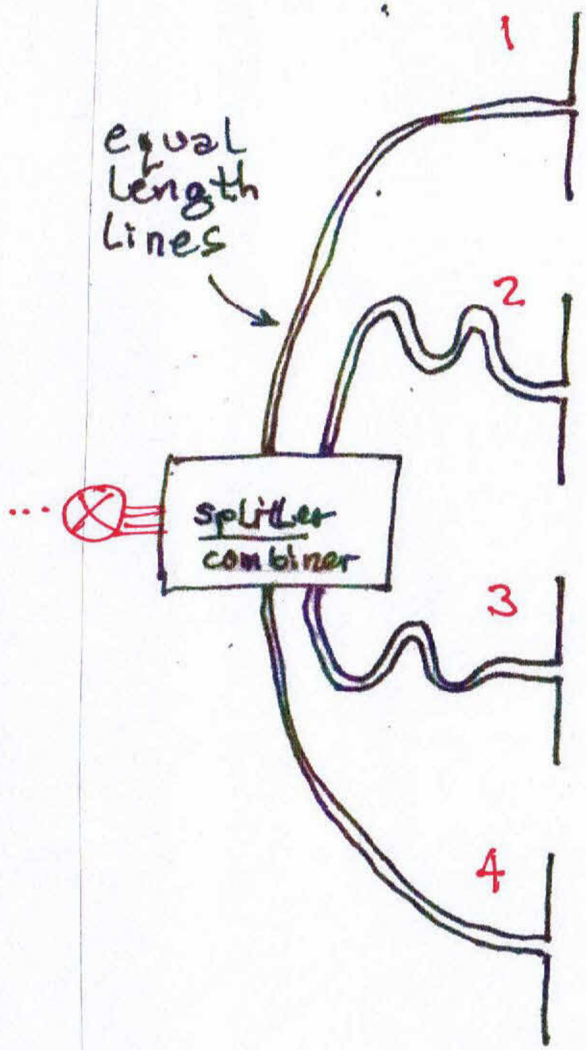
Four ½ wave dipoles
spaced ¾ wave center-to-center



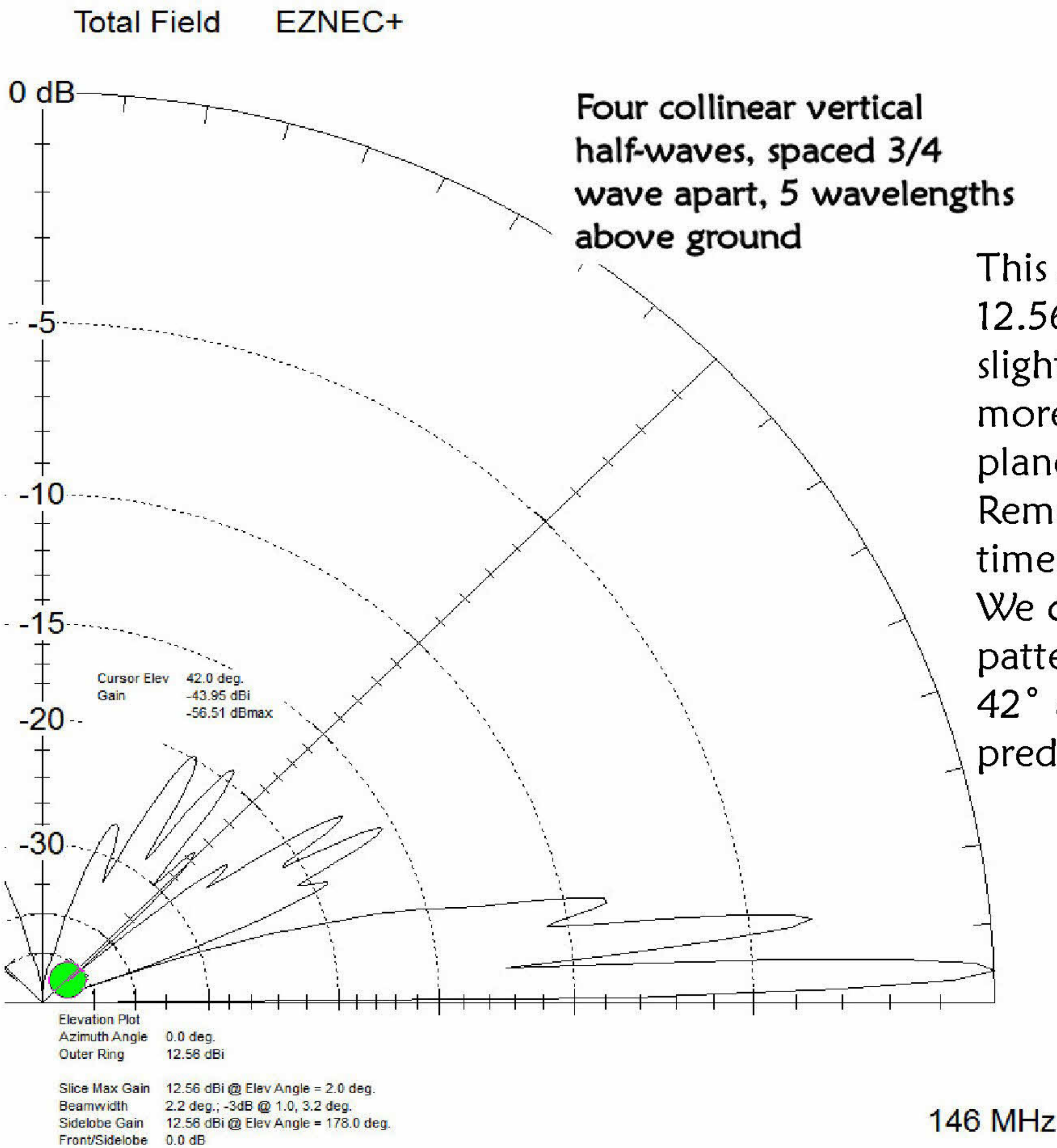
Waves coming in at an angle arrive at the antennas at different times.

If the angle causes 90° shift from one antenna to the next, antenna 3's signal will cancel the signal from antenna 1, and 2 an4 will also cancel. For this geometry (¾ wave center-to-center) this happens at 19.47° elevation angle

Four ½ wave dipoles
spaced ¾ wave center-to-center



Cancellation also happens if the phase difference from one antenna to the next is 180° — and again when it's 270°. For this geometry, those happen for 41.8° and 90°.



Four collinear vertical half-waves, spaced 3/4 wave apart, 5 wavelengths above ground

This antenna has 12.56dBi gain, just slightly less than 6dB more than the ground plane antenna. Remember, 6dB is four times the power. We can see nulls in the pattern, just at 19.5°, 42° and 90°, as predicted.

The collinear we just looked at requires matched transmission lines and some form of combiner. It's also fed from the side, which isn't always convenient. Each antenna element mounts separately. In some situations, it's ideal, but at other times, it just isn't the right answer.

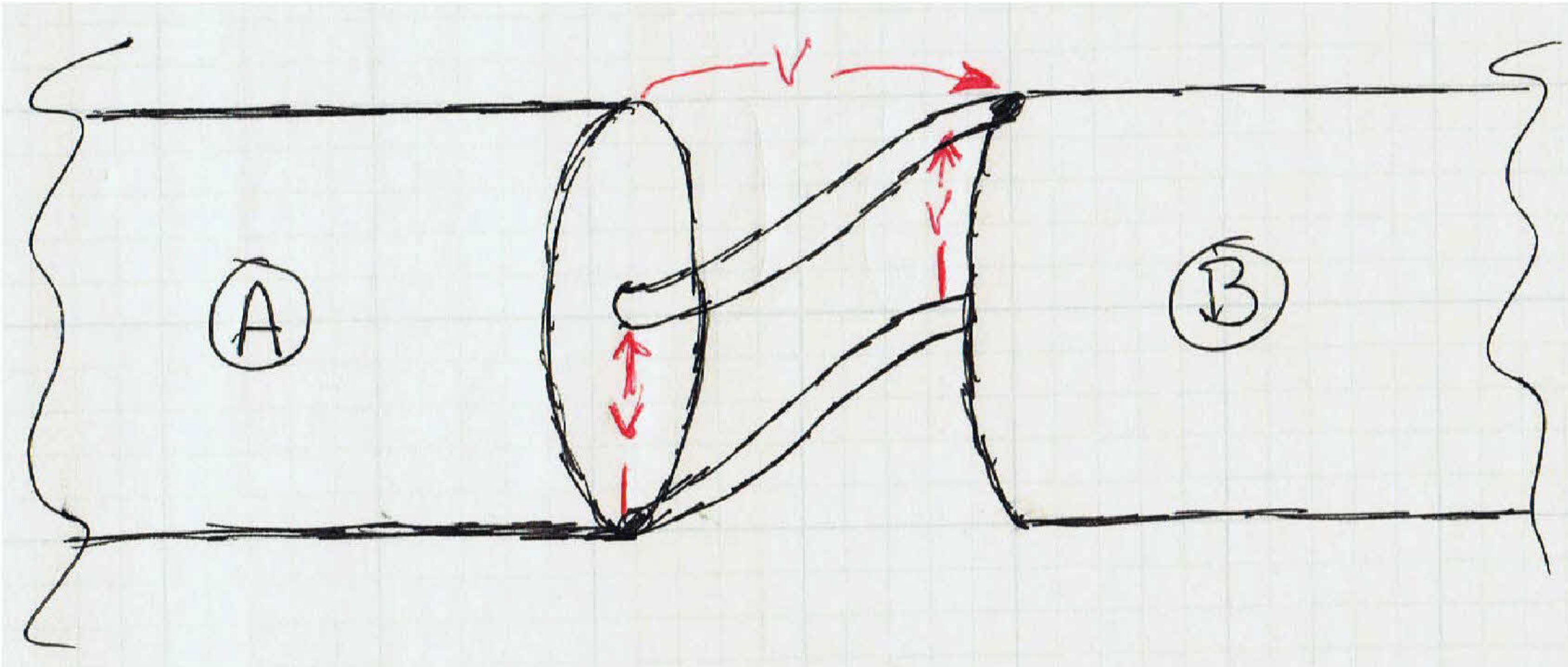
The Coaxial Collinear integrates the feed line into the antenna, and the result is an antenna you can put in a fiberglass tube and mount it on top of a mast, or with a little different mechanical design, roll it up and take it backpacking, to hang from a tree.

The basic idea is to have several elements all in a line, with a voltage source put in between each pair of adjacent ends. The voltage sources are all equal amplitude and in phase. It looks like this, except you'd normally put it vertical:

How do we get all those sources to be in phase and equal amplitude? Here's where the magic of transmission lines (coaxial cables) comes in. In a lossless line, if two points are ½ wave apart (accounting for the propagation velocity of the line), the voltages at those two points are exactly equal magnitude and exactly 180 degrees out of phase. It doesn't matter if the SWR is 1:1 or very high. In a real line with a little loss, they're still very nearly equal.

All the transmission line currents and voltages are INSIDE the coax. The OUTSIDE of the coax is perfectly happy to have antenna currents and be a radiator, just as if it was a solid wire.

So to build the antenna, we cut pieces of transmission line to be ½ wave long (accounting for propagation velocity), put them all in a row, and connect them together, REVERSING the inner and outer conductors at each junction…so we get 180 degrees phase shift through the line and another 180 degrees from reversing the inner and outer. The voltages between all the lines/elements are all equal and in phase!



The voltage at the end of A is also the voltage between the outer conductors of A and B. It also launches down B, but inverted polarity from how it comes out of A, since the wires are reversed. When it comes out of B, it's shifted by 180 degrees, so the other end of B looks just like this end of A, and the process repeats all the way down the chain.

So the transmission line pieces take care of distributing the energy along the array of elements, but we still need to feed energy in. We could actually feed it in at any of the junctions, but most likely we'll want to feed it in one end. And we'll want to match whatever the antenna impedance is to the feedline from our transceiver. And we'll want to make sure the antenna currents stay on the antenna, and don't get on the feedline, or on other pieces of metal in the area.

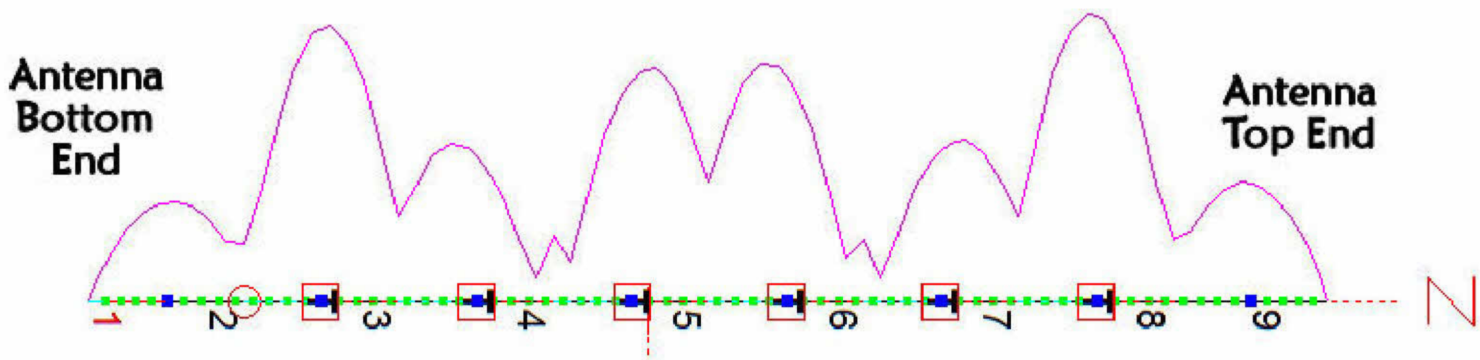
Once we understand WHAT we need to do and WHY, then we can see we have choices about how to accomplish those tasks.

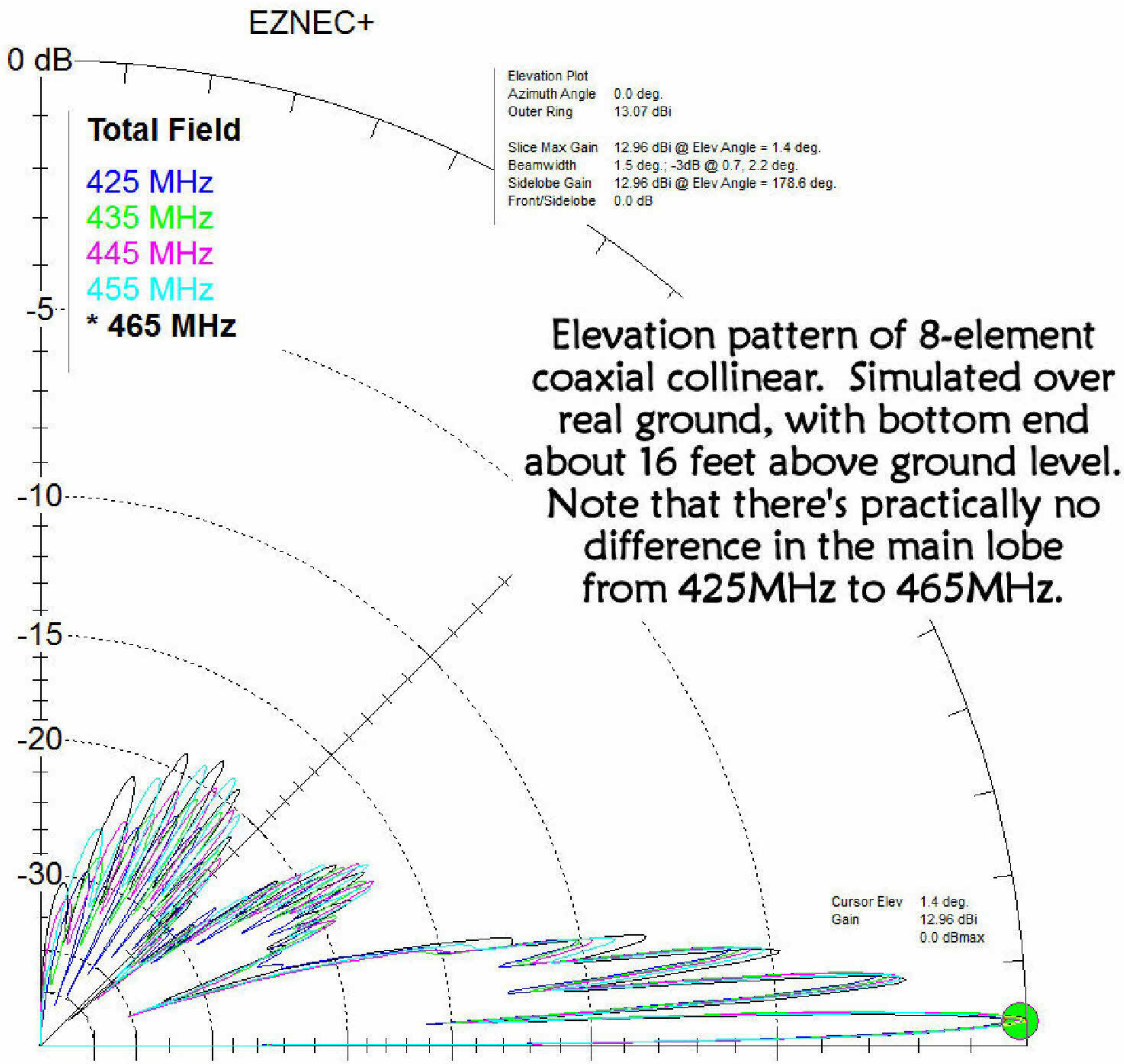
We can match the antenna impedance to the line with a simple L-C network (just one capacitor and one inductor), or with pieces of transmission line, or possibly even with a little RF transformer. Because it's relatively easy to adjust, the L-C network is a good choice for one-off antennas, but if we want to make several identical ones, it may be worthwhile to work out a network using short pieces of coax.

Isolating the antenna from other conductors, and especially from the feedline, is important so that those other conductors don't act like part of the antenna and mess up the gain pattern we've worked so hard to get. You'd usually get isolation from other conductors by putting the bottom of the antenna well above any metal tower or mast. You can isolate the feedline with a "balun" – which can be ferrite toroids on the feedline, or a self-resonant coil of the transmission line. There are other common baluns that can be used, too: a ¼ wave "sleeve" balun, or a ¼ wave piece of wire running parallel to the transmission line (and properly connected), for example. For really good isolation, put a second balun about a quarter wave down the line from the one that's right below the antenna.

So what does a simulation suggest the performance of a coaxial collinear should be? Let's have a look at some images for an 8-element antenna made from 75-ohm RG-6 type cable…common TV cable:

Current along an 8-element coaxial collinear
(EZNEC simulation)



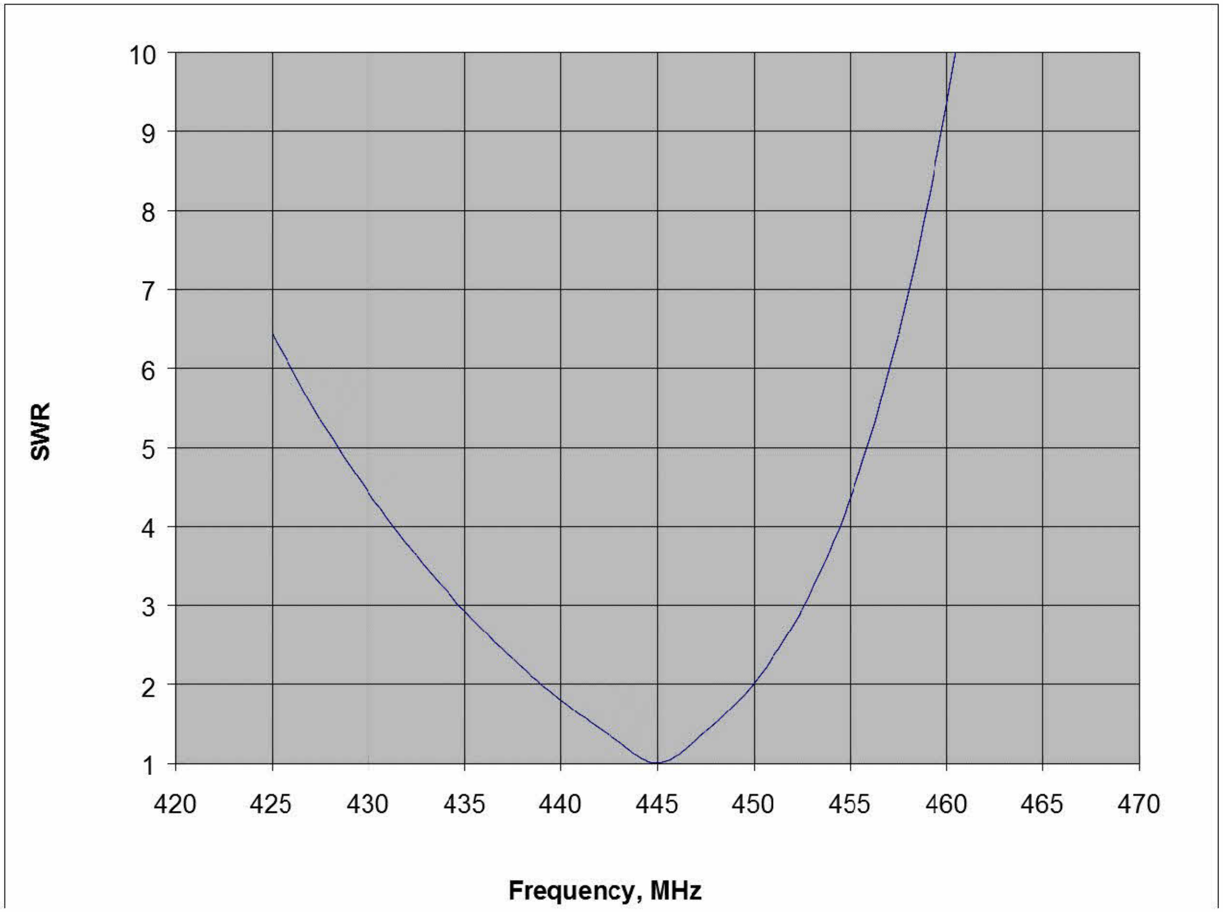


Elevation pattern of 8-element coaxial collinear. Simulated over real ground, with bottom end about 16 feet above ground level. Note that there's practically no difference in the main lobe from 425MHz to 465MHz.

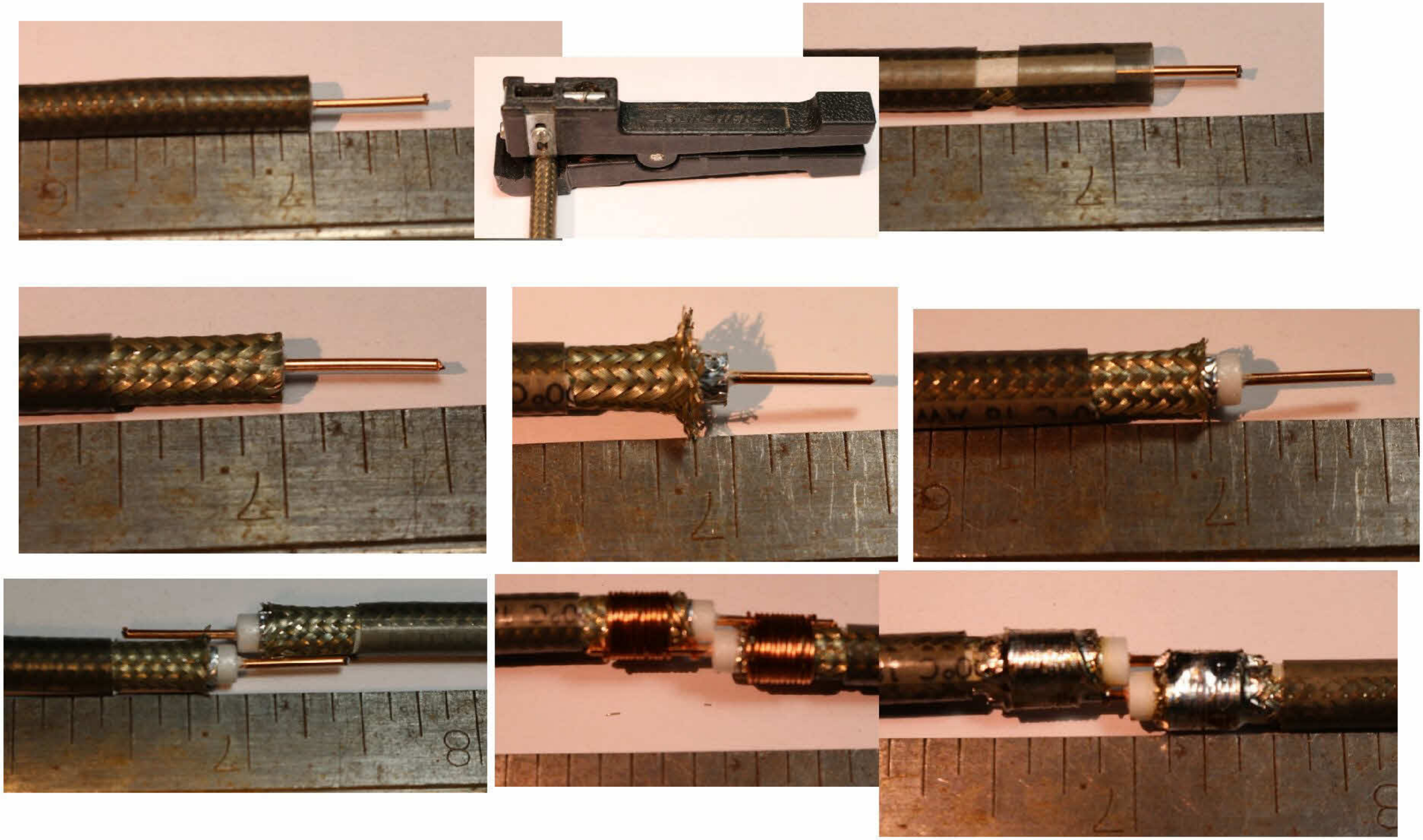
Although the PATTERN doesn't change much over a pretty wide frequency range, the SWR does!

8-element Coaxial Collinear: SWR versus frequency

(Assumes perfect match at 445MHz)



Some pictures of coax/element end preparation and joining two ends:



The following pages are some added thoughts I wanted to share, beyond what I presented at the November Snohomish County Hams Club meeting.

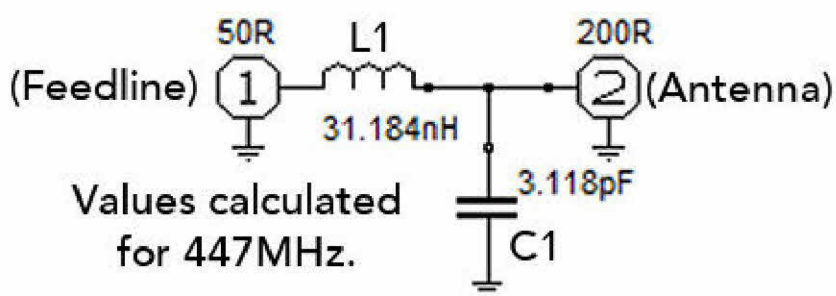
Although this presentation emphasized feeding the antenna at the end, since the voltage is the same across each point where two elements are joined, you can feed the antenna at any of those points. If you do, the SWR versus frequency is somewhat flatter. The antenna will work well over a wider frequency range. If you have a tower and it's easy to hang the antenna off to the side of the tower, separated from it by at least ¼ wave, this may be an attractive way to go. If you have an even number of elements, feeding it in the center will be perfectly balanced (assuming its surroundings are symmetrical). You could feed it with a balun or a balanced line. You still need to make sure the impedance is matched properly.

Now some notes on impedance matching…

There are always options for doing an impedance match. I'll assume you want to match the antenna to a 50 ohm feedline, and that the antenna's feedpoint impedance is roughly in the 100 to 250 ohm region, probably with some reactance.

For one-off antennas, I've always felt that having an easily adjusted matching network is a big advantage. If you're building 100 antennas all just the same, then you can design and test and refine a fixed arrangement that will be inexpensive and easy to duplicate, but trying to adjust it so it works right is a lot harder than using a network with one or two variable elements like tuning capacitors.

A circuit that works well to match between 50 ohms and the impedance of a typical coaxial collinear as described here is an "L" network:



If you make C1 a small variable capacitor, say 10pF maximum capacitance (or even 5pF maximum), you can tune for minimum SWR, and then adjust L1 by compressing or expanding its turns. If you need to, you can replace L1 with a coil with one or more additional turns, or remove a turn from the coil you started with. These coils are typically quite small for 440 antennas, and just a little bigger for 2 meter antennas. For example, you can make a 31nH coil as required for L1 on the preceding page with less than 3 turns of 18AWG wire wound around a ¼" diameter dowel (and then remove the dowel!). There's a good chance you'd only need two turns, but three turns is probably a good place to start.

How do you find the values of capacitor and inductor to start with, and how do you know how to make the inductor? There are lots of software tools available, as apps on websites and as downloadable programs. I like "RFSim99" for RF calculations. It has an impedance matching tool that I used to generate the schematic on the preceding page. Unfortunately, the inductance calculator I use is no longer readily available, but there's a good one at http://hamwaves.com/antennas/inductance.html if you don't mind using millimeter measurements. You can find lots of others.

And please feel free to ask me for help if any of this seems daunting to you.

If you want to do impedance matching for a batch of antennas that are all the same, a good way to do it is with short pieces of transmission line. The process would involve first making as accurate as possible an estimate of the actual antenna feedpoint impedance. Then you can use various tools (or a lot of hand calculations!) to figure out what transmission line stubs and series elements will work best for you. Then you have to try it out, and you should expect to make some adjustments on your first trial, because the mere fact that you put some pieces of conductor (the coax elements) near the antenna feedpoint will change the feedpoint impedance a little. It helps a LOT to have a good way to measure the actual impedance at the antenna feedpoint if you want to go this way!

Now a few thoughts on supporting a coaxial collinear…

The usual way if you want to do a permanent installation is to put the antenna inside some sort of tube. You can use PVC pipe, but it's pretty flexible and may be hard to support properly. A better option is fiberglass tubing…perhaps telescoping sections if you're building a long antenna. Max Gain Systems sells appropriate pieces that can be shipped, though the shipping is expensive. It would make sense to make a group purchase, as the shipping charge seems to be the same for anything up to 70 pounds, I believe. There may be a local supplier, too…Goodwinds LLC in Mt. Vernon does supply fiberglass tubing, but I'm not sure they can do the telescoping sections. Someone is supposed to be checking on that for us… In any event, be aware that putting an antenna in a plastic/fiberglass pipe will change the tuning. Do the final matching while the antenna is in the pipe. And of course, do NOT use carbon-fiber pipe!

There's also no reason you can't hang the antenna from a tree limb, for example. Some fishing line or similar might do the trick. Do try to keep it straight and vertical. This may be a good option for your portable/backpacking operations.

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I'm always happy to help by explaining things in different ways if anything is not clear, and in getting things to work right if you're having trouble.

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