A Case For Casual Feed of Quadrature Phased Horizontal Dipoles

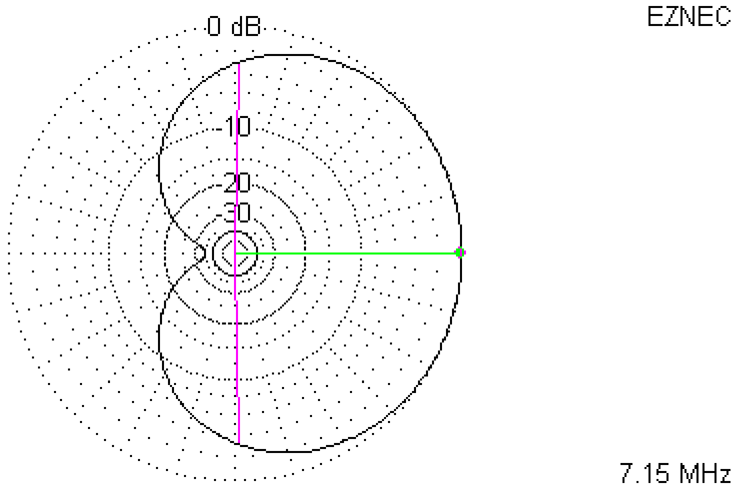
One of the simpler beam antennas to construct is a pair of parallel horizontal half wave dipoles, spaced ¼ wavelength apart. When these dipoles are quadrature fed, that is, with equal currents, 90 degrees out of phase with each other, a unidirectional radiation pattern is created. Unfortunately, this antenna has received little attention because of the complexity of achieving precise equal current, 90 degree feed.

The principle of operation of this antenna is simple. The quarter wave spacing results in a quarter RF cycle, 90-degree delay in the travel of the RF field from one dipole to the other. When we also supply a quarter cycle, 90-degree delay to the feed current of one of the dipoles, the RF fields around the two dipoles are in phase and add in one direction. In the opposite direction, they are 180 degrees out of phase and cancel.

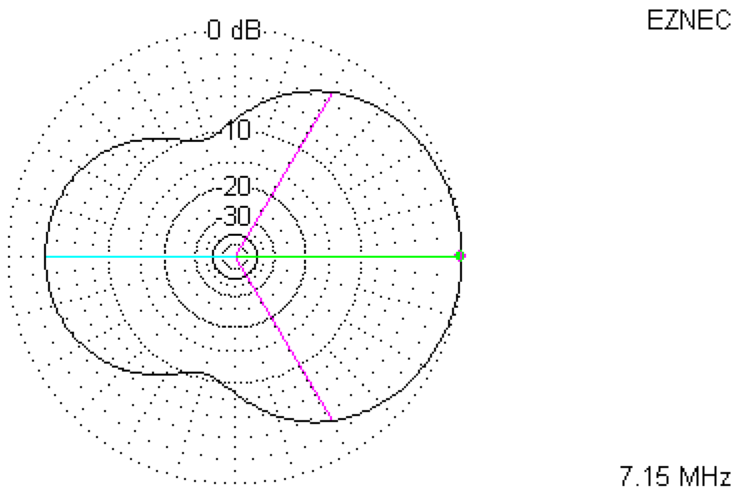
Obtaining precise quadrature feed is made difficult by the interaction of the two dipoles. Quarter wave spacing is well within the near field of the dipoles so electromagnetic and electrostatic coupling between them is fairly strong. One experiences the influences of coupling from a 90-degree lagging field. The other, therefore, experiences the influences from a 90-degree leading field. The induced currents are different so the dipoles feed impedances are different – very different.

As an example of the dipole feed impedance problem, let’s consider a simple resonant half wave dipole mounted at 60 feet. EZNEC shows its feed impedance to be 79 Ohms when installed over average soil. When we add a second dipole a quarter wave away fed 90 degrees lagging phase, the original dipole’s feed impedance shifts to 122 –j41 Ohms. The lagging dipole’s feed impedance is shown as 34 +j39 Ohms. Designing networks to provide precise quadrature feed is tedious at best. Of course, as with all antennas, the real physical surroundings of an antenna are usually not well known so those network calculations would likely be wrong anyway.

What is the big deal about getting precision current feed for the dipoles? Antenna books usually give an example like the following where precise and imprecise feed currents are used.



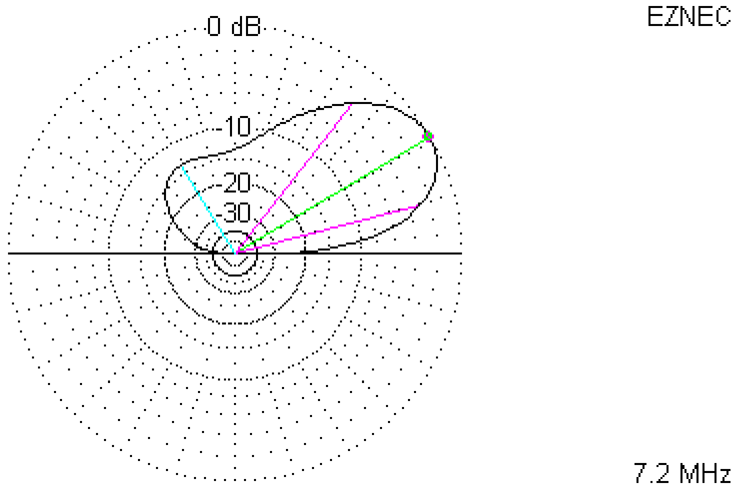
The above plot shows what should be expected from perfect quadrature feed.



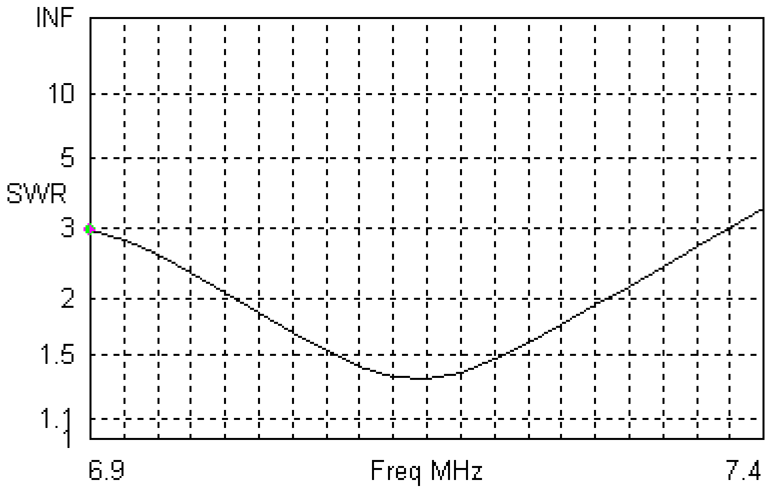
This second plot shows the expected radiation pattern if we just simply used an extra electrical quarter wavelength of feedline in an attempt to achieve quadrature feed. In this case, one feedline is ¼ electrical wavelength long and the other ½ so there is physically enough coax to reach between the two dipoles. That kind of plot is probably unexciting enough to discourage most experimenters. Not everyone though.

Tom Berquist, K3MRG, had been experimenting with phased dipoles for 20 years, off and on. One evening a while back during a casual rag-chew QSO, Tom demonstrated his antenna. It was oriented so it could beam east or west by switching dipole phasing. He had a strong signal for the prevailing band conditions. The front-to-back ratio appeared to be very good. Tom described his antenna as using simple coax delay line feed scheme. That got my curiosity up.

Tom e-mailed me description of his antenna design. When I translated his schematic into an EZNEC antenna definition, EZNEC verified Tom's design.



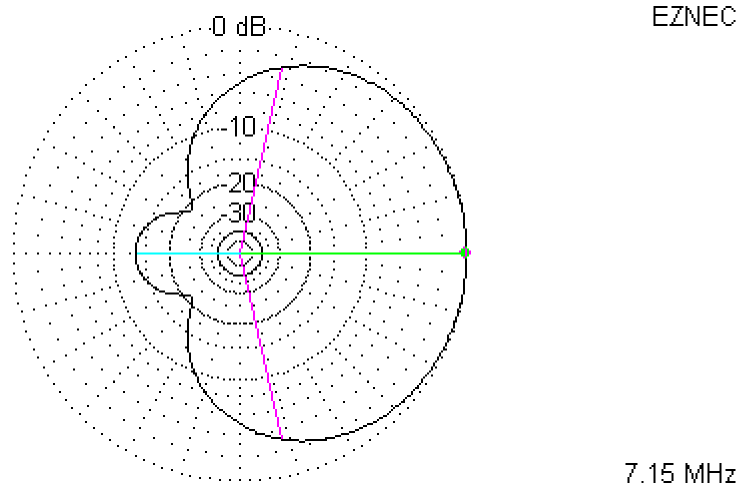
This plot shows EZNEC's guess of Tom's antenna pattern. His antenna was installed 60 feet above the ground. The front-to-back ratio I noticed on the air was better than what the graph above shows but variations in soil conditions, coax velocity factor, and other practical considerations could explain that difference. Tom had also said his the SWR was 1.7 to 1 or lower across the band.



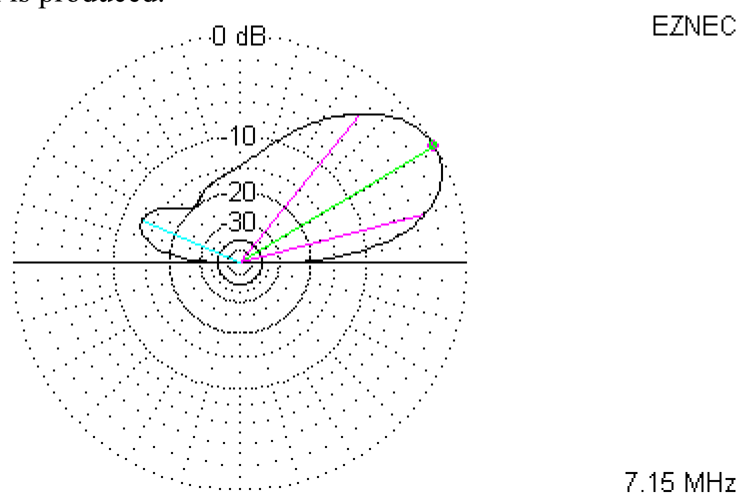
EZNEC's guess at the antenna's SWR curve was a little higher than Tom's measured values but this is often the case. Environmental factors often have large impacts on antenna feed impedances. Also, EZNEC does not include transmission line losses in its calculations. These losses tend to moderate SWR readings toward 1 to 1.

Ok, so what is the deal here? This antenna works but it isn't supposed to. This is the kind of question that computer programs like EZNEC are useful for answering. I could try lots of variations to see what does what, without using up my stock of coax and antenna wire.

What I discovered is that Tom's antenna is very forgiving. There is a wide range of coax lengths that will make this antenna play. In fact, even the casual feed method that showed such a poor radiation pattern above could be made to work. By simply turning on of the dipoles around 180 degrees so it was out of phase with the other, the pattern could be made to look much better.



The above plot is the same EZNEC antenna description as for casual feed configuration that gave the poor radiation pattern above, except one of the dipoles is turned around 180 degrees. That is looking a bit better. When the antenna is modeled above real ground, another interesting pattern is produced.



Elevation Plot		Cursor Elev	31.0 deg.
Azimuth Angle	0.0 deg.	Gain	10.51 dBi
Outer Ring	10.51 dBi		0.0 dBmax
Slice Max Gain	10.51 dBi @ Elev Angle = 31.0 deg.		
Beamwidth	36.9 deg.; -3dB @ 14.4, 51.3 deg.		
Sidelobe Gain	-2.47 dBi @ Elev Angle = 157.0 deg.		
Front/Sidelobe	12.98 dB		

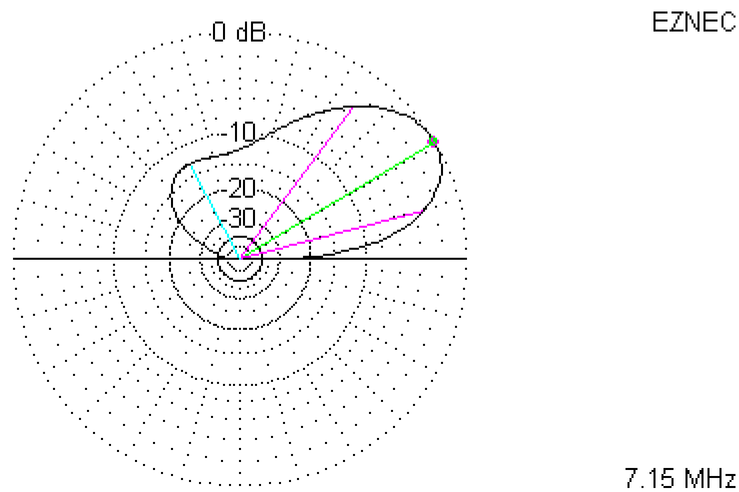
An exciting detail shows up in the plot above of the casual feed of the dipoles at 60 feet. Notice that the pattern off the back of the antenna has a better attenuation for high angle signals than even low angle signals. This is great for 40-meter operation. While good low angle rear rejection is good, high angle rejection is necessary to reject QRN and local QRM. Looking at the free space pattern before in the previous plot, we can see the pattern notch that provides that rejection.

Another detail about this feed scheme showed up as I tried different combinations of feedline lengths. The radiation pattern of the antenna is exactly the same whether the feedlines were multiples of ½ electrical wavelength or odd multiples of ¼ electrical wavelength. There is a trick to this however. When multiples of half wavelength lines are used, the dipoles must be fed in phase with each other. When odd multiples of quarter wavelength lines are used, the dipoles must be out of phase with each other. In phase means that the legs of the dipoles that are in phase with the center conductors of the feedline coax are pointing in the same direction. Out of phase means they are pointing in opposite directions.

That detail about the in-phase/out-of-phase dipoles confused me a bit. After all, when the quarter wavelength delay line inserted, one or the other line length would be a multiple of a half wavelength and the other an odd multiple of a quarter wavelength. It seemed like there should be no difference but then my brain engaged for a few extra seconds.

The reason why dipole phasing matters is that with this casual feed system, the dipoles, feedlines, and delay line together make up a system. Interaction occurs not only between the closely spaced dipoles but also via the voltages and currents in coax. Dipole interaction induces currents that are coupled between them modifying the voltage and current in the feedlines, which in turn modifies the dipole fields, and so on until a balance is achieved. One line length combination produces a nice unidirectional radiation pattern, the other doesn't unless a 180 degree rotation is made on one of the dipoles.

That interesting improvement in high angle rear rejection shown in the previous plot made me curious about what a "perfect" feed plot might look like.



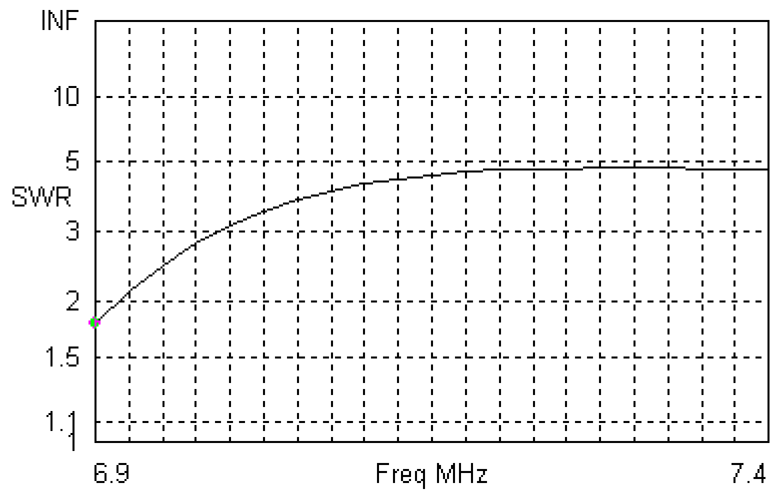
Elevation Plot		Cursor Elev	31.0 deg.
Azimuth Angle	0.0 deg.	Gain	9.87 dBi
Outer Ring	9.87 dBi		0.0 dBmax
Slice Max Gain	9.87 dBi @ Elev Angle = 31.0 deg.		
Beamwidth	38.2 deg.; -3dB @ 14.8, 53.0 deg.		
Sidelobe Gain	-3.01 dBi @ Elev Angle = 118.0 deg.		
Front/Sidelobe	12.88 dB		

The plot above is EZNEC's guess at what a radiation pattern from the "perfect" quadrature feed antenna mounted at the same height above real ground as the casual feed example in the plot before this one. Notice that high angle rear rejection is not as good. Notice also, that the gain is less also, although, 0.6 dB difference has little practical impact.

Now, back to the casual feed scheme, what about SWR. There are many interesting antenna designs that provide good gain or front-to-back ratio but are quite unwieldy to feed. Let's see how Tom was able to get good SWR with relatively low transmission line losses.

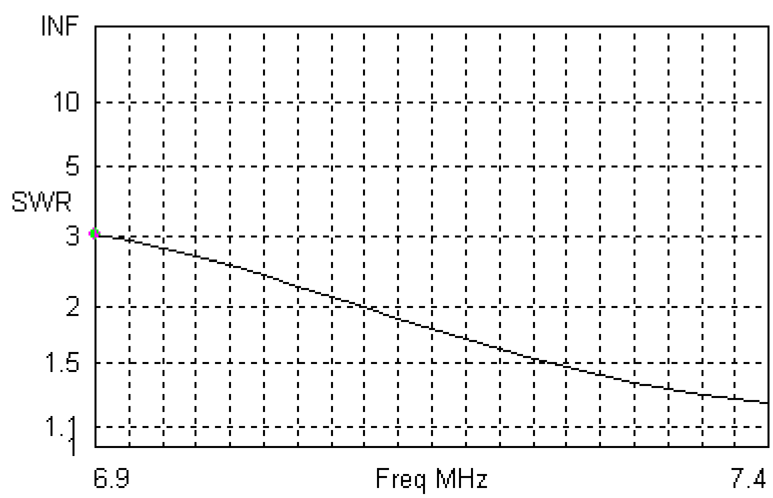
EZNEC allowed me to dissect this antenna's feed system and see what the individual feedline impedances and SWR's are. At 7.15 MHz, the individual feedlines from delay line switch box to the dipoles are 1.8:1 for one and 3:1 for the other. This is low enough that losses should be minimal between the switch box and the dipoles.

The SWR at the transmitter side of the delay line switch box is 4.5:1 with an impedance of 11 –j7 Ohms.

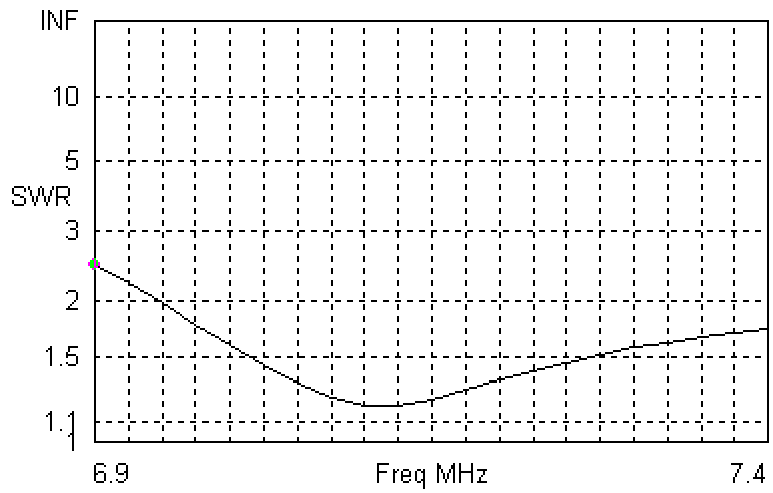


The plot above shows the SWR as it would be across the entire 40-meter band. Obviously, something needs to be done to bring this into a more transmitter friendly range.

Tom's approach was to add an in-line matching stub. EZNEC makes it easy to see if that would help here. Adding a simple 25 Ohm quarter wave matching line section at the phasing line switch box dropped the SWR at 7.15 MHz to 1.8:1 with an impedance of 40 +j24 Ohms. The 25 Ohm matching line is made by simply paralleling two piece of 50 Ohm coax.

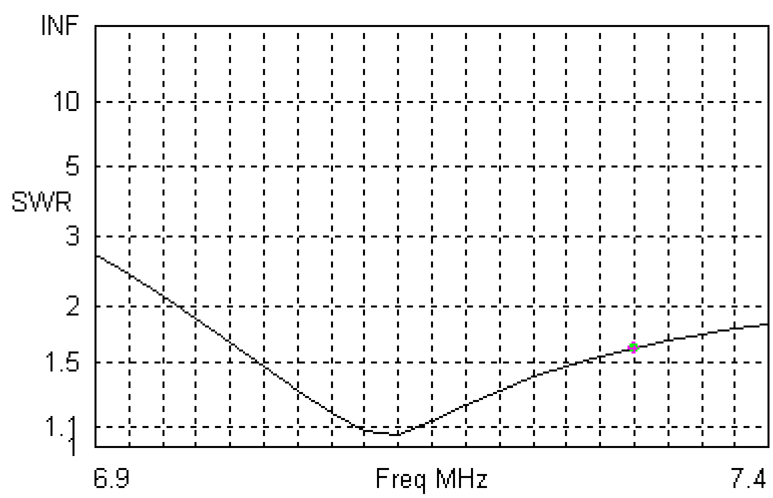


The SWR plot now looks like the plot above. It is better but still not nearly as good as Tom's antenna. I noticed that Tom specified a matching line section length that is not exactly ¼ electrical wavelength long. Taking that as a hint, I tried adjusting the matching section length to see how it affected the SWR curve.



With a 25-Ohm matching section electrical length of 0.31 wavelength, the above SWR curve was achieved. This length provides a SWR under 1.6:1 across the entire 7.0 to 7.3 MHz band. That is clearly acceptable for amateur use. There is a caveat to this however. I expect that the matching section length need for individual installations will vary widely. This is the adjustment that will provide most of the compensation for variations in actual installations.

Since adjusting the length of a 25-Ohm chunk of transmission line fabricated from two parallel 50 cables is difficult, I looked for an alternative method of improving SWR curve that would be a little less difficult. I noticed that the impedance at the transmitter end of the 25-Ohm matching section was a below 50 Ohms and inductive, I tried adding a parallel capacitor at that location.



The plot above shows the SWR curve obtained by connecting an open stub of 50 Ohm coax at the transmitter end of the original quarter wavelength 25-Ohm matching section. In this case the stub needed turned out to be only about 8 feet long. The curve is not quite as good as what is available using Tom's method of adjusting the matching section length but it does point out that simple stub matching can be made to work.

A closing point should also be made. All of the plots shown above other than those of Tom's original design were of a single theoretical configuration. While the casual feed method I described is good, the fact that Tom's dimensions differ indicates that there are many other designs possible. Some may be better than this generic design or even Tom's.

So what is the conclusion from all this? It appears that Tom's experiments uncovered a method for feeding phased dipoles that is generally overlooked in antenna literature. It also shows that perseverance in developing an idea can often succeed. Tom tested and adjusted his design, without the aid of computers and fancy lab equipment. His effort paid off.