The End-Fed Half-Wave Antenna

by

Todd Longfellow, N7TWL

(Revision 2, Feb. 2025)

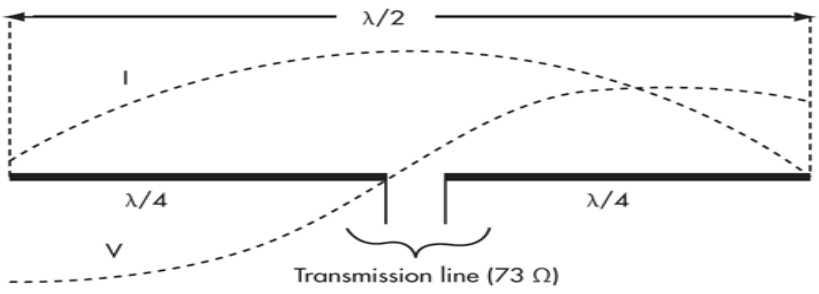
Disclaimer

My entire presentation is based upon my own experience with building, deploying, and using this antenna design. It is cut for 40 meters, and I use two of these antennas at my home on an A/B switch. One antenna is pretty much a vertical going up at least sixty feet, and the other antenna has its element in a more horizontal configuration in an approximate inverted Vee. The vertex of the element is somewhere between 20 and 25 feet off of the ground, and about three-quarters of it is over my corrugated steel roof. In the immortal words of Woody, KJ7YYI, "…with antennas, everything effects everything…" So, your mileage may vary.

Presentation

Perhaps the simplest antenna is a single wire hanging out the window, or running up into some near-by tree branches. If you ever played around with a crystal radio, you soon discovered that you needed a longish wire for an antenna, AND you needed to have a good ground wire! However, the game changes significantly when we want to transmit signals on our antenna as well as receive them.

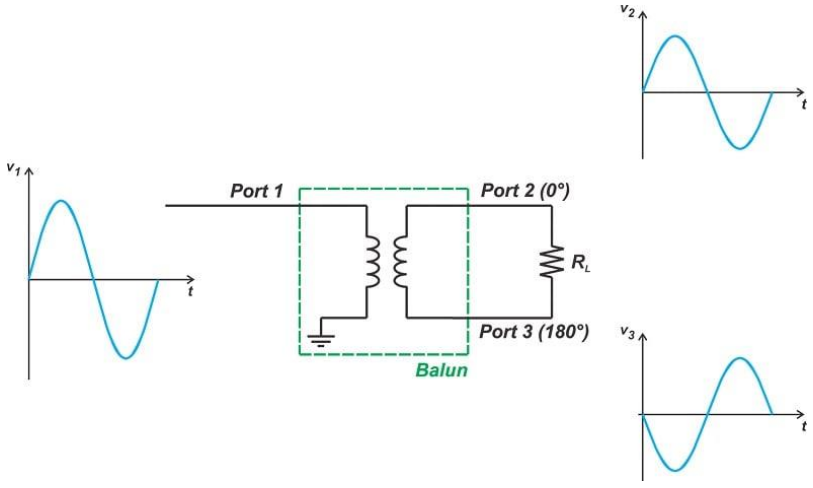
The first antenna for a great many amateurs is the half-wave dipole. Dipoles are simple to construct and the parts are usually cheap. Even the commercially built dipoles are relatively inexpensive as compared to other types of manufactured antennas. And a good way to understand how the end-fed half-wave (EFHW) antenna works is by first looking at the dipole.



The Greek letter lambda (λ) - it looks like an upside-down y - stands for wave length. For example, in the 40-meter band, the full wave length of a single RF wave is 40 meters. That's a little more than 120 feet long! So why is this important? In order to transmit a 40-meter signal, our antenna has to be resonant at the wave length of 40 meters. It turns out that we can still get all the transmitted information just using half of the wave length – hence, the idea of a half-wave dipole.

So, what does it mean to be resonant? I like to work from a visual concept first. Suppose you have a movie camera and it takes pictures at a certain number of frames per second, and suppose that you are filming a spinning wagon wheel with wooden spokes. When the rotation speed of the spokes matches the film speed, the spokes of the wheel will appear to be standing still when the film is viewed. When a wire (or any antenna element) is cut to a specific wave length, is exposed to a radio wave of the same length, it creates a standing wave on the element. If you could see the wave on the wire, the wave would appear not to be alternating; it would just stand still. This is resonance. No doubt you have heard the term SWR. That stands for Standing Wave Ratio.

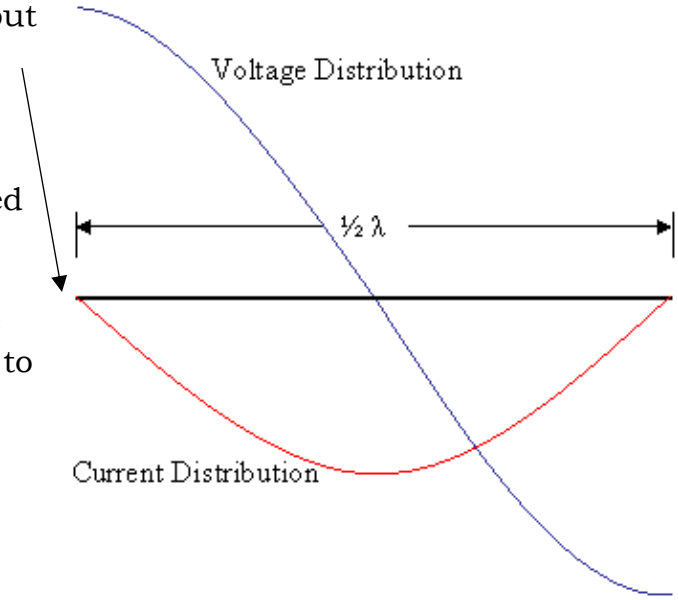
A dipole antenna or any antenna for that matter is a two-connection device, and you will notice that our 40-meter dipole is fed exactly in the middle of the wave so to speak, with each side being 1/4 of a wave length. The center is chosen because it is at the center where the impedance is the lowest; usually somewhere around 50 to 70 ohms. Perhaps the most common feed line to an antenna is 50-ohm coax cable. However, a dipole antenna is a "balanced" antenna, meaning that both parts of the antenna are driven with equal but opposite voltages. The output of a typical transmitter is unbalanced. The signal goes out on the center conductor, while the shield connection is held at ground. Therefore, most amateurs use a "balun" to connect the radio's feed line to the dipole antenna. BALUN stands for balanced to unbalanced.



In the diagram, Port 1 is the radio/feedline side of the connection to an antenna. Port 2 is the antenna side of the connection. Note that on the radio side, one side of the transformer is grounded (unbalanced), while on the antenna side, both ends of the transformer carry the signal (balanced).

How does all of this apply to an end-fed half-wave antenna? Let's start by moving the feed point of the antenna from the center to one of the ends.

For the sake of this drawing, let's put the feed point on the left-end.



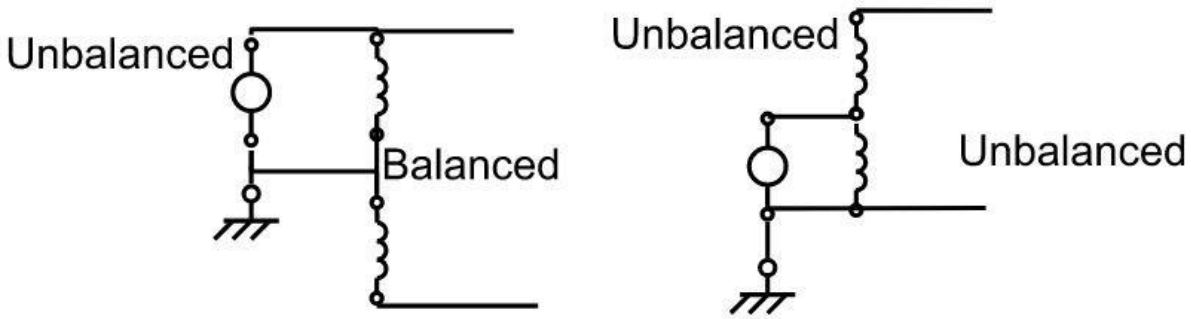
Notice that he voltage and current curves have not moved from where they were when the antenna was fed at the center. The voltage is at zero in the middle of the antenna, while the current is at its maximum. The relationship of voltage and current to impedance can be expressed as follows:

$$Impedance\ (Z) = \frac{Voltage\ (V)}{Current\ (I)}$$

Notice that when the voltage is zero the impedance is near zero, zero divided by any number (not zero) is zero. It turns out in the real world, that this impedance is usually around 50 to 75 ohms. That makes it a great match for 50 ohm feed line.

On the other hand, at the end where we have moved our feed point, the current is at its minimum and the voltage is at its maximum. The current will not be zero, as there is always some level of current on the element due to capacative and inductive influences. With current at a minimum, this makes the impedance pretty much equal (proportional) to the voltage. Since the voltage is high, then so is the impedance. This is some where on the order of 2000 to 3000 ohms of impedance. Since we are attaching our radio/feedline, which has an impedance of about 50 ohms, we have a severe impedance mismatch. This mismatch can be solved by using an impedance matching transformer.

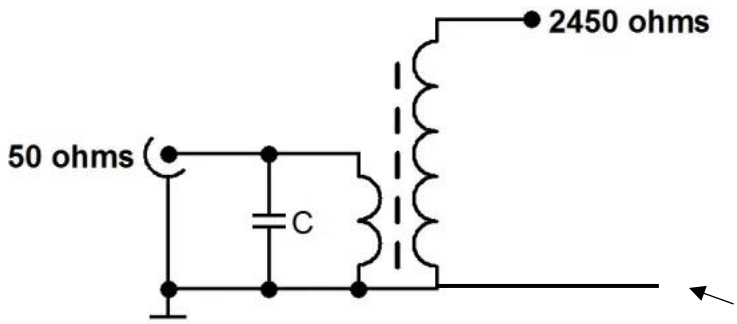
Notice also, that by moving the feed point to the end of our antenna element, we have changed a balanced antenna system to an unbalanced antenna system. Fortunately for us, instead of a device for balanced to unbalanced, we can use a device for unbalanced to unbalanced. This device is the Unun.



For the purpose of comparison, these diagrams are representative of the Balun on the left, and the Unun on the right. It turns out that baluns are most typically used in converting unbalanced systems to balanced, and ununs are most typically used for impedance matching. So, let's see just how that is done!

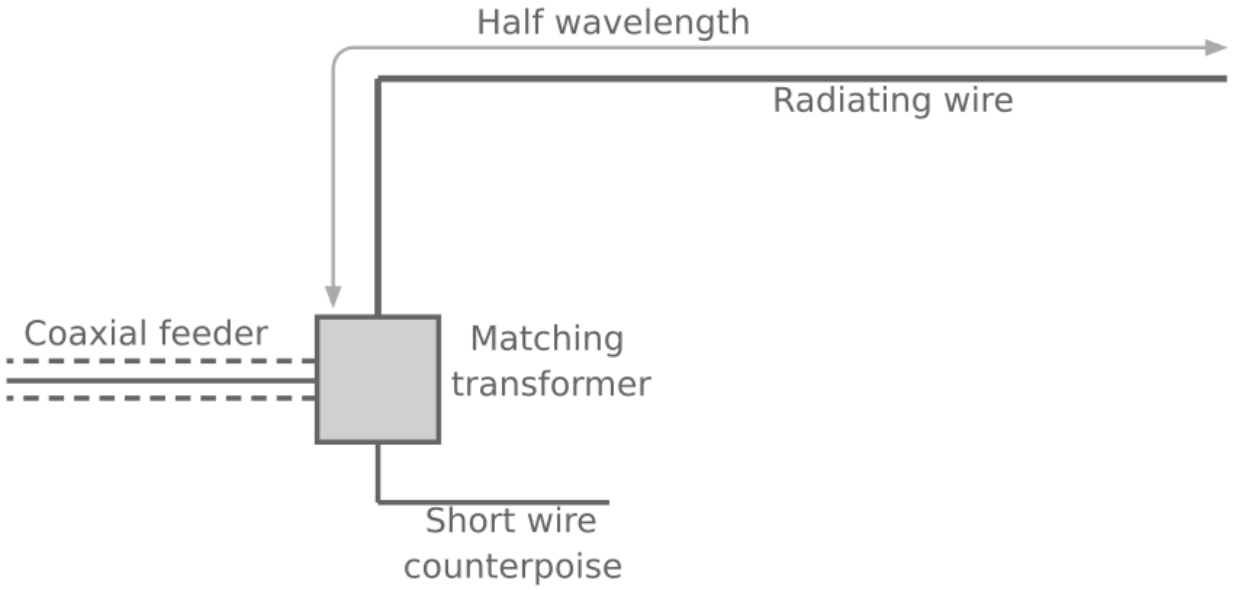
The first thing we need to find out is the impedance value at the end of our antenna. In the wild, this value can be very difficult to measure. Fortuately, enough actual data have been taken over the years to provide us with sort of the sweet spot in the rather large impedance range of values. That sweet spot is nominally 2500 ohms of impedance.

The next thing we need then is a matching transformer that takes 50 ohms of impedance on the feedline side and provides 2500 ohms impedance on the antenna side. This matching transformer is very easy to construct and the parts are minimal in cost, but before we get into the particulars of construction, let's look at its schematic.



At the input of the system, we can connect the 50 ohm coax, and the outputs of the system are the antenna wire connection, marked 2450 ohms, and the other connection is ground. However, we will (usually) want a counterpoise to the radiating element and this is kept at ground potential. If we do not use a counterpoise, then the signal will use the shield of the coax as the return path. Many amateurs set up their end-fed system that way.

The complete system diagram looks like this:



Now that we know what the system looks like electrically, let's see what it takes to build one.

At the heart of the matching transformer is n iron core of suitable material. A toroid core is ideal for this, and one of the most popular is the ft240-43 core.

The outer diameter is 2.4 inches; the inner diameter is 1.4 inches; the thickness is .5 inches. The dash 43 part of the model number is the material composition. 43 is great for RF antenna work.

The cost varies depending upon the seller. Amidon Corp. sells theirs for $12 plus shipping. If you have an Amazon Prime account, the price $12 including the shipping.

Actually, I prefer a different core. Fair-Rite Products Corp. has a number 2643251002 core (I call it the 1002 core) that is made from 43 material and about the same weight as the ft240-43, but is chunkier.

According to Colin Summers, MM0OPX, on his YouTube channel, his tests show this core to be about 20% more effective. This additional effectiveness could be a game-changer in hearing weak signals. I have tried this out at my house doing A/B tests between the core types in my antennas, and I can verify that I can hear the difference. I cannot tell if the gain is 20%, but it is certainly human detectable.

These cores are available from Digikey for less than $8 plus shipping.

The next item we need is the wire that gets wrapped around our core. Again, prices vary depending upon the source and quanity. I get a small spool from Amazon for about $12 including the shipping.

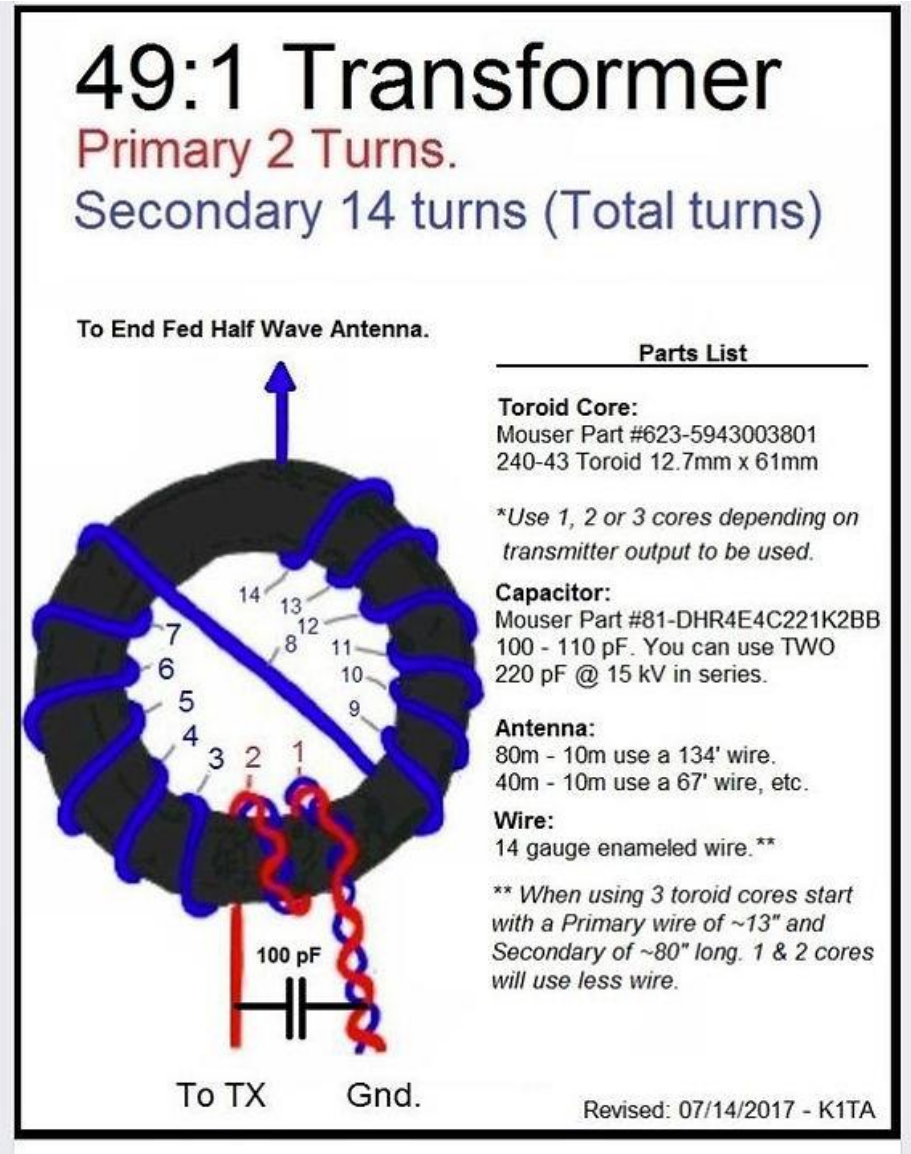
Then you are going to need an SO239 socket for your PL259 coax plug, some assorted nuts, bolts, washers, and an eye-bolt for hanging, and of course a plastic box to contain the assembled transformer system. And lastly, you will need a 100-foot roll of 18 gage wire for the antenna element and the counterpoise.

Last time I added all this up, I seem to recall the total price somewhere around the $35 mark.

Of course these EFHW transformers come as kits and ready made. For example, ARRL sells a compete kit for $80 plus shipping. Other brand-name ready made transformers for $100 to $200! I saw some complete units on Amazon for under $30. These are made in China and have some limitations on how much power can be run through them. Less than 80 watts for digital modes, is an example. The ones I make are good for 250 watts of power, so you sort of get what you pay for, perhaps.

Construction

First, let's take a look at a diagram of what the transformer should look like.



The main part of this picture to pay attention to is the toroid itself, and don't worry too much about this person's parts list. The rest of the construction I am taking out of my first presentation.

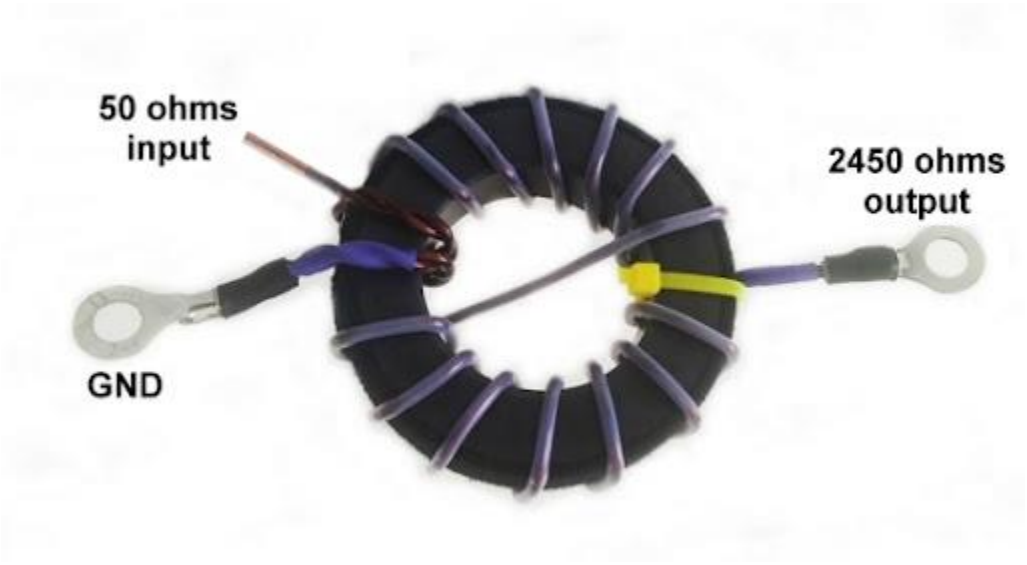
It follows on the next page.

[Transformer Construction]

It is probably best to be looking at the picture on the previous page while you read these instructions.

Assuming 49:1, I start with a good 6 feet of 18ga. enameled wire. I fold up about 7 inches of one end and place the loop created in a pair of pliers with padded jaws to protect the wire coating from scars. I then hand-twist the wire, leaving an inch or two for the short end. This is the primary winding. In figure 4 it is the green wire. In the diagram, it does not show being twisted, but again, the popular choice is to twist the wire to ensure tight coupling for the primary to the secondary. Next, I lay the wire on top of the edge of the core, pass the wire down through the middle of the core, and bring it up tight against the outside of the core. A wrap is each time the wire passes through the middle of the core. The first two wraps are for the primary, so make sure to separate the twists so that you can continue winding the secondary. Continue winding for five more wraps, giving a total of 7 wraps on the bottom half of the core. The eighth wrap is the crossover wrap. Make sure you are going from the top edge of the side, through the middle and wrapping up from the bottom. Then, continue on the top half of the core for six more wraps. This should be a total of fourteen wraps. The main reason for the crossover is to distribute both flux and heat evenly over the core.

When you are done, it should look similar to this:



The rest of the construction is doing the necessary mods to the enclosure, mounting the hardware, and putting in the finished transformer. For that, download my original document and you can read the final comments.

73, Todd, N7TWL