The End-Fed Half-Wave (EFHW) Dipole Wire Antenna

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Let's start with the obvious: The purpose of an antenna at the amateur radio station is to transmit and receive radio signals. The type and design of the antenna is based on any number of parameters: specifically, the frequency or band of frequencies, location, directivity, and intended power range. This paper discusses some of the more important aspects of the End Fed Half Wave (EFHW) dipole antenna. The frequency band is HF (40 meters), and the intended power is 100 watts.

Interest in the EFHW antenna has increased significantly over the last few years. Perhaps the main reasons being: It is inexpensive and easy to build, easy to deploy, can be portable, and it is multi band. The last reason may be the strongest selling point for many of us. It turns out that an EFHW cut for 40 meters is resonant not only on 40 meters, but also on 20, 15, and 10 meters, all without a tuner. If a tuner is used, the antenna performs well on 12 and 17 meters too.

The EFHW Antenna – the parts

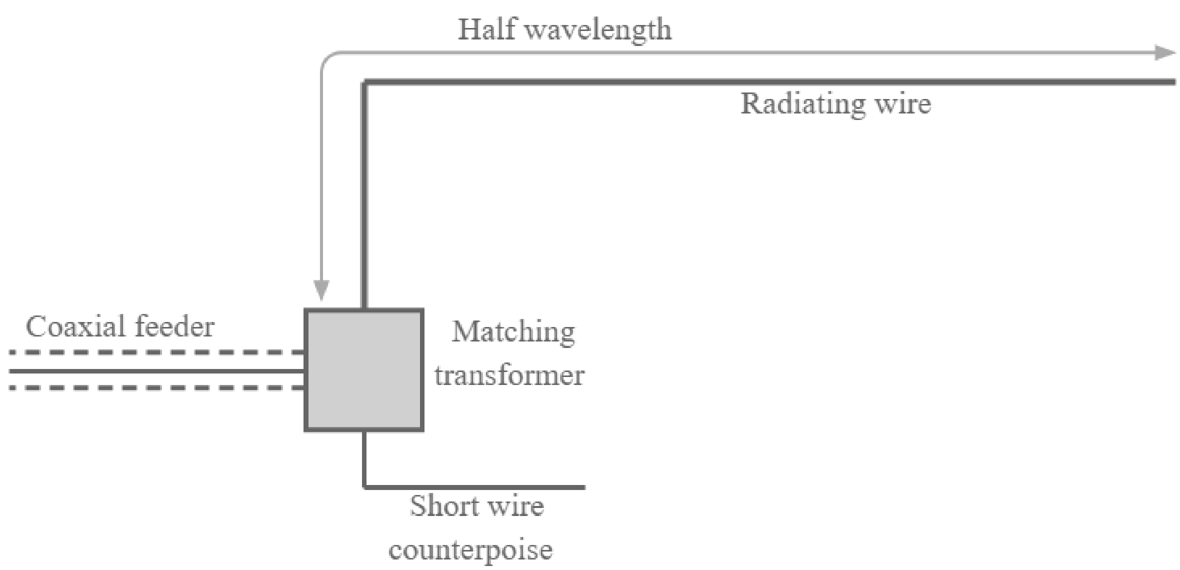

Figure 1 (from reference number 2)

Figure 1 shows the four components of a typical EFHW antenna. At the top, we start with the radiating element of the antenna. Its purpose is to radiate or receive a radio signal. It is usually cut for the longest wave length to be used. In our case, it is cut for 40 meters, so somewhere around 66 feet.

The next component is the impedance matching transformer and connection box. Its purpose is to provide a convenient place to connect the coax feed line, radiating element, and counterpoise. The box itself contains the impedance matching transformer. The impedance matching transformer is sometimes referred to as an Unun – unbalanced to unbalanced matching transformer.

The next component is the coax feedline coming from the radio. Typically, this is a 50-ohm, low loss coax cable that feeds the antenna system.

The last component is the counterpoise, which is cut for 0.05 λ (wave length). Its purpose is to provide something for the radiating signal to push against.

All four parts will be discussed in detail later in this document.

<u>The EFHW Schematic</u>

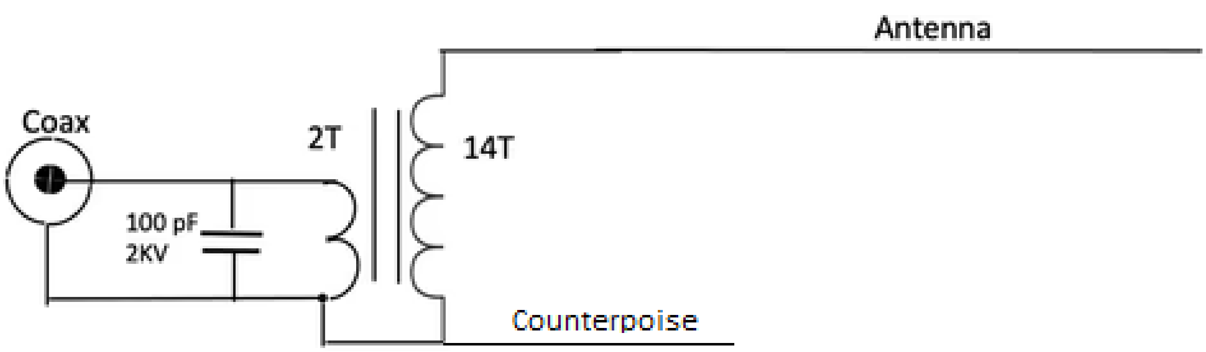

Figure 2 (from reference 3, modified by N7TWL)

Figure 2 shows the complete schematic view of a typical EFHW antenna system. Briefly, the 100pf/2kv cap across the primary of the impedance matching transformer is there to allow better tuning in the 10 meter band. The transformer is a step-up with an impedance ratio of 49:1, and wound on a type 43 toroid core. Both the Antenna wire and counterpoise wire are 18ga, 16 strand insulated wire.

Simplified Theory of Operation

Since the EFHW antenna is in the dipole antenna family, it might be best to look at the voltage and current distribution of a typical dipole antenna first.

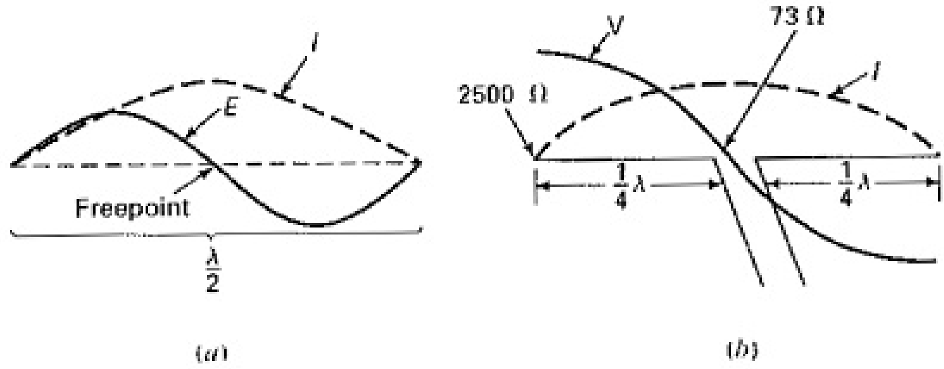

Figure 3 (from reference 4, modified by N7TWL

As noted in figure 3, the feed point for a dipole is in the middle. The voltage is at a minimum, and the current is at its maximum. The impedance is roughly the voltage divided by the current ($Z = \frac{V}{I}$). At the feed point the impedance is about 50 to 75 ohms which matches the impedance of the typical coax feedline and the transmitter output on the radio. Generally, all that is required is a 1:1 balun (balanced to unbalanced). According to the ARRL Handbook, many amateurs have great success using no balun.

So, what happens if we shift the feed point from the middle of the dipole to the end?

Looking at figure 3b, imagine moving the feed point to the left-end of the dipole. You will note that the impedance rises to 2500 ohms nominally, current is near its minimum, and voltage is near its maximum. This presents an impedance mismatch to the feedline/transmitter. To fix the mismatch we need an impedance matching transformer, but before looking at the transformer in detail, you may wonder why move the feed point to begin with? The answers are many and varied, but moving the feed point to the end allows much greater flexibility in deploying the antenna, both as a portable antenna or a base antenna. Secondarily, it turns out that the EFHW antenna is relatively insensitive to the physical layout of the radiator. For example, I have two EFHW antennas. One goes 66 feet straight up a tree and acts like a vertical. The other antenna has its radiator going over a tree limb in an inverted V and acts more like a horizontal.

The Impedance Matching Transformer

The heart and soul of the EFHW antenna system is the impedance matching transformer. Its task is to match the incoming feedline impedance of 50 ohms to the 2500 ohms impedance present at the end of the dipole. The transformer can be wound in a variety of ways, depending on the desired results. The most popular design currently is a 49:1 ratio. For example, if our input is 50 ohms, and we multiply that by 49, we get 2450 ohms. That is a pretty good match. Here is a table of other ratios:

Transformer Ratio	Impedance (ohms)
9:1	450
16:1	800
25:1	1250
36:1	1800
49:1	2450
64:1	3200

Table 1 (from reference 3, modified by N7TWL

As mentioned before, the 2500 ohms impedance is a nominal value, meaning that the first rule in antennas applies: Everything affects everything! It turns out that it is very challenging to find the impedance of an EFHW antenna after it is deployed. Based on popularity, the 49:1 appears to work well for most of us. One consideration might be if you are mostly portable and want really light weight stuff, you might be using really small diameter wire for your antenna. Smaller diameter wire means more impedance, so you might want to try a 64:1 first. I have used both ratios at home using the same 18 gauge 16 strand wire and I could not hear any difference in weak signal reception.

<u>Construction of the Impedance Matching Transformer</u>

Materials: toroidal core, 18 ga. enameled solid core wire, 100pf 1kv cap

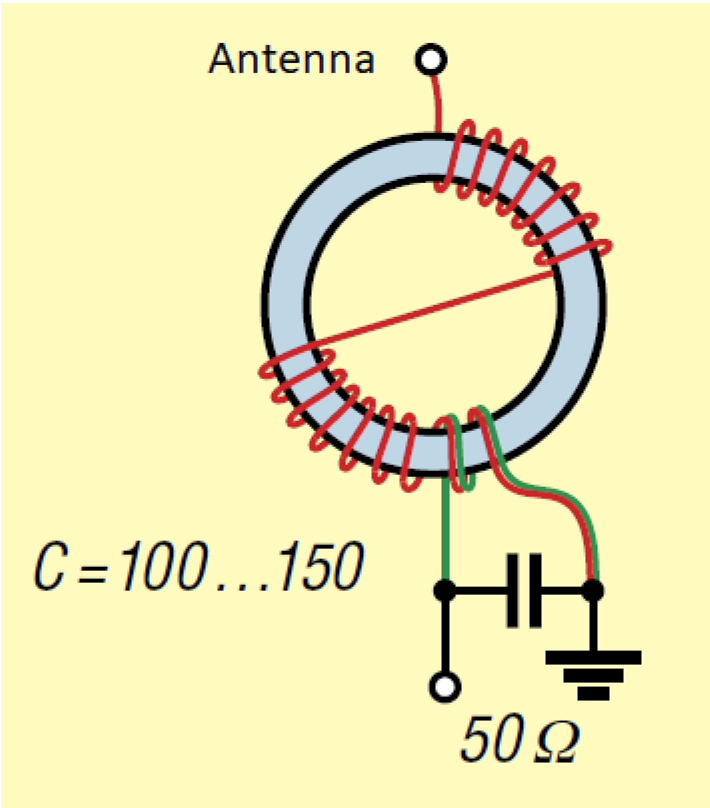

Figure 4 (from reference 1, modified by N7TWL

The most important choice is the core. The current popular design calls for the FT 240-43 core. They are available from Amazon and Digikey for about $13. HOWEVER, the 240-43 is not the most efficient core that can be used. Based on research and testing done by Colin Summers, MM0OPX (reference 5). The Fair-Rite 2643251002 core is about 20% or more efficient than the FT 240-43 core. The 1002 core is also made from type 43 material and is about the same weight. It is chunkier than the 240. I built both and did my own A/B testing one morning when propagation was not great. I routinely tune into 7.039.3 to hear a Russian navigation beacon that puts out the letter K in CW. On the antenna with the 1002 core, the station was weak but readable; with the 240 core, the station was not heard. So, if you are working the weaker DX, I suggest using the 1002 core over using the 240 core. Another advantage of the 1002 core is that it costs about $7 from Digikey. This core is now my core of choice when building EFHW antennas for HF.

Transformer Construction: 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.

The best suggestion that I can make in winding the core is to search on YouTube and find a video that shows how to do the windings. You can disregard how many cores or type of core, you just want to get the actual turns correctly placed on the core. You will notice that figure 4 is wound to 64:1. Additionally, you can contact me, and I will be happy to show you how I do it.

Mounting the Transformer et al: When building your own EFHW, you will need a box for the transformer and making connections to the feedline, antenna radiator, and ground/counterpoise. I get plastic project boxes from Amazon, mounting hardware (stainless) from Ace or Home Depot. I get a 100-foot spool of 18ga. stranded wire from Amazon. Again, I am happy to give to you some specific details on parts, cost, and where to purchase.

As for constructing the box and mounting hardware etc. my best advice is to watch some YouTube videos. I am not gifted in the area of mechanics, but I find that if I take my time and measure things out and keep a steady hand on my hand-drill, I get respectable results.

If you are only going to build one antenna, it may not be cost-effective when factoring in your time. My total cost for a 40 meter EFHW is somewhere around $40 - $50. MFJ makes a ready for use one for $90. ARRL has a decent kit for $80. I have not found other kits that I particularly recommend, mainly because of the core type and low quality parts.

To Counterpoise or Not

You may find a lot of debate about using a counterpoise with an EFHW antenna. The physics says that the radiated signal has to have something to push against. If you choose not to use a counterpoise, the signal will most likely use the shield in the coax feedline. It has been noted that this can cause some noise. On my own system, I could not tell whether or not I had my counterpoise connected. I also tried various lengths of counterpoise, but I could not tell any difference. At this moment in time, I use a single 18ga. stranded wire, about 13 feet, for a counterpoise.

Pros and Cons

The important Pros: multi-band, typically 40, 20, 15, and 10 meters with no tuner, and add 12 and 17 meters if you use a tuner. Easy to deploy. Works well horizontally, vertically, or as a sloper. The deployed shape of the radiating element is not particularly critical. Low cost off the shelf or building from discrete parts. Can be highly portable for field use.

Important Cons: performance may not be as good as single band antenna. High voltages exist on the ends of the antenna. Some amateurs have reported RF back in the shack. My opinion on this is that the shack/antenna ground system may need some attention. I have two EFHW antenna in the air and have not experience any RF in the shack – keeping in mind that I am operating at less than or equal to 100 watts.

Disclaimer

First and foremost, I do not claim to be an expert in the area of HF antennas. The information provided in this document is based on my own experience in building, testing, and using EFHW antennas, and the results of my own searching the topic on the Internet, ARRL Handbook, and the ARRL Antenna book. Your mileage may vary.

References

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5. Colin Summers, MM0OPX. Check out his YouTube channel. Here are some links: using the 1002 core - https://www.youtube.com/watch?v=Xe0wvbOQeok&t=48s
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