

An Easy Tuning Method for End-Fed Half-Wave Wire Antennas

Jim Giammanco, N5IB
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A popular method for quickly shortening the length of a wire antenna, when making adjustments, is to fold the far end of the wire back on itself. We can chuckle that we have fooled the electromagnetic fields into thinking that the end of the wire is at the fold, rather than at the cut end of the wire. Low cost measurement tools such as the Nano VNA can quickly evaluate the results. The nice part is that the adjustments are quickly reversible – no cutting required.

While experimenting with some sloping end-fed half-wave antennas (EFHW) in the back yard the thought occurred that the same technique might work at the feedpoint end of the EFHW. There would be no need to haul down the upper end of the wire to make the adjustments. The short answer is yes, it does work – surprisingly well, in fact. This discussion relates the results of some experiments.

For convenience, the first experiment was performed with an EFHW cut for 30 meters (10.10 – 10.15 MHz). The *sacred formula* predicts a half wave wire to be a little more than 46 ft long.

$$\text{length in ft} = \frac{468}{f, \text{MHz}} = \frac{468}{10.11} = 46.3 \text{ ft}$$

For a real sloping wire with one end near the ground and the other in a tree, that calculated length will almost certainly be too long. The proximity of the ground and tree foliage makes the antenna behave electrically as if it is longer than its physical dimension. The formula incorporates a compensation for this *end effect*, shortening the value by about 5% compared to a free-space half wavelength. But that is an estimate for the case where the wire is relatively high, horizontal, and clear of obstructions. An even greater shortening would be expected for this sloping, near the ground EFHW. Nevertheless, an initial overall wire length of 47 ft was chosen. After all, the point of the experiment was to determine if the electrical length could be shortened just by folding. If proved correct, there would be no need to be precise in cutting the wire to length. Just make it **PLE** -- a very technical **TLA** (Three Letter Acronym) standing for “Plenty Long Enough.”

The test antenna was assembled, as seen in Fig 1, by hoisting one end of the 47 ft wire about 24 ft (dimension **H**) up into a pine tree. The lower end was suspended about 2½ ft (dimension **h**) above the ground and terminated with a ferrite-core toroidal matching transformer (Fig 3) with a 9:1 turns ratio (81:1 impedance ratio). Any of the several varieties of the transformer, commercial or home brewed, can be used. The specific transformer used here is sold as part of the *Spark Plug Antenna*: <https://www.sparkpluggear.com/shop>.

About 30 ft of RG-58U coax connected the transformer to a Nano VNA H4 for measurement of VSWR. A quick and crude common mode choke was made by scramble winding about 8 or 9 turns of the coax about 6 inches in diameter and securing them with hook-and-loop straps. That should yield 15 to 20 µH inductance, for at least 650 Ω reactance at 7 MHz. Not as elegant and predictable as a neat solenoid winding, but adequate.

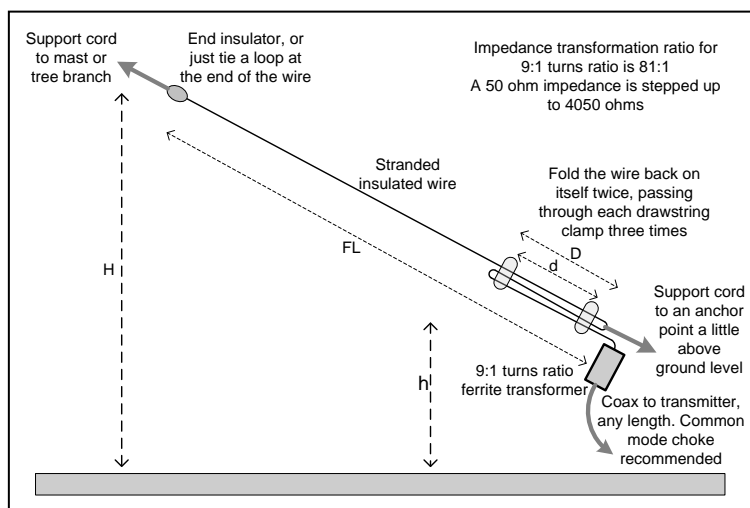


Fig 1. 30m EFHW sloping ~30°
Not to scale.

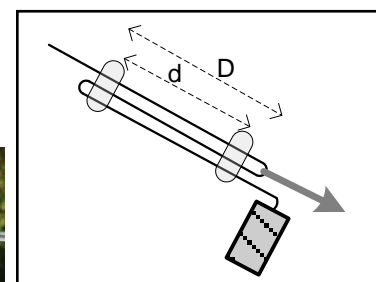


Fig 1a. Foldback detail



Fig 2. Scramble-wound common mode choke and transformer



Fig 3. Spark Plug Transformer detail
The EFHW wire was first tested



Fig 4. Drawstring clamp detail

extended to its full 47 ft length. VSWR minimum was observed near 9.3 MHz, verifying the wire was indeed much too long.

The wire was folded back on itself as shown in Figs 1 and 1a, and secured with a pair of plastic *drawstring clamps* (Fig 4, and circled in red in Fig 5) that can be found at fabric stores or on-line vendors. The length of the foldback loop (dimension **D**) was adjusted until the VSWR minimum was within the 30 meter ham band.

Fig 5. Drawstring clamp, transformer, and common mode choke

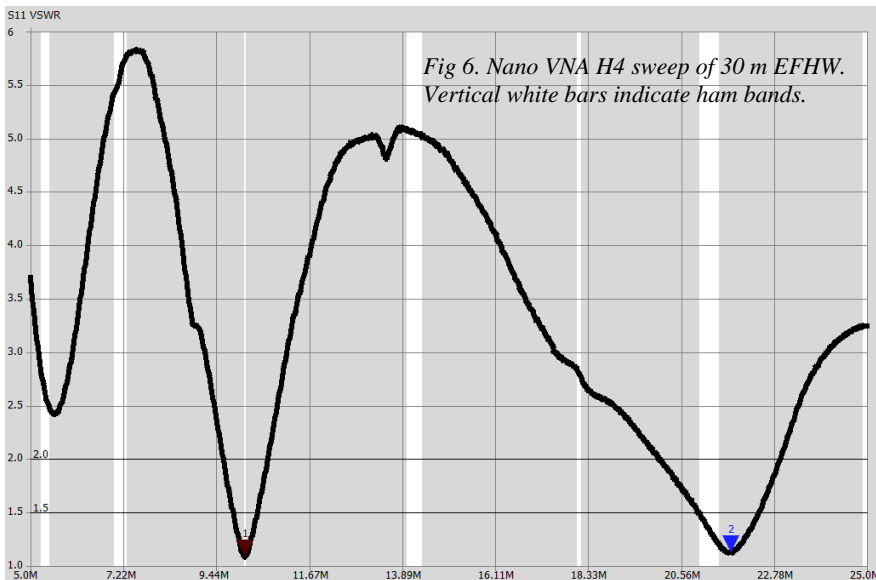


The table below shows the results of that first 30 m experiment as well as the follow up 40 m wire.

Frequency	Overall Wire Length, WL	Folded Wire Length, FL	Foldback Length, D	Clamp Spacing, d	Upper End Height, H	Lower End Height, h	Minimum VSWR
30 m band 10.10 – 10.15 MHz	~47 ft	41' 4"	2' 11"	2' 9"	~24 ft	~2½ ft	< 1.2 @ 10.13 < 1.2 @ 21.75
40 m band 7.0 – 7.3 MHz	~67 ft	62' 5"	2' 3"	1' 9"	~24 ft	~2½ ft	< 1.5 @ 6.75 < 1.2 @ 13.82 < 1.2 @ 21.41 < 1.4 @ 28.73

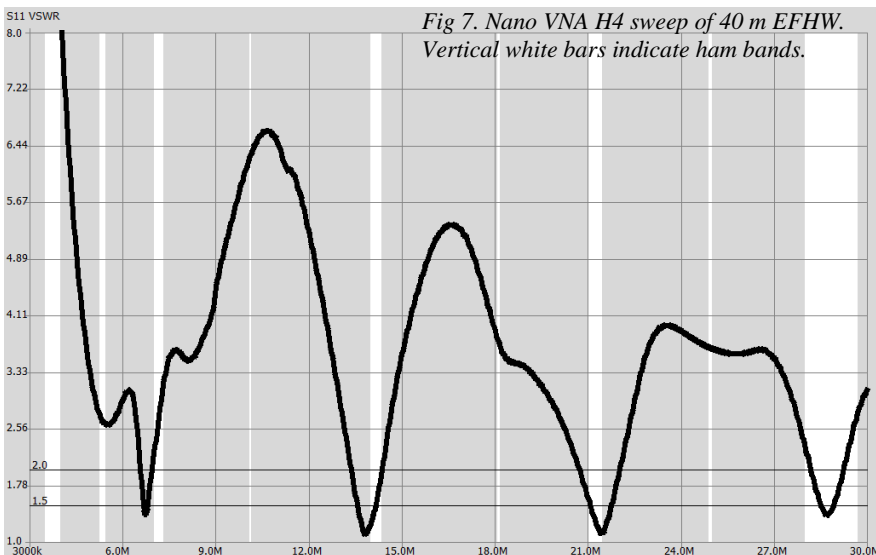
Before discussing the results, a bit of background... the feed impedance of a resonant EFHW is a pure resistance of several thousand ohms. The transformer's impedance transformation ratio is the square of the turns ratio. The 9:1 turns ratio yields an impedance transformation of 9^2 , or 81:1. That means the 50 ohm characteristic impedance of the coaxial cable will be transformed to about 4000 ohms. Practical experience has shown that to be a satisfactory transformation.

It is important to note, though, that the frequency at which an EFHW wire is resonant (zero reactance, pure resistance) generally will NOT correspond to the frequency which exhibits the minimum VSWR on the coaxial cable feedline. The two frequencies will be close, but not the same. The goal is to achieve a minimum VSWR which is low enough that the transmitter output stage will see a good match and no additional antenna matching unit (aka *antenna tuner*) will be required. A VSWR of less than 2.0 is acceptable, under 1.5 would be great.



The tables above and the VSWR graphs at left bear witness that the goal has been met. For the 30m EFHW a VSWR of less than 1.5 is observed across the entire 15 m band, and it is well below that level over the targeted 30 m band. If desired, the foldback could be released a little bit to move the minima slightly downward in frequency and provide an even closer match across the lower end of 15 m.

A second wire, 67 ft long was prepared for the 40 m band, just a bit longer than the formula predicted. The foldback was adjusted in the same manner, but to place the VSWR minimum a little below the bottom of the 40 m band. That adjustment allowed for decent matches on 20, 15, and even 10 m, at the price of 40 m performance that would need re-tweaking or the use of a tuner.



To summarize:

1. Cut the wire a little longer than the formula predicts.
2. Slip on the drawstring clamps and string it up using whatever supports are available.
3. Use your antenna analysis tools to tweak it to frequency as you prefer.
4. Connect Radio. Get on the air. No antenna tuner needed.

After completing these experiments a little 3W homebrew 20m rig was connected to the 40m EFHW. No antenna tuner was used. A POTA activator in VA was heard and worked on the first call. LA to VA on a straight key, 3 watts, and a hank of wire. That's QRP fun. 72 y'all.

APPENDIX

The goal of the preceding article was to describe a quick *and reversible* method of adjusting the length of antenna that does not depend on precise measurement and permanent trimming of wire lengths. Only a rough calculation of a starting point was needed. But for readers who would like a little more background on the determination of EFHW dimensions, this peek into the mathematics may be useful.

The premise of a multi-band EFHW is that it will act as a near resonant half wave antenna at the lowest frequency for which it is designed, and will be also able to operate near resonances at integer multiples of that frequency (the *harmonics*). The starting point in designing such an antenna is to calculate the wire length required for a half wavelength ($\lambda/2$) at the lowest frequency. The aforementioned *sacred formula* can be applied:

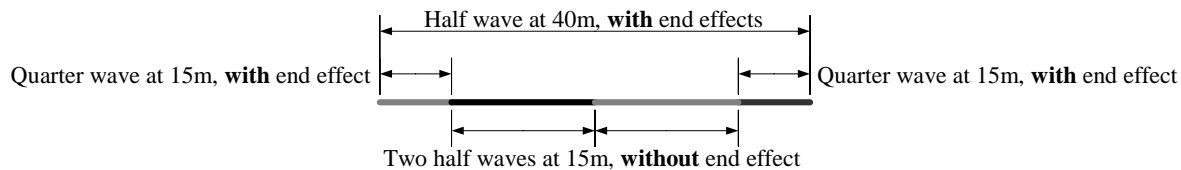
$$\frac{\lambda}{2} \text{ in feet} = \frac{468}{f, \text{ MHz}} \quad \text{or} \quad \frac{\lambda}{2} \text{ in meters} = \frac{143}{f, \text{ MHz}}$$

But there are some subtle details buried in that formula. It incorporates a correction factor to account for the *end effects*, a capacitive loading that caused the wire to behave electrically as if it were longer than its physical dimension. The usual estimate of the effect is about 5% of the physical length. Thus the above formula is crafted to compute a length which is about 5% shorter than a *free-space* half wavelength. Many years and many hams have confirmed that is a reasonable and useful approximation.

If the formula were reconstituted to show the free-space length (no end effects considered) it would be:

$$\frac{\lambda}{2} \text{ in free space, feet} = \frac{492}{f, \text{ MHz}} \quad \text{or in meters} = \frac{150}{f, \text{ MHz}}$$

Here's where it gets interesting for the EFHW operating at harmonics of its lowest frequency. Operating on a harmonic, there will be an integer multiple (2, 3, 4, *etc*) of half wavelengths of wire at the operating frequency. For example, consider an EFHW cut for 40 meters (7 MHz), but operating on 15 meters (21 MHz, its 3rd harmonic). The physical half wave for 40 meters will be, electrically, three half waves at 15 meters. The drawing represents this as a quarter wave at each end, and two half waves in the middle.



The important takeaway is that *the two middle half wavelengths on 15m are not subject to the end effects*.

It's possible to re-cast the sacred formula to more properly calculate the physical length of a wire that is an (electrical) integer multiple of a half wave at a given frequency. The end effects are applied only to the outer quarter wave segments. In the case of a single half wave ($N = 1$) the equation reduces to the familiar form. In words beloved of math students everywhere, "*the proof is left to the reader*"

For a wire N half wavelengths long at an operating frequency F in MHz, the physical length L_N should be:

$$L_N = \frac{492}{F} (N - 0.05) \text{ feet}, \quad \text{or} \quad L_N = \frac{150}{F} (N - 0.05) \text{ meters}$$

But wait, there's more... The above calculations are for bare, uninsulated wire. The presence of a layer of insulation around the wire has the effect of slowing down the EM waves surrounding the wire by an amount represented by a *velocity factor*. The whole length of the wire would be subject to the velocity factor, vf , which is approximately 0.95 to 0.97 for the sorts of insulated wire many hams use for antennas:

$$L_N = \frac{492 \text{ } vf}{F} (N - 0.05) \text{ feet}, \quad \text{or} \quad L_N = \frac{150 \text{ } vf}{F} (N - 0.05) \text{ meters}$$

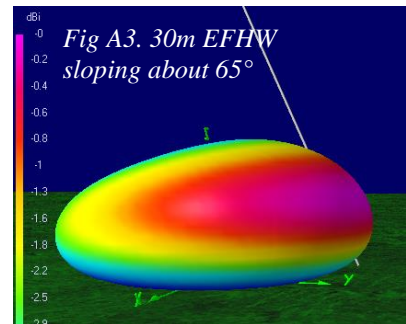
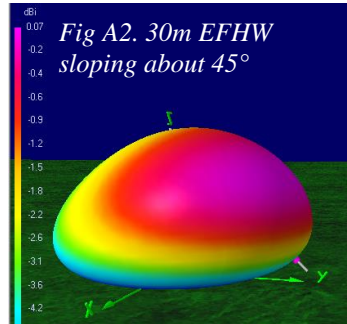
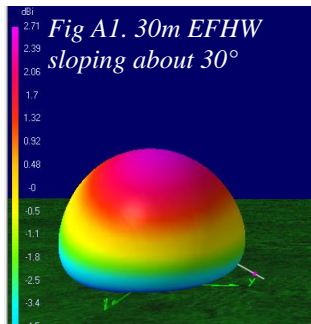
Using a velocity factor of 0.97 for vinyl insulated wire...

40 m EFHW, optimum length for operating on 7.05 Mhz:	64.3 ft	19.61 m
40 m EFHW, operating on 14.05 MHz, optimum length:	66.2 ft	20.19 m
40 m EFHW, operating on 21.05 MHz, optimum length:	66.9 ft	20.39 m

The tabulated results above illustrate why maintaining a fixed length of an EFHW will always be a compromise if multi band operation without any length adjustment is desired.

It would be an opportunity missed if there were not some investigation of the theoretical radiation patterns of the EFHW. The **4NEC2** modeling software was used to simulate the antenna in several different installation and operating circumstances.

The first three patterns illustrate the effects of a changing slope angle for an EFHW operating at its lowest frequency. The wire slopes from a point up on the +z axis downward towards the +y axis, and is just visible enough in the images to reveal the slope. As expected, as the slope gets closer to vertical the pattern shows a lower and lower *takeoff angle*. At 30° it's a cloud warmer, but that is fine for close-in *near vertically incident skywave* (NVIS) operation. At 65° or more it takes on the characteristic of a good low angle DX antenna. Notice the peak directivity oriented in the +y direction.



The next three patterns investigate what happens when the EFHW is operated on harmonics of its lowest frequency, with the slope angle held constant and fairly small. As before, good NVIS properties on the lowest frequency are apparent. But look what happens on the upper bands. Not only does the pattern become more complex, with nulls and sidelobes appearing, but the direction of best radiation flips to the **opposite** (-y) direction of the wire slope.

Matchin

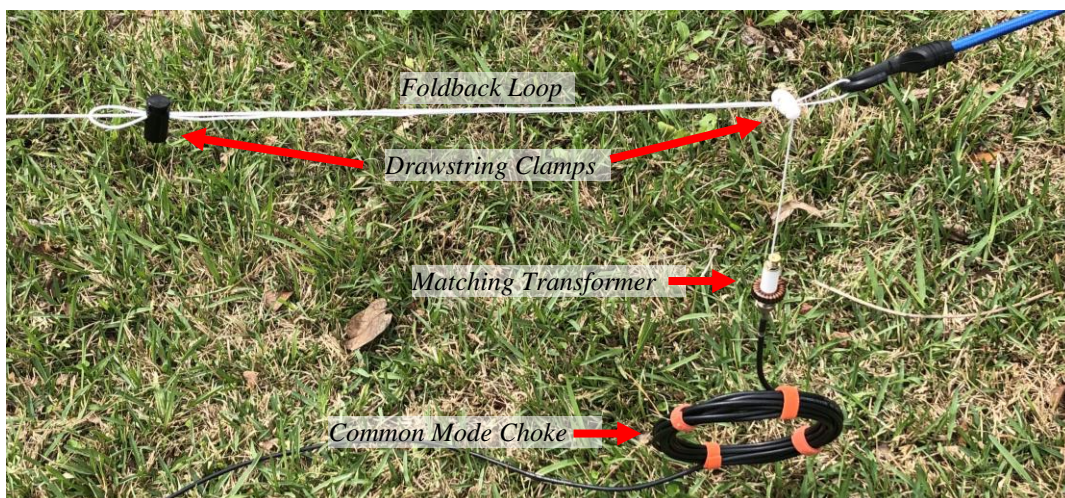
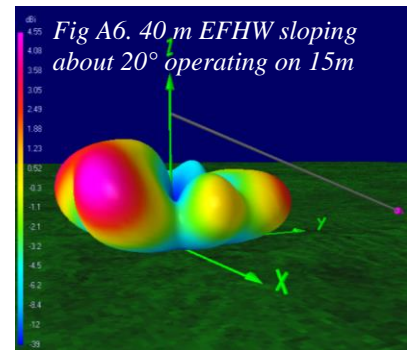
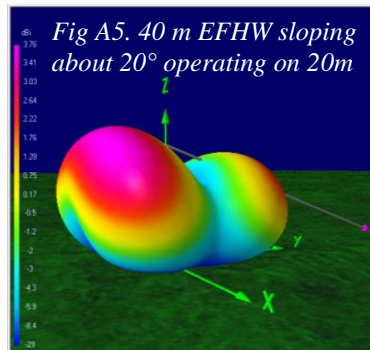
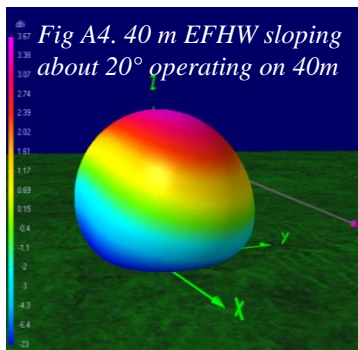


Fig 8. Feed point of the EFHW, as assembled for testing