EFHW Antenna

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What is an EFHW

An EFHW stands for End-Fed-Half-Wave antenna, which is an antenna that’s made of a wire that’s half the wavelength of the lowest band it is designed to work on. The antenna is fed at the end of the wire which has a high impedance of around 2,500 Ohms. Due to the high impedance, a matching network is required to transform the impedance to around 50 Ohms which works with most transmitters.

The EFHW is a variation of the much more common half wavelength dipole.

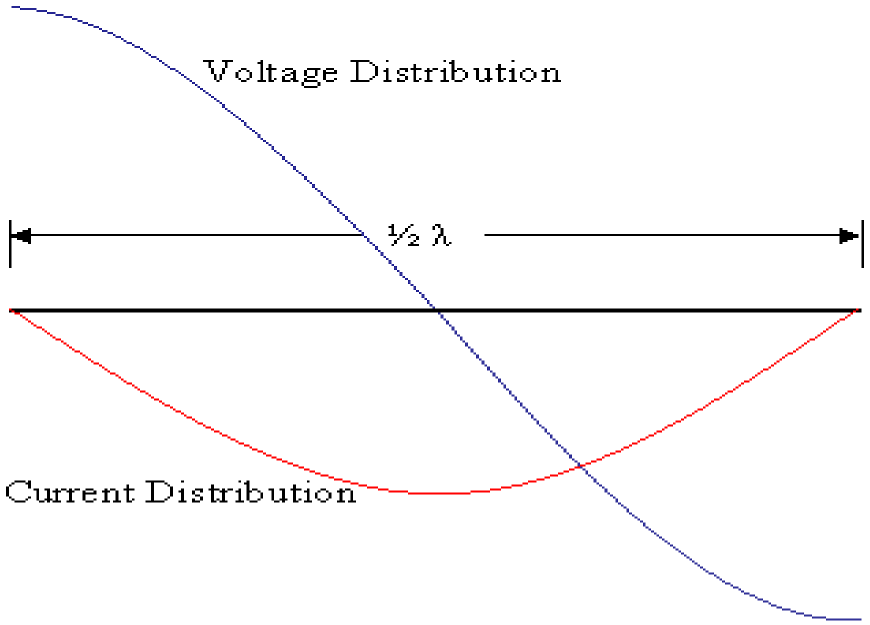
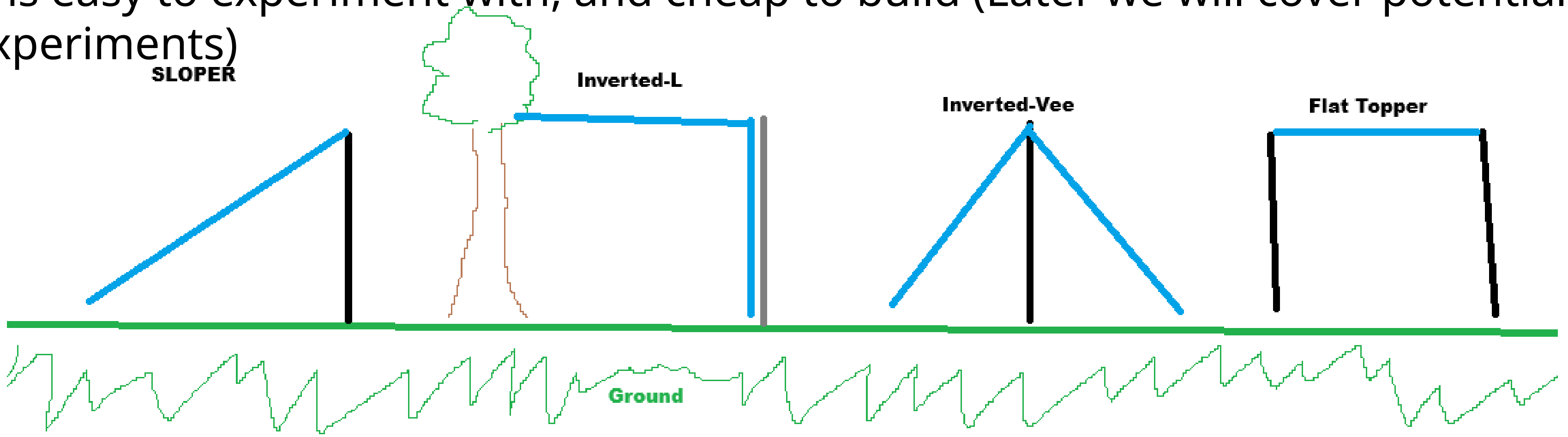


Image from Steve Yates – AA5TB

Why use an EFHW

- Very simple to build and setup, as the feed point is typically near the ground.
- A resonant EFHW can cover multiple bands without a tuner
  - Depending on the wire length (80m, 40m, 20m, 15m, 10m don't need a tuner)
- Great for rapid frequency changes in portable setups like POTA or SOTA
- Work well with 49:1 or 64:1 impedance transformers
- Unlike an end-fed random wire, a resonant EFHW has lower losses
- The EFHW is lightweight and portable, and only needs one elevated support point
- Works well with QRP and 100 watts (or more in some cases)
- There is no need for extensive ground radials, but they do benefit from a raised counterpoise
- If hung from a tree a thin wire EFHW is nearly invisible (stealthy in an HOA)
- It is easy to experiment with, and cheap to build (Later we will cover potential experiments)



When not to use an EFHW

- EFHW take some space to setup, so it is not a good choice if you have limited space
- We are building a 10m thru 20m EFHW which will require just over 30 feet of space.
  - For reference a 40m EFHW takes about 66 feet and 80m EFHW needs 132 feet
- EFHWs are susceptible to common mode current (CMC) issues and sometimes high RF Interference (RFI), which leads to a noisy antenna
  - If these become an issue in the shack, an off-center-fed dipole (OCF) with proper grounding may be a better choice
- If you need reliable NVIS (Near Vertical Incident Skywave) for regional HF communications, a low horizontal dipole typically would be more effective.
- EFHW are best on harmonic bands (80m, 40m, 20m, 15m, and 10m), other bands will likely require a tuner
- Poor performer on 160m without adding additional loading

Does a $15 antenna work in real-life?

- While testing today's antenna build here are some of the QSOs I made from a POTA activation using 100 watts without a tuner, on 10m

What does RF exposure look like?

- RF exposure is a bit harder to calculate with an EFHW. Below is some basic information and some sample exposure information for a EFHW configured as a sloper with the high point at 30 feet. The gain on an EFHW will typically decrease as the height of the high point decreases due to increased ground interaction.
- The distance from the antenna for safe operation is rounded up to the nearest inch

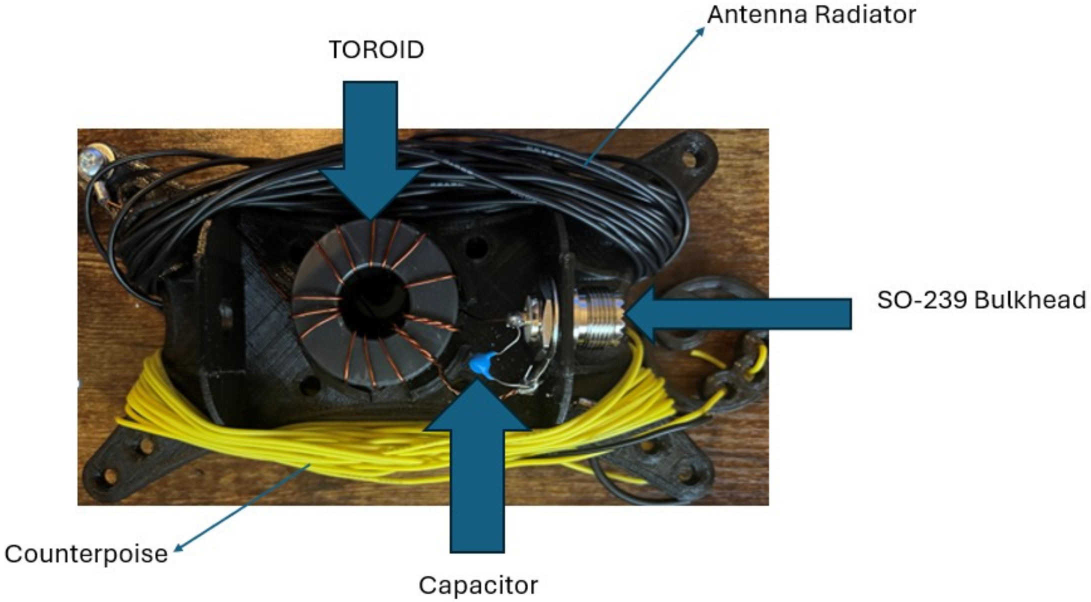
Band	Mode	Wavelength	Typical Gain	Radiation Pattern	10 watts* Ctrl | Non-Ctrl	100 watts* Ctrl | Non-Ctrl
20m	SSB**	1 λ	~2.1 dBi	Broadside, low-angle	6” | 1’1”	1’ 6” | 3’ 3”
20m	Data	1 λ	~2.1 dBi	Broadside, low-angle	8” | 1’6”	2’1” | 4’7”
15m	SSB**	1.5 λ	~2.5-3 dBi	Some lobes, moderate gain	9” | 1’ 7”	2’ 2” | 4’ 10”
15m	Data	1.5 λ	~2.5-3 dBi	Some lobes, moderate gain	1’ | 2’ 2”	3’ 1” | 6’ 9”
10m	SSB**	2 λ	~4-5 dBi	Multiple lobes, higher gain	1’ | 2’ 2”	3’ | 6’ 8”
10m	Data	2 λ	~4-5 dBi	Multiple lobes, higher gain	1’ 4” | 3’	4’ 3” | 9’ 5”

Calculations performed by ARRL calculator at https://www.arrl.org/rf-exposure-calculator

* Assumption is transmit for1 minute then receive 1 minute

** Assume conversational SSB, with heavy speech processing

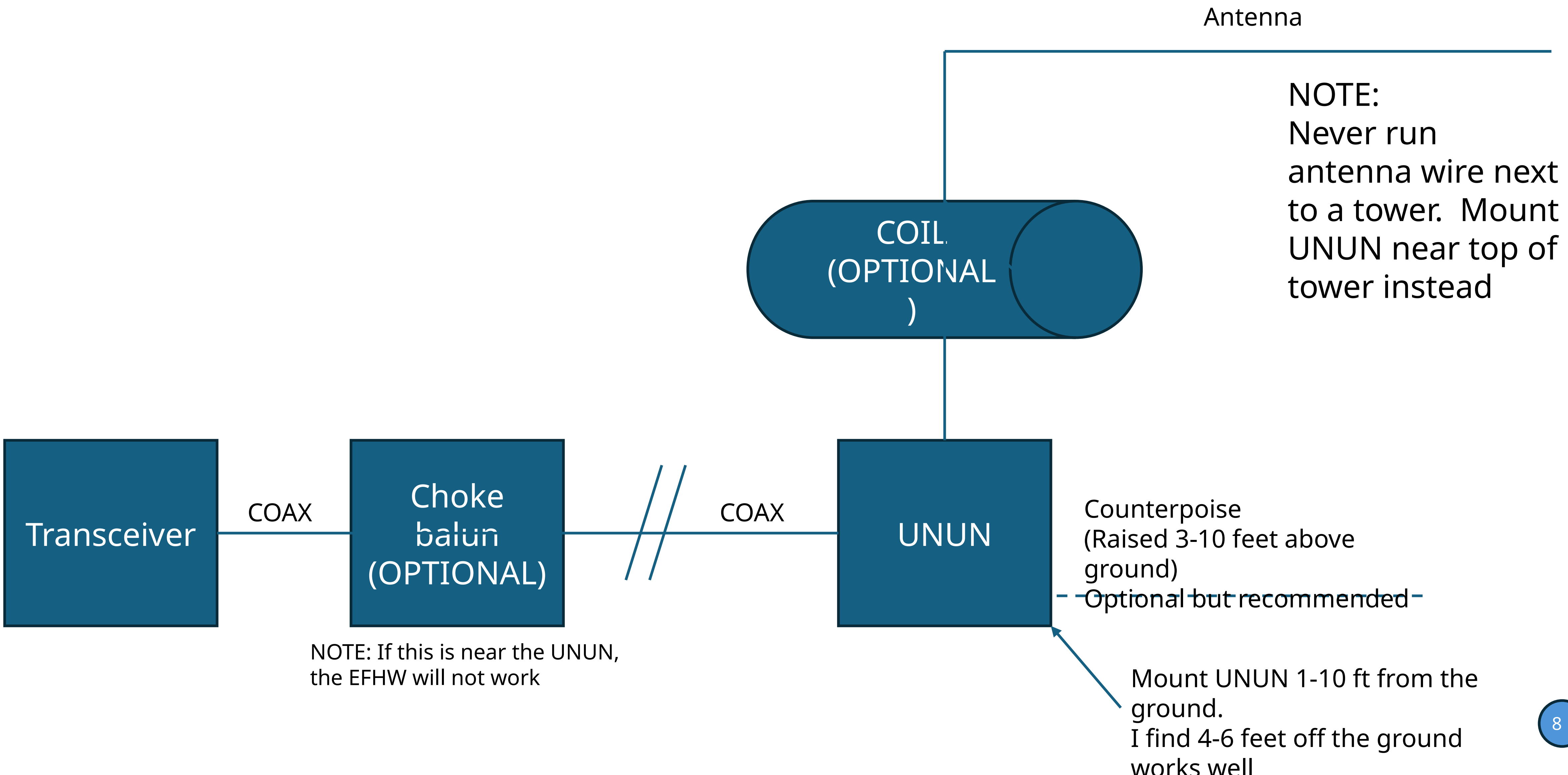
Parts of a EFHW UnUn



- Capacitor – Used to expand the bandwidth of the antenna and help improve high frequency performance (Typically 100pF for 3KV or higher)
- Toroid – is used for the transformer
- Radiator – Many options to try, we will be using the simplest, a wire that can be tuned for 10m thru 20m (Later we will discuss options)
- Counterpoise – some manufacturers will tell you this is not needed. If it is omitted your coax shield will be used. Ideal length is 0.25 λ, but I like to use 17-21 feet on average

- We use a 49:1 UnUn to bring down the impedance of the antenna to near 50 Ohms
  - Other windings are possible like 56:1 or 64:1, however most resources reference 49:1
- For HF frequencies a type 43 ferrite toroid is typically used. Type 52 is available, but I have not tried one yet.

EFHW – How to configure



EFHW Antenna Power

- Power is limited by the transformer core size
- You must select the proper core size
  - This is a core with enough mass to absorb and dissipate heat
- Higher wattages typically require stacking toroids together and wrapping as a single toroid
- Some power will always be lost in the matching unit (toroid)

- Where do we lose power?
  - Power is lost through resistance:
    - **Radiation resistance** = Good loss, you want the power to go here
    - **Conductive resistance** = I^2*R (Heating of the wire)
    - **Ground resistance** = losses to the ground
      - Typically applied to 1/4λ verticals with a ground system, but EFHW also have ground loss which are minimized when the high point is > 0.5λ above ground
    - **Reflection losses** = lost in the feedline
    - **Transformer losses** = lost when using a transformer

How do you test the efficiency of the UnUn?

2 methods exist to measure transformer efficiency with a NanoVNA

- Back 2 Back Method - Simplest
  - Build two identical transformers
  - Connect antenna to antenna
  - Connect one to S_{11} and the second transformer to S_{21}
  - Measure the dB loss and divide in half

- Resistor Method - Harder
  - Build a single transformer
  - Build a resistor wire that has the same resistance as the antenna
  - Connect the transformer to S_{11}
  - Connect the resistor wire to the antenna
    - Connect the other side of the wire to the center pin of S_{21}
  - Measure dB of S_{21} and S_{11} and calculate

Back to Back Method

- Need 2 transformers, and attach the two antennas together
  - Since we have two transformers, we can divide by two for the insertion loss
- Reset the VNA (under Calibrate)
- Set the Start at 1.8 MHz stop at 30 Mhz
- Set Channel to S_{21} (Thru)
- Set display to LogMag
- Calibrate Open, Short, Load, Isolation (keep 50 Ohm connected), Thru connect both wires
- S_{21} should show 0.00 dB loss
- Connect one transformer to each port and measure S_{21}
- Take the S_{21} dB reading, and divide in half for **dB_Loss**
- To find the efficiency percentage, calculate $10^{(\frac{DB\_Loss}{10})}$

Resistor Method

- This method only requires one transformer
- It does require you to simulate the resistance on the antenna line, by building a string of resistors to closely match the Ohms in the antenna (2450 Ohms for a typical EFHW)
- The math required to calculate the efficiency is much more complex using this method

<u>Configure NanoVNA for Resistor Method</u>

- Port 1 - S_{11} - "Reflection Port"
- Port 2 - S_{12} - "Transmission Port"
- Turn on NanoVNA
- Calibrate the NanoVNA, using Open, Short, Load
  - Keep 50Ohm resistor on for the Isolation calibration
  - Then connect S11 and S21 and calibrate the Thru
  - Click Done and save the result
- Build a resistor string
- Change display to turn on trace 0,1,3
- Select trace 0, set Display | Format to check LOGMAG
- Select Trace 1 set Display | Format then select SWR
- Select Trace 3 set Display | Format then check LOGMAG
- Setup stimulus to start at 3MHz and stop at 30MHz
- Build Resistor method
  - S_{11} to connect to feed portion of the transformer
  - 1 side of resistor string to the antenna side of the transformer
  - Other side of the resistor to the center conductor of S_{21}
- Now drag marker 1 to the appropriate frequency and start working the math

Calculations for the Resistor Method

- **Calculate the Antenna Loss**
  - Antenna Loss = -(10*Log10(***<Resistor Wire Ohms>***/50))
- **Calculate Insertion Loss**
  - Insertion Loss = S_{21}-***Antenna Loss***
- **Calculate Reflective Power %**
  - Reflective Power % = 10^(S_{11}/20)^2
- **Calculate Through Power**
  - Through Power = (1 – ***Reflective Power %)***
- **Calculate Transmitted Power**
  - Transmitted Power = 10^(***Insertion Loss***/10)
- **Calculate Transformer Efficiency**
  - Transformer Efficiency = ***Transmitted Power*** / ***Through Power***
- **Calculate Transformer Power Dissipated (%)**
  - Transformer Power Dissipated = 1 – **Transformer Efficiency**
- **Calculate Mismatch Loss (dB)**
  - Mismatch Loss (dB) = -(10*(Log10(1/**Through Power**)))
- **Calculate Transformer Loss (dB)**
  - Transformer Loss (dB) = ***Insertion Loss*** – ***Mismatch Loss***

Averaging the efficiency results

- In my testing I find on average Back to Back method gives better efficiency than the resistor method.
- I also don’t have a serious testing spot, I test in front of my keyboard on the same desk as 3 monitors, a computer, several radios, and an electronic picture frame
  - I can’t rule out interference
- I have been averaging the two sets of results as my assumption is that in the middle is probably a good idea of performance

Band	Frequency (MHz)	Efficiency
80	3.54	90.54%
60	5.43	90.98%
40	7.05	91.76%
30	10.29	92.99%
20	14.07	92.38%
17	18.12	87.99%
15	21.09	84.93%
12	24.87	74.43%
10	28.38	63.07%

Why Tune Your Antenna

- The radiator will be long after building this 20 Meter EFHW
- It will need to be cut to tune it.
- If you don't have a device to measure SWR
  - Borrow or buy one
  - Attempt to use the length that worked for me (**NOT RECOMMENDED**)
    - ****WATCH YOUR RADIO SWR IF YOU DO THIS, STOP IF SWR IS OVER 3****
    - The length that worked for me was 31 feet 3 inches

How to Tune a Wire Antenna

Measure SWR across all bands you designed for

- Use an antenna analyzer or SWR meter to check resonance on all desired frequencies
- Record the resonant frequency and SWR for each band

Adjust the wire length

- If the antenna is too long
  - Resonant frequencies will appear **below** the desired band
  - Shorten the wire 5-10 cm at a time and re-measure SWR
    - Alternatively, fold back the excess wire instead of cutting it. Secure the folded section with cable ties or tape to allow for further adjustments.
    - The fold back can affect the antenna's behavior. Minimal impacts if the fold back is kept to less than 5%-10% of the total antenna length, and do not tightly wind.
    - Impacts to behavior are more noticeable on the higher frequencies VHF/UHF
    - If performance deteriorates after a fold back, trim the wire instead of folding back
- If the antenna is too short
  - Resonant frequencies will appear **above** the desired bands
  - Add wire (if feasible)

Check resonance after each adjustment

- Ensure that adjustments to one band do not negatively affect other bands.
- For multiband operation, prioritize tuning the most frequently used bands

(Optional) Add a common mode choke

- To reduce RF interference, add a chock near the transceiver
  - Never add the choke near the feed point of an EFHW

Band Specific Tips

Low Bands (160m, 80m, 40m):

- These bands require the entire wire length to radiate efficiently.
- Ensure the antenna height is sufficient to reduce ground losses and maximize radiation. (For 160m at least 15m high)

Mid Bands (20m, 15m):

- Resonance is typically easier to achieve on these bands due to harmonic alignment with the wire length.
- Adjust the wire length or transformer placement as needed to optimize SWR.

High Bands (12m, 10m):

- These bands may show multiple lobes in the radiation pattern due to the antenna's electrical length.
- While SWR may rise slightly, performance is generally acceptable without major adjustments.

Common EFHW Antenna Issues

Issue	Cause	Solution
High SWR on all bands	Incorrect transformer installation	Verify transformer placement
Low efficiency on lower bands	Insufficient height above ground	Raise the antenna or improve ground plane
RF interference in the shack	Common-mode currents on feedline	Add a common-mode choke near the transceiver or ground the coax cable
Poor performance on high bands	Excessive wire length causing detuning	Shorten the wire or use a tuner

A fun experimental platform

- Today's antenna will give you a platform to start experimenting with. It is designed to allow you to swap counterpoises and radiator wires which leaves many options open.
  - It also gives you the knowledge to build your own UnUn and try 56:1 or 64:1, etc
  - You don't need a fancy 3d-printed base like we have today
  - My first EFHW was build on a scrap piece of wood which I drilled some hole into

- I've included several pages of ideas at the end of the presentation but at a high level:
  - Try different UnUns
  - Try using 66 ft of wire for 40m (my favorite)
  - Build a 110uH coil and 1m of wire add to the 40m radiator wire to expand to 80m without using 132 ft of wire. (This also works for 40m)
  - Try using traps to make 12m and 17m work with out a tuner
  - Cut a wire specifically for 30m and try CW or digital
  - Go camping at a wide-open campground and try 132 ft of wire for 80m at night
  - Try a linked counterpoise cut for specific bands
  - Try a linked radiator for different bands
  - Try different configurations and heights

Other UnUn windings to Try

- For a 49:1 winding
  - 2 Primary and 14 Secondary
    - Works for 10m to 40m.
  - 1 Primary and 7 Secondary
    - I did not have good performance.
  - 3 Primary and 21 Secondary
    - Supposed to work well for 80m
- For a 56:1 winding
  - 2 Primary and 15 Secondary
- For a 64:1 winding
  - 2 Primary and 16 Secondary
  - 1 Primary and 8 Secondary
  - 3 Primary and 24 Secondary
- Some QRP users of EFHW use 81:1 winding
  - 2 Primary and 18 Secondary

Other Ideas

- Add a new radiator wire to include 40m
  - Measure a wire that is 68 feet long and replace the existing radiator wire. This is my favorite length. Don’t forget to retune the antenna.
- Short EFHW Antenna with a coil
  - https://digipaintersblog.wordpress.com/wp-content/uploads/2022/01/makeacoil.pdf
- How to extend your EFHW to the 80M band
  - https://www.youtube.com/watch?v=sifNJQHK-m4
- Using Traps
  - https://www.youtube.com/watch?v=-qfCQTZSIus&t=1s
- Linked EFHW
  - Part 1 - https://www.youtube.com/watch?v=jFl4lOwHsVg
  - Part 2 - https://www.youtube.com/watch?v=XU-1jtDHau0

Different Toroids To Try

Many of the toroids can be bought on Amazon, along with the capacitor. I found Fair-Rite toroids on Digi-Key

- **Toroids - Normal**
  - FT240-43 – Typically see in most EFHW instructions
    - Diameter: 61mm (2.4”) | Thickness: 12.7mm (0.5”)
  - FT140-43
    - Diameter: 35.6mm (1.4”) | Thickness: 12.7mm (0.5”)
  - FT240-61
    - Diameter: 61mm (2.4”) | Thickness: 12.7mm (0.5”)
  - Fair-Rite 5943003801
    - Diameter: 61mm (2.4”) | Thickness: 12.7mm (0.5”)
- **Toroids – QRP only due to small size**
  - FT50-43
    - Diameter: 12.7mm (0.5”) | Thickness: 4.9mm (0.2”)
  - FT37-43
    - Diameter: 9.5mm (0.4”) | Thickness: 3.175mm (0.125”)
  - FT240-52
    - Diameter: 61mm(2.4”) | Thickness: 12.7mm (0.5”)
  - Fair-Rite 5943000301
    - Diameter: 12.7mm(0.5”) | Thickness: 4.9mm(0.2”)
  - Fair-Rite 5943000901
    - Diameter: 5.84mm (0.23”)| Thickness: 3.05mm (0.12”)

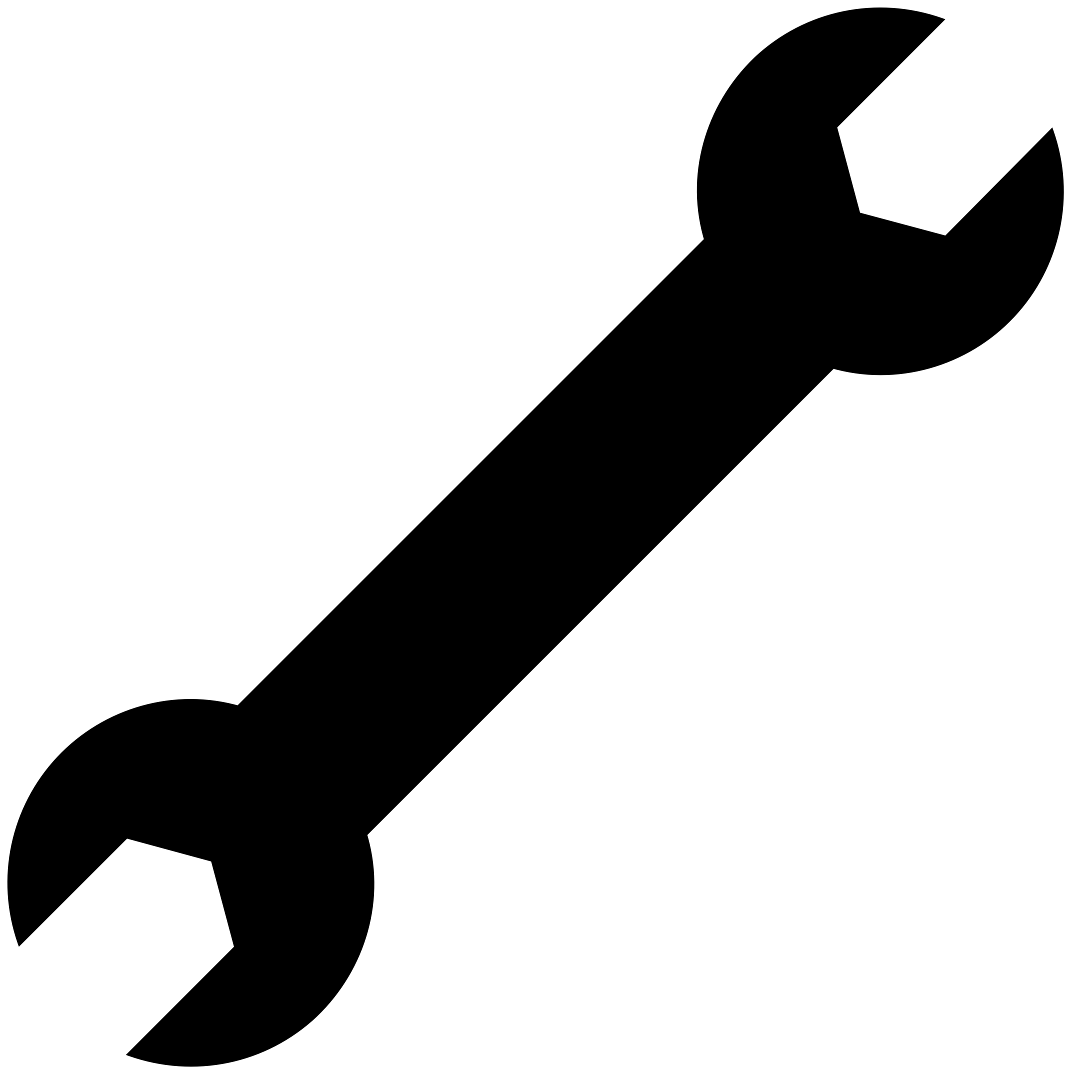
Online Calculators

- Single Layer Coil Calculator
  - https://coil32.net/online-calculators/one-layer-coil-calculator.html
- EFHW Antenna Designer
  - https://portable-antennas.com/efhw.php
- Loading coil and pig tail
  - https://reflector.sota.org.uk/t/short-efhw-design-loading-coil-and-pigtail-length/31928/21?page=2

Parts as of March 2025

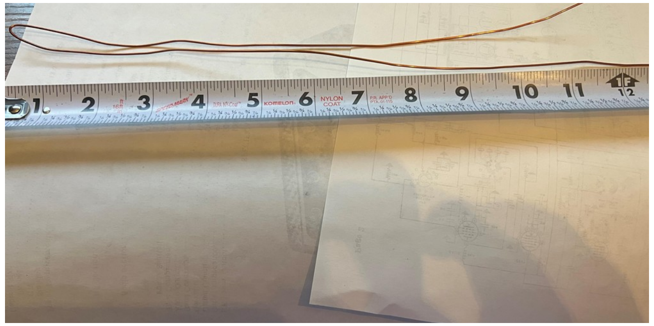
Part	Source	Cost	Note
Toroid (FairRite #2643251002)	DigiKey	$7.56	DigiKey Part # 1934-1079-ND
Capacitor 100pf 10KV	Amazon	$11.99	Brand: Baauye (Ships in sets of 10)
BNTECHGO 22 AWG Stranded Tinned Copper Wire	Amazon	$23.98	250 ft of wire, used for the antenna
BNTECHGO 26 AWG Stranded Tinned Copper Wire	Amazon	$18.48	250 ft of wire, used for counterpoise
Emtel 22 AWG (505 ft(99.9% pure copper wire, enameled magnetic wire	Amazon	$24.99	Used to wind the toroid
SO239 Bulkhead Connector 4-pack PL259 Female Nut Bulkhead Panel mounting straight socket	Amazon	$7.90	Brand is exgoofit, comes in a pack of 4
Uxcell Heat Shrink Tubing, 80mm Dia 128mm flat width 2:1 shrinkable tube cable sleeve 1m-black	Amazon	$9.49	
uxcell M4 Wing Nuts, stainless Steel 304 Fasteners	Amazon	$8.59	Pack of 20
Juvielich M4-0.7 Hex Nut, 304 Stainless Steel Nut Fastners, Hex drive, Metric, Right Hand	Amazon	$6.49	Pack of 100
Glvaner M4-0.7 x 16mm Binding Screws, Flat Round Head Phillips Drive Machine Screw 304 Stainless Steel 18-8 Full Thread	Amazon	$8.54	Pack of 100
Assorted kit of ring connectors	Amazon	$14.98	360 pieces in assorted gauges
3D Printed support base	Bob French		

Let’s Make an EFHW

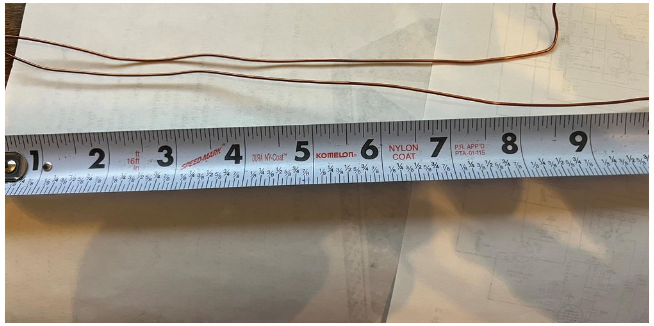


Preparing the Enameled Wire

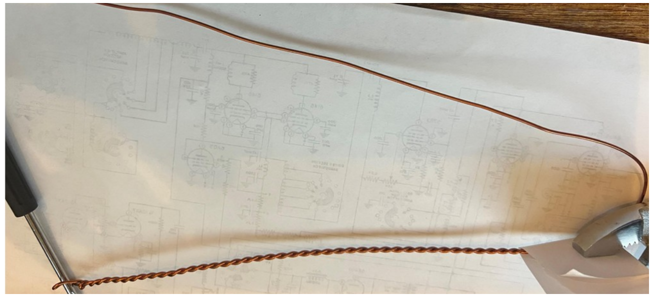
- Take the 60 inches of enameled wire (AWG 22/0.65mm), and measure 12 inches from one end, and fold over.



- Measure 3” from the short end of the wire that was folded back and bend the wire 90 degrees

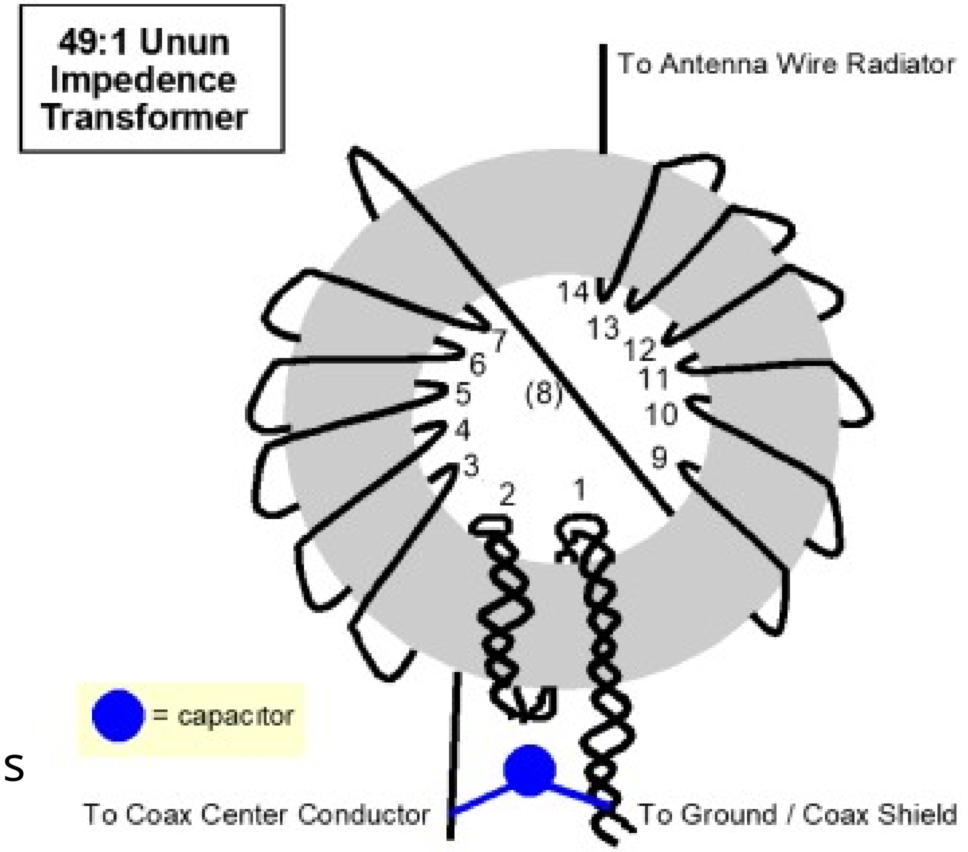


- Carefully hold with pliers at the 90 degree bend and twist about 30 times to create a tight twist. **NOTE**: Use provided paper to wrap the wire where you hold it with the pliers. We need to protect the wire



Wrapping the Toroid

- Wind the toroid keeping your windings tight against the toroid and NOT overlapping or kinking up
- Follow the diagram
- After it is wrapped even space the turns as much as possible

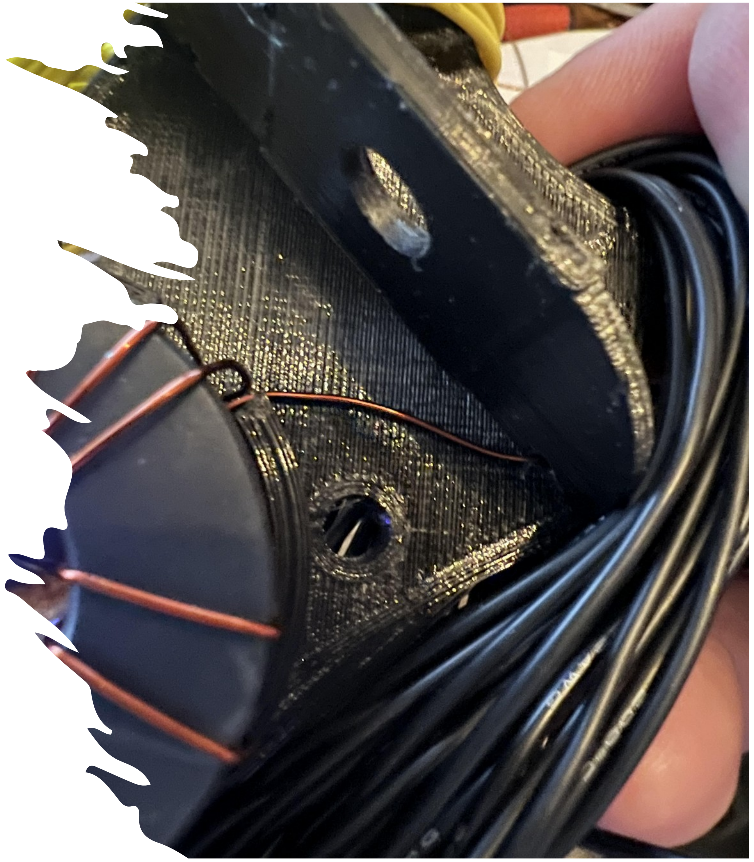


49:1 wrapping
- 2 Primary turns
- 14 Secondary turns

* Image from KM1NDY

Initial Assembly

- Place either a SO-239 or BNC bulkhead into the provided hole
- Place the toroid in the appropriate location on the wire winder
- Cut the TX wire so it fits into the center conductor of the SO-239
- Cut the GND wire so that it fits into the SO-239 ground
- Remove ¼” of enamel from the end of the TX and GND wires using sandpaper
- Feed the ANT wire through on of the holes in the bulkhead on the opposite side
- Trim the ANT wire so it ends at the edge of the last hole on the wire winder arm
- Solder the TX wire to the center connector
- Solder the GND wire to the ground point on the SO-239



Finish the 49:1 UnUn

- Take a spare piece of enameled wire and like the antenna wire run it through the bulkhead and remove ¼" of the enamel on the toroid side of the bulkhead
- Solder the new ground wire to the existing ground wire
- Solder the capacitor between the ground wire and the center conductor
- On the outside of the bulkhead cut the GND wire to end at the edge of the first hole
- Remove ¼" of the enamel from the end of the ANT and new GRD
- Solder a ring terminal onto each
- Connect each to the wire winder in this order:
    - Bolt – Small Ring – Washer – ANT Winder – Nut
- Zip tie the Toroid to the wire winder

Build the Antenna Wire

- The antenna wire used in this project is BNTECHGO 22 AWG silicone wire (stranded tinned copper wire)
    - I have tested at 10 watts digital/CW and 100 watts SSB
    - If building a 40M antenna, I typically use AWG 18 wire
- Measure 35 feet of wire (in the BARC tech night kit pre-measured)
- Strip ¼" of coating and solder a small ring terminal onto the end (already done in the BARC tech night kit)
- Measure 2-3 inches from the ring terminal and pinch the wire and push through the large ring terminal
- Wrap the loop around the ring terminal and pull any loose wire back out
- This is the strain relief
- Attach an insulator to the other side of the wire

Build the Counterpoise

- The counterpoise wire used in this project is BNTECHGO 26 AWG silicone wire (stranded tinned copper wire)
  - I have tested at 10 watts digital/CW and 100 watts SSB
  - If building a 40M antenna, I sometimes use AWG 22 wire or bigger
- Measure 21 feet of wire (in the BARC tech night kit pre-measured)
- Strip ¼" of coating and solder a small ring terminal onto the end (already done in the BARC tech night kit)
- Measure 2-3 inches from the ring terminal and pinch the wire and push through the large ring terminal
- Wrap the loop around the ring terminal and pull any loose wire back out
- This is the strain relief
- Attach an insulator to the other side of the wire

Finish the Build

- Double check all the connections
- Slide the heat shrink over the wire winder so a small portion is equally overhanging each curved/raised bulkhead
- Use a heat gun to shrink the wrap onto the antenna
  - Be careful and don't heat too much or the base unit will deform
  - Let it cool on a flat level surface
- Put the antenna wire ring terminal on the ANT side and secure with a wingnut
- Put the counterpoise wire ring terminals on the GND side and secure with a wingnut
- Wrap the antenna and counterpoise wires on opposite ends of the wire winder in a figure 8 configuration

Go Have Fun Making QSOs

Tune your new antenna
Connect it to your transmitter
Start making QSOs

Credits

- Various websites and videos were used to put this information together
- I would like to specifically call out the following resources I found useful:
  - KM1NDY - https://km1ndy.com/diy-491-unun-impedence-transformer-for-end-fed-half-wave-efhw-antenna/
  - Randy Thompson (K5ZD) - https://k5zd.com/efhw-basics/
  - Steve Dick (K1RF) - http://gnarc.org/wp-content/uploads/The-End-Fed-Half-Wave-Antenna.pdf
  - Frank Dörenberg (N4SPP) - https://www.nonstopsystems.com/radio/frank_radio_antenna_multiband_end-fed.htm

  - Colin Summers (MM0OPX)- YouTube videos
  - RF Guru for tuning tips https://shop.rf.guru/pages/tuning-advice-for-an-end-fed-half-wave-efhw-antenna
  - Scott KI5NPL - https://bvarc.org/home/lets-build-an-efhw-antenna/
  - Steve Yates AA5TB - https://www.aa5tb.com/efha.html