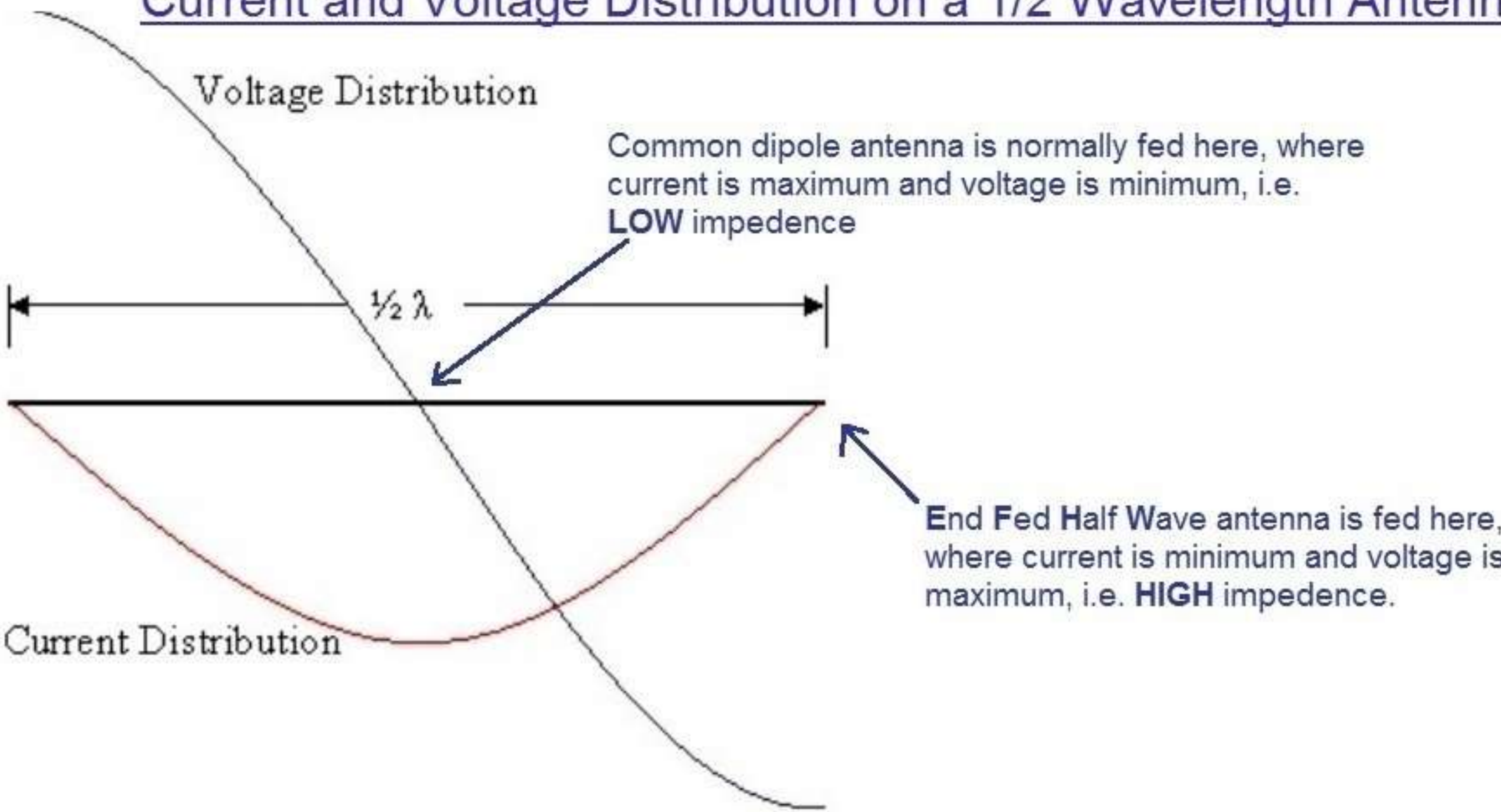
Ramblings on construction and use of the

End Fed Half Wave Antenna

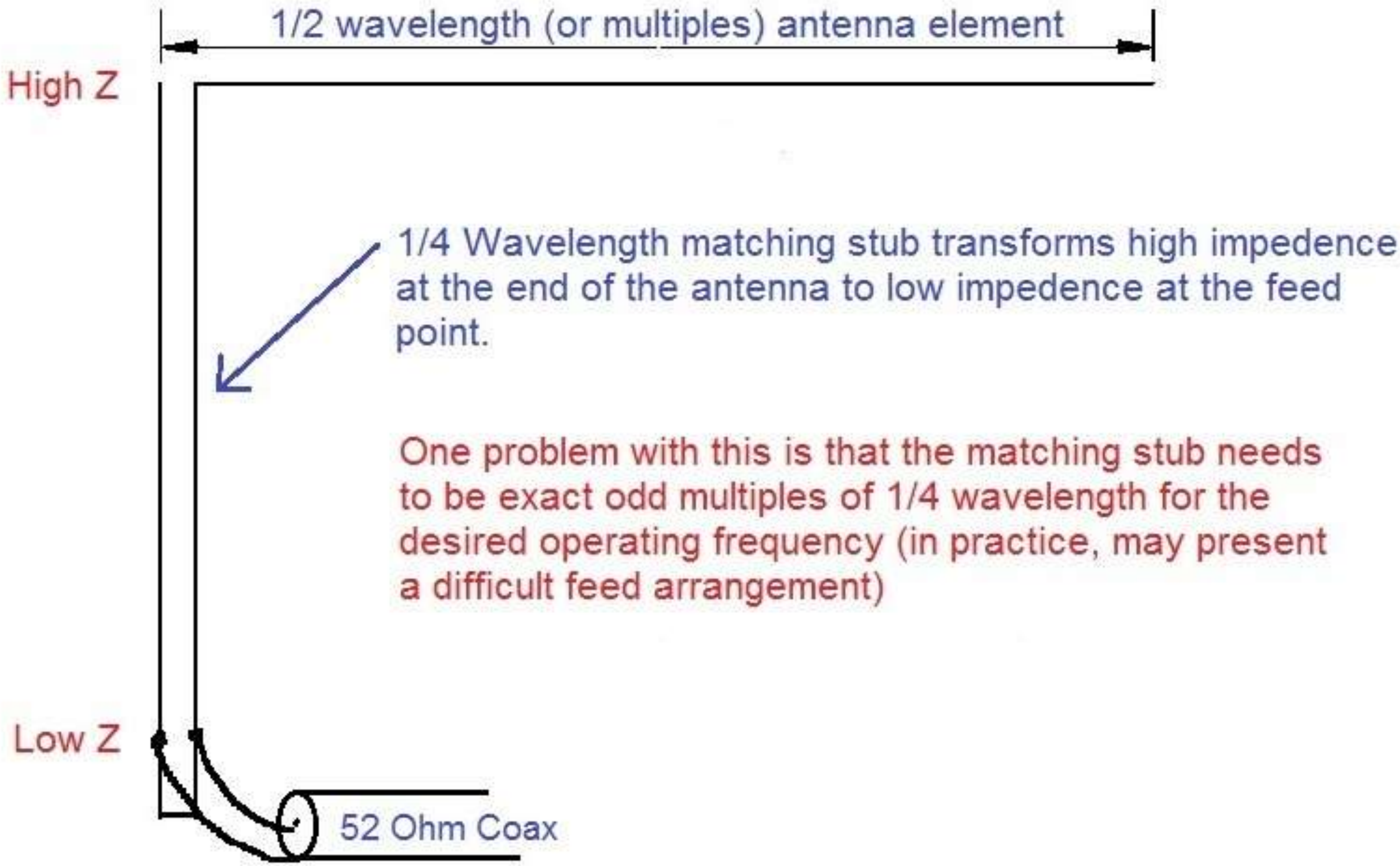
by Rick Reeve VE3ORY

When considering the End Fed Half Wave antenna, it is beneficial to keep in mind this fundamental principle of a half wave radiator...

Current and Voltage Distribution on a 1/2 Wavelength Antenna

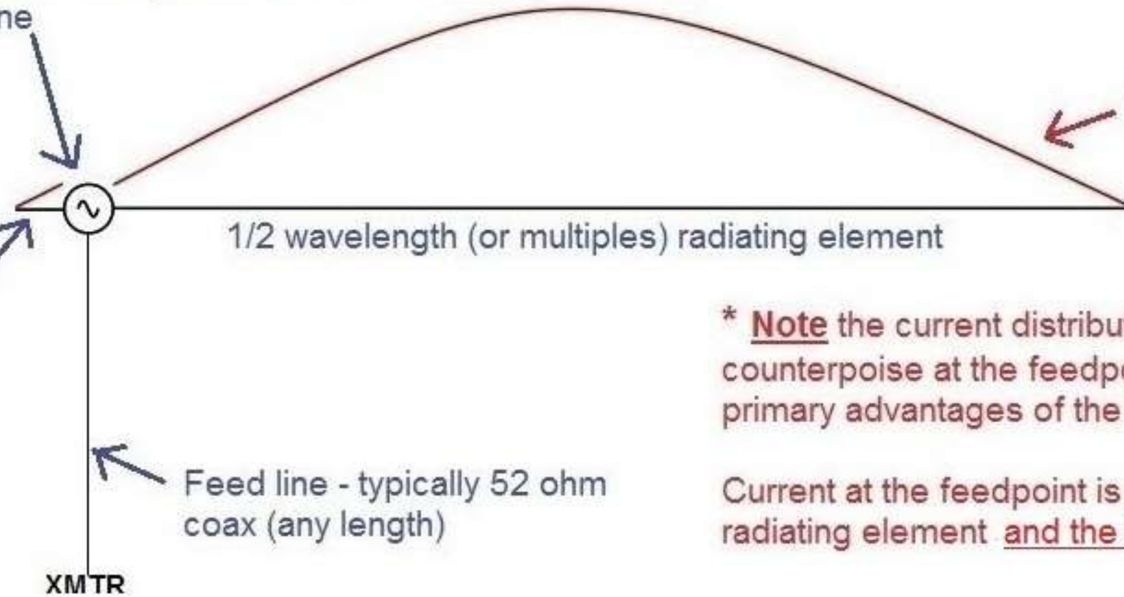


An End Fed Half Wave antenna is similar in principal to that of the End Fed Zepp Antenna



Basic End Fed Half Wave Antenna

** Impedence matching transformer: to change High Z at end of antenna to a Low impedence that will match a 52 ohm feed line



Current distribution

**Short (minimal) ground counterpoise

Feed line - typically 52 ohm coax (any length)

<u>*Note</u> that at the feed point, the current on the ground counterpoise is the same as current on the 'radiating element'.

And <u>both currents are minimal at the half wave frequency</u>

* <u>**Note**</u> the current distribution on the ground counterpoise at the feedpoint. This is one of the primary advantages of the EFHW antenna.

Current at the feedpoint is <u>minimal</u> into both the radiating element <u>and the ground counterpoise.</u>

<u>It is for this reason that only a minimal ground counterpoise is required for use with the EFHW</u>

<u>Advantages</u>

1. Conveniently fed from one end of the antenna (typically within a few feet of the ground), yet the high current point (max antenna radiation) is 1/4 wavelength up the antenna

2. Requires only a minimal ground counterpoise...either a short length of wire or a portion of the coax shield will suffice. (Cushcraft verticals are an example of 1/2 wave end fed antennas that operate efficiently with only minimal ground requirement)

3. Also resonant at frequencies that are multiples of 1/2 wavelength

Matching Transformer for an EFHW Antenna

Practical impedance at the end of a 1/2 wavelength antenna is typically in the range of **2000** to **4000 ohms**

So for example, if the antenna impedance was **2450 ohms** you would need a **matching transformer with a transformation ratio of 49 to 1** in order to match to a 50 ohm feed line impedance.

Similarly an antenna with **3200 ohm** impedance would require an impedance transformation ratio of **64 to 1**

EFHW matching transformers are usually wound for one of the impedance transformation ratios noted above.

Note that this is completely different from the case of the 9:1 matching transformer used with a random length end fed antenna, which is made so as to be purposely **not a 1/2 wavelength** on any frequency. Impedence at the end of a random length antenna is typically only ~450 ohms (hence the use of a 9:1 transformer).

Calculating Matching Transformer Turns

Transformation Ratio = $(\text{Turns Ratio})^2$

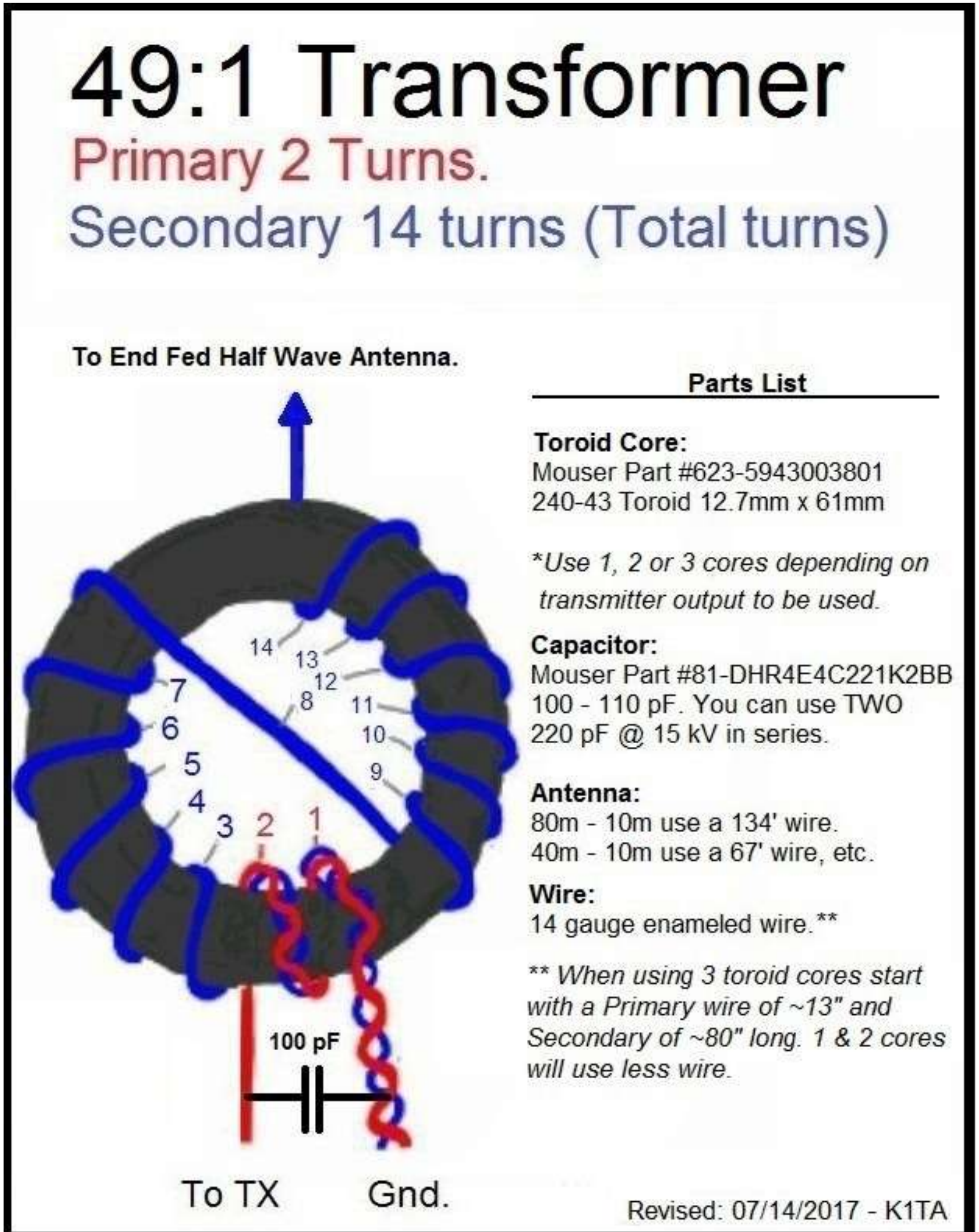
e.g. Secondary = 14 Turns, Primary = 2 Turns

-> Turns Ratio = 7:1

-> Impedance Transformation Ratio = 49

This matching transformer would bring an antenna impedance of 2450 ohms down to an impedance of 50 ohms (2450 / 49 = 50)

Note that when winding toroids, each time the wire passes through the toroid counts as one turn.



- You will find this diagram by K1TA on numerous web sites.

  It is a good reference when trying to remember how to wind an EFHW matching transformer.

Typical EFHW Matching Transformer

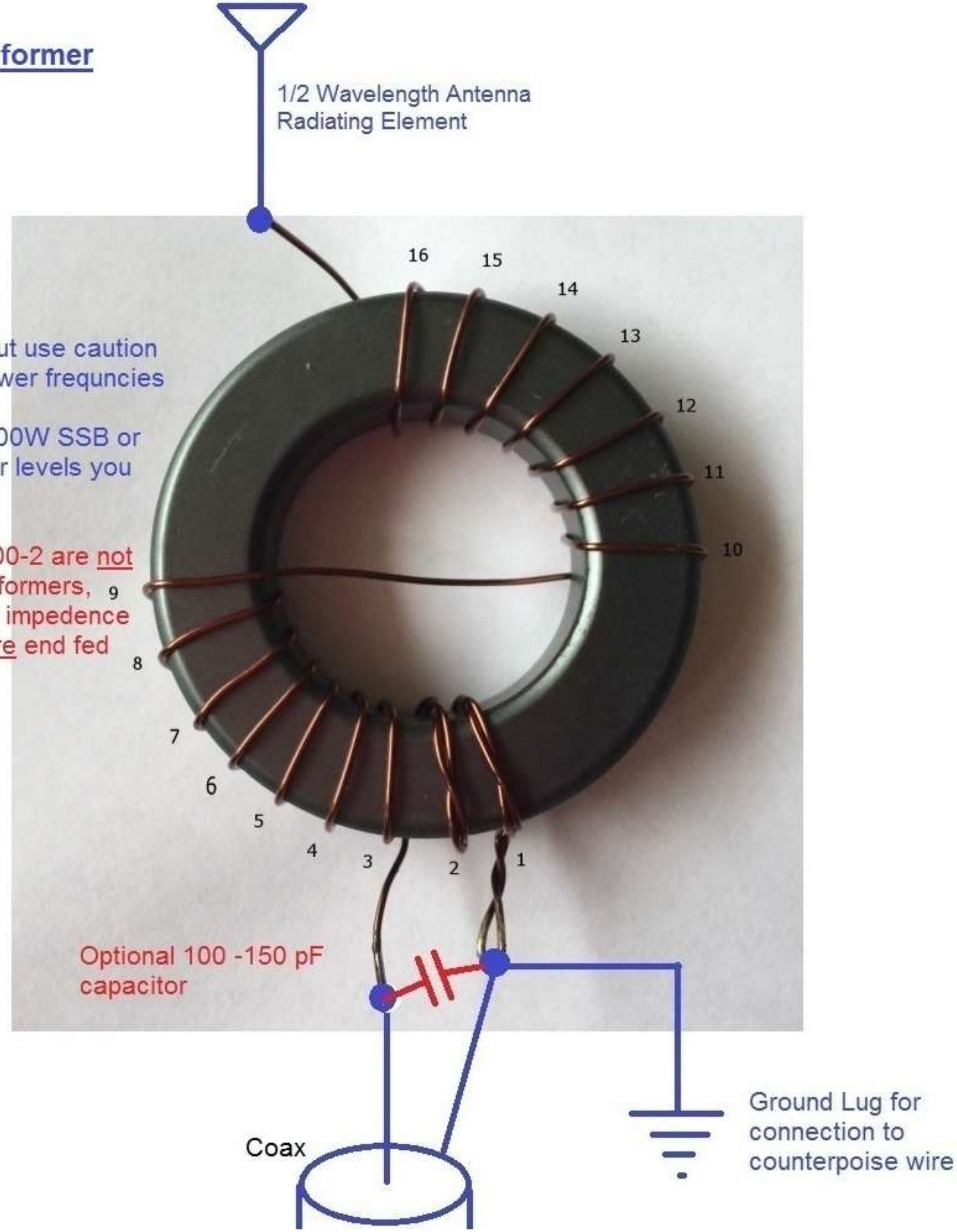
This one wound for an impedance transformation ratio of 64:1

Ferrite Toroid Core(s)
Typically FT 240-**43** or **-52** or **-61** mix

Smaller core can be used for QRP but use caution as cores will heat up, especially at lower frequncies

One FT 240 core is likely good for 100W SSB or 50W CW or Digital. For higher power levels you can stack 2 or 3 cores

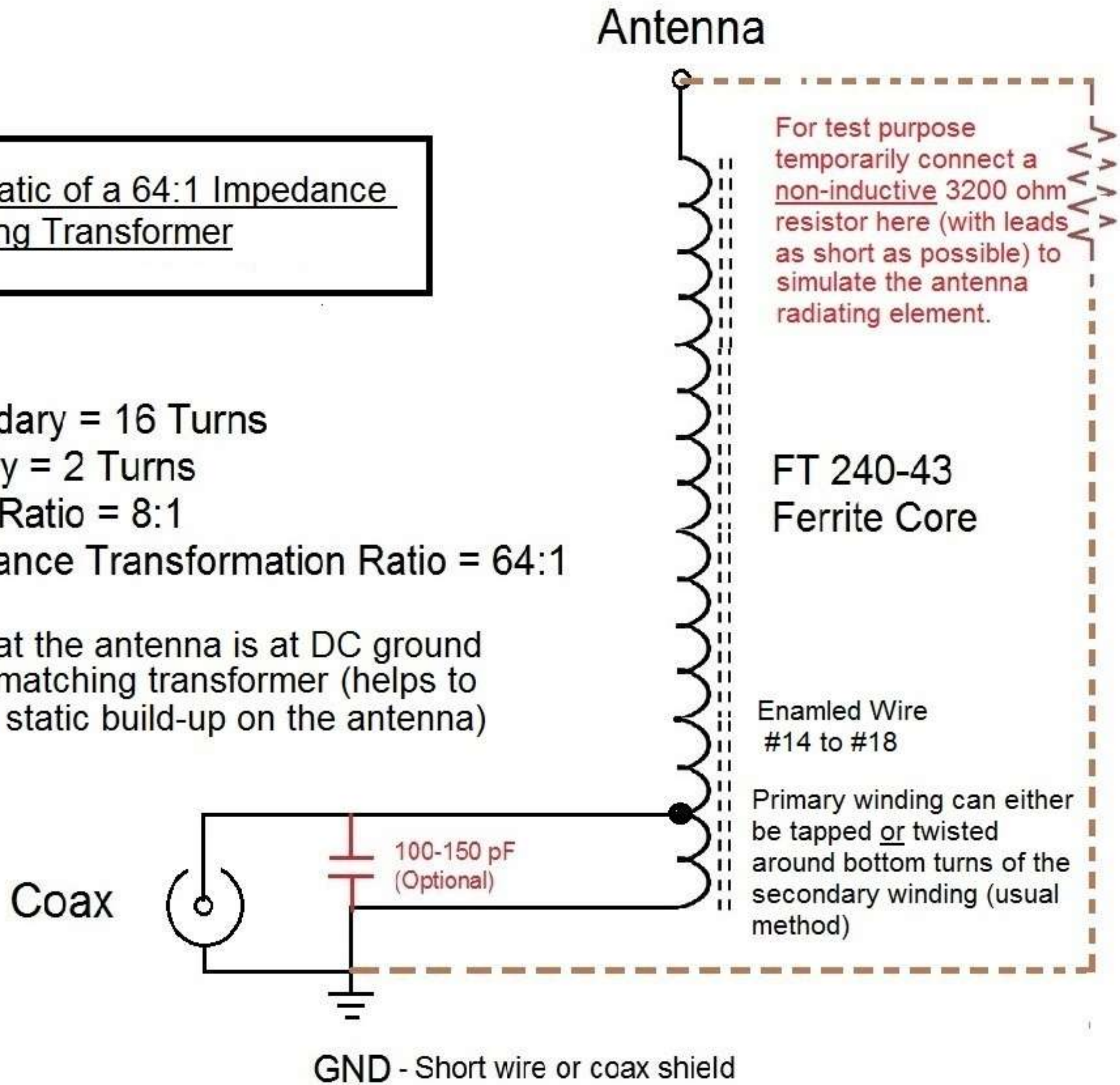
Powdered Iron Toriod cores e.g.T-200-2 are <u>not</u> suitable for <u>1/2 wave</u> matching transformers, (although they can be used for lower impedence transformers such as 9:1 <u>random wire</u> end fed antennas)



Schematic of a 64:1 Impedance Matching Transformer

Secondary = 16 Turns
Primary = 2 Turns
Turns Ratio = 8:1
Impedance Transformation Ratio = 64:1

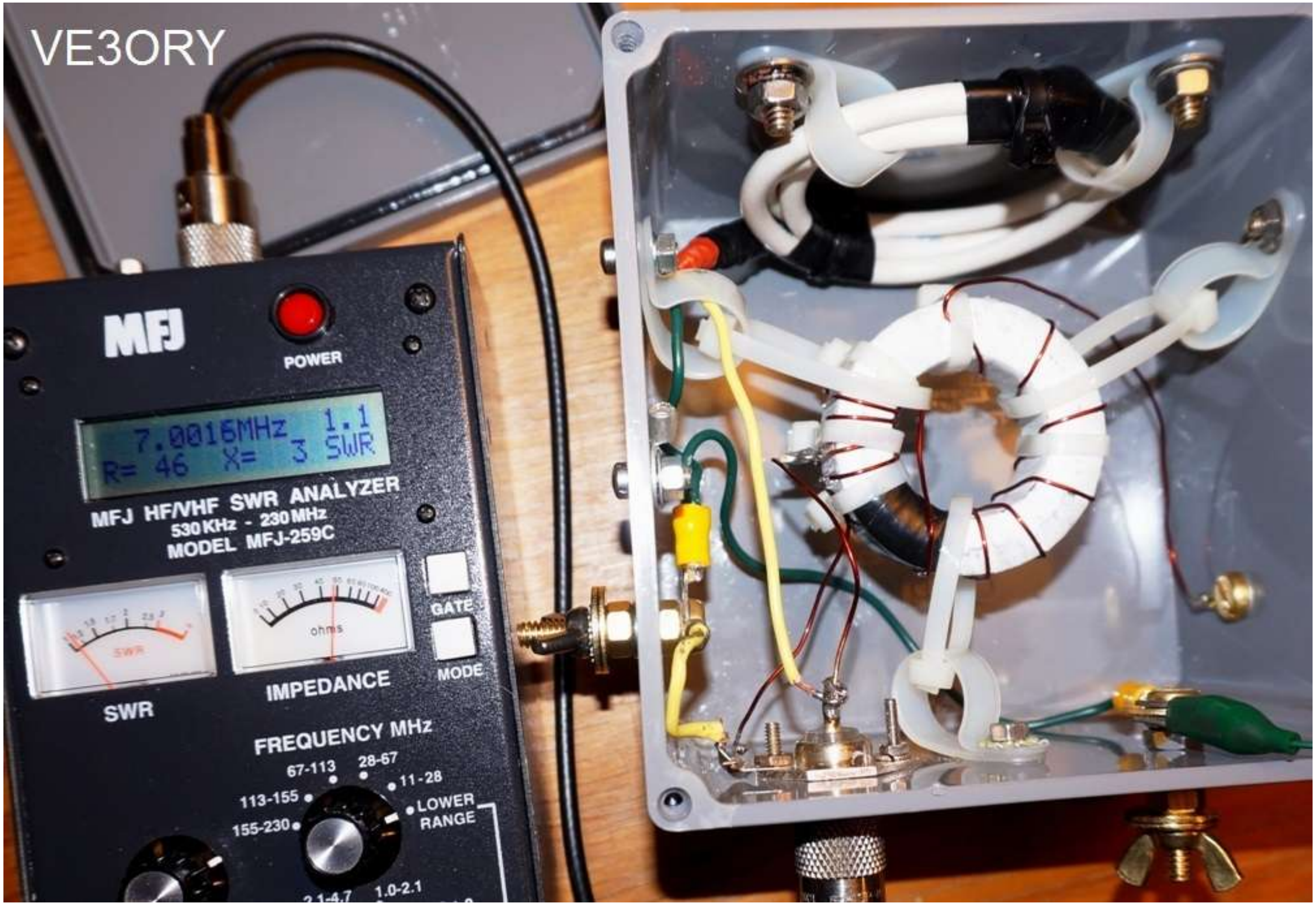
** Note that the antenna is at DC ground via the matching transformer (helps to prevent static build-up on the antenna)



Testing one of my single core transformers using a 4200 ohm resistive load to simulate the impedance of a ½ wave radiating element. This is a good way to asses characteristics of the transformer across the intended frequencies. The disk capacitor helps offset the tendency for SWR to increase at higher frequencies due to inductance of the transformer windings.

For this transformer I experimented with using a piece of coax cable to provide the capacitance across the input winding. You can do without this capacitor if your antenna is targeted for the lower bands (80/40m) and you don't care so much about SWR increasing at the higher frequencies.

Also keep in mind that this capacitor sees your full transmitter output so important that it be appropriately rated for the intended power levels.

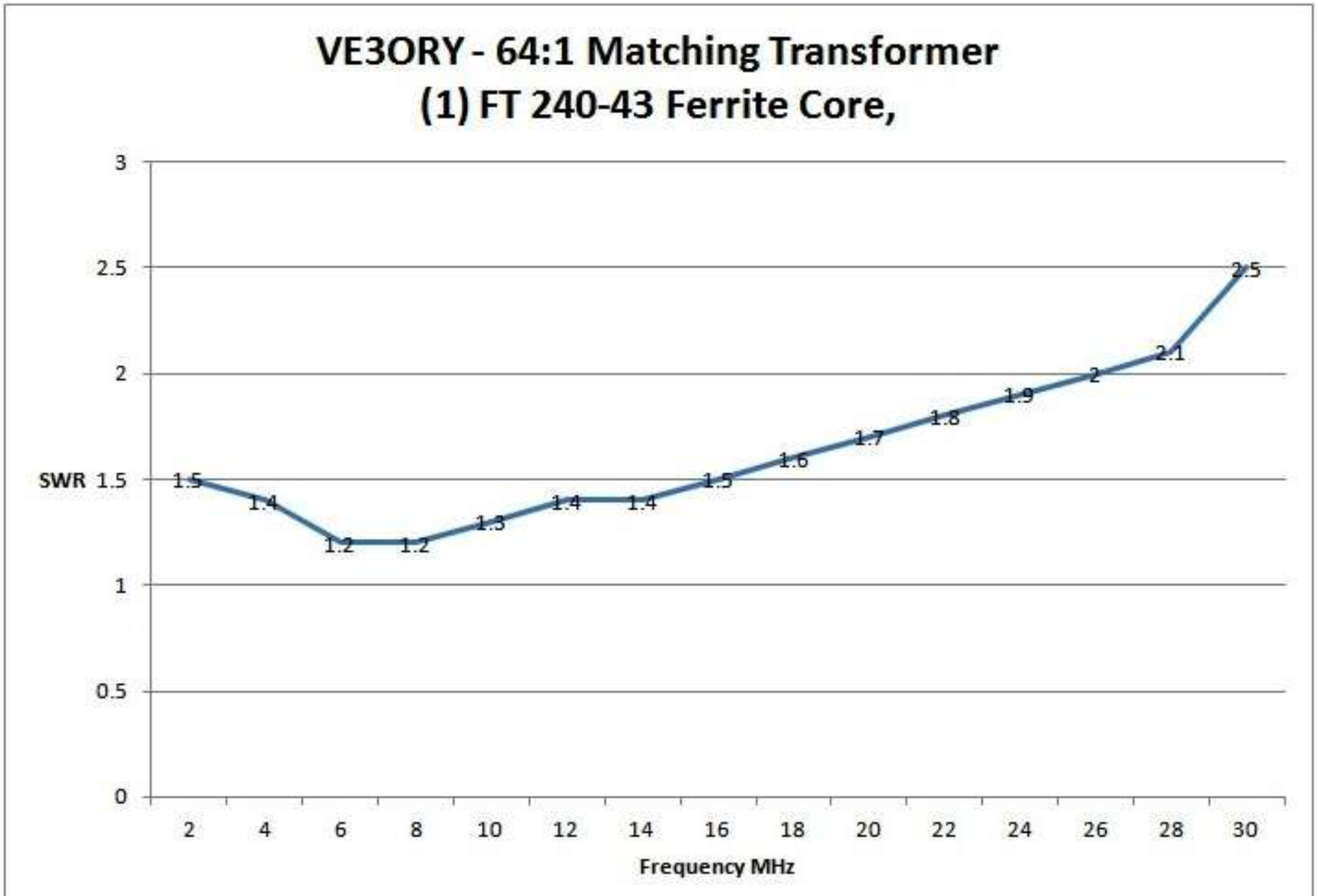


Here is a plot of SWR for one of my transformers taken using an MFJ-259C antenna analyzer. Fairly pleased with this one, as the SWR is less than 2:1 across most of the HF band. I have found it relatively easy to obtain good results when winding on a single core. It seems to become more difficult when stacking multiple cores for purposes of better power capability. I think in theory due to resulting higher inductances.

Core = (1) FT 240-43 Ferrite, Primary = 2 Turns, Secondary = 16 Turns, Turns Ratio = 8:1, Impedance Ratio = 64:1

Ideal Test Load Resistance for 52 ohm input = 52 X 64 = 3328 ohms (non-inductive)

Actual Test Load Resistance used = 3320 ohms (non-inductive)



Here is an example of what I mentioned in the previous slide. This transformer wound on a stacked pair of FT 240-43 cores. The SWR rises very quickly at the higher frequencies. The 100 pF capacitor on the input winding will not fully offset this tendency. Different core mix will make a difference. Note also for this one I chose to use a 3-turn primary and 24-turn secondary which likely compounded the problem at higher frequencies. There is still a lot of 'black art' magic about these transformers that I don't yet fully understand.

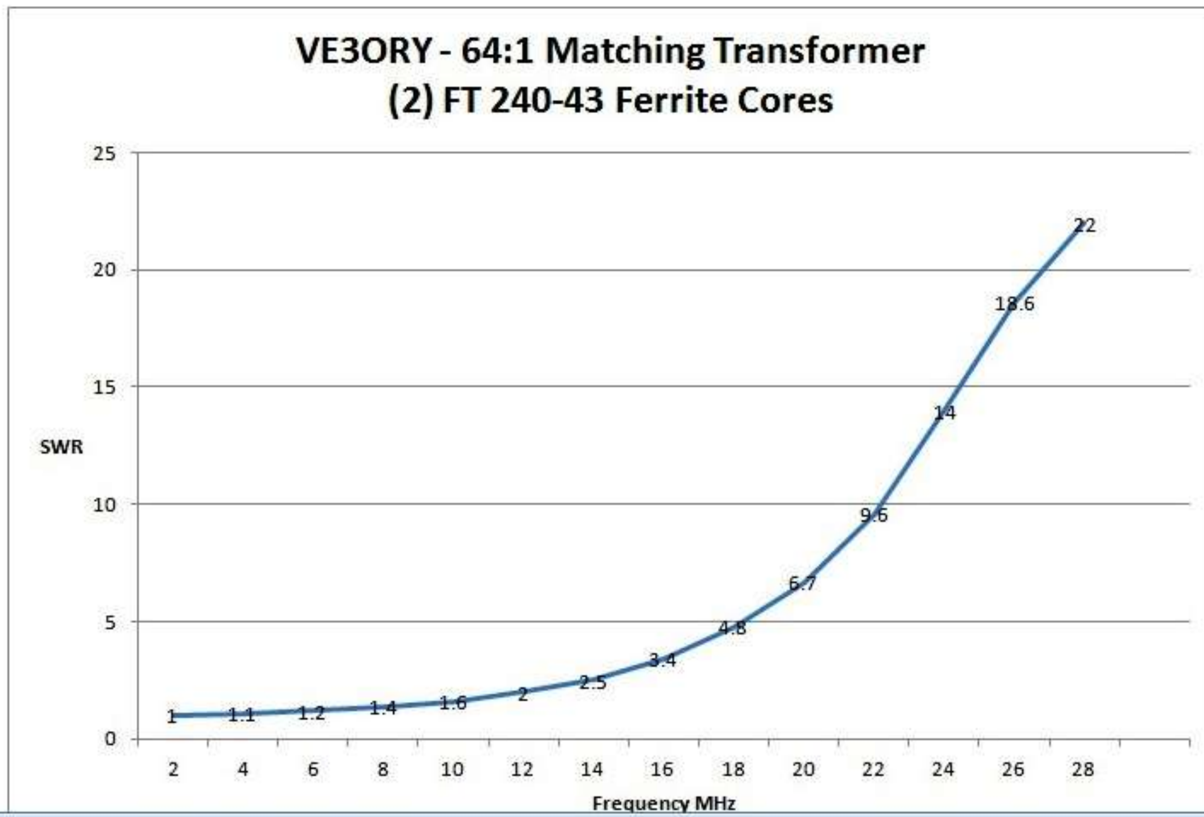
VE3ORY - 64:1 Matching Transformer, Stacked (2) FT 240-43 Cores

Construction / Testing Data

Core = (2) FT 240-43 Ferrite, Primary = 3 Turns, Secondary = 24 Turns, Turns Ratio = 8:1, Impedance Ratio = 64:1

Ideal Test Load Resistance for 52 ohm input = 52 X 64 = 3328 ohms (non-inductive)

Actual Test Load Resistance used = 3320 ohms (non-inductive)



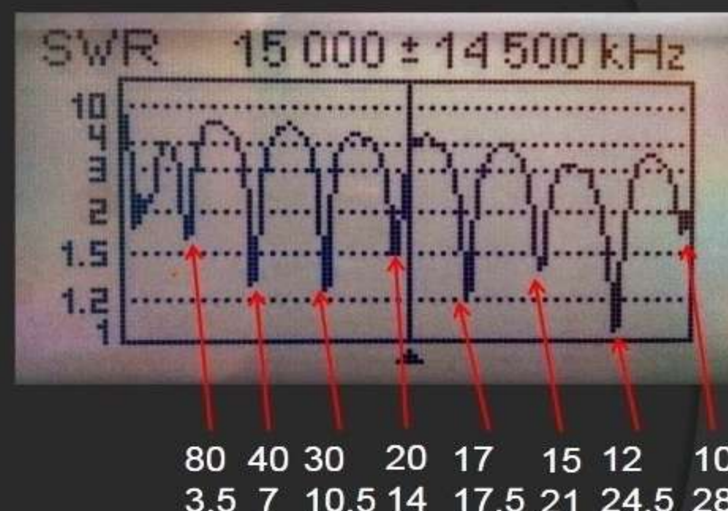
Keep in mind that the previous SWR plots shown were only looking at performance of the transformer itself, using a resistive load to simulate an ideal antenna connected to the output terminal. The real-life situation is a lot different. Primarily due to the fact that, as you change frequency on the antenna, it is in reality no longer an exact ½ wavelength, and impedance at the end of the antenna will decrease rapidly. The matching transformer is then 'over-compensating' and the result is that SWR rises rapidly as shown in the SWR plot here.

It is also for this reason that it can be difficult to get an EFHW antenna to operate on multiple bands where the higher frequencies may be close to, but not exactly, a ½ wave multiple of the lowest fundamental frequency that the antenna was tuned for. There are other tricks that can be used to offset this tendency (as used in some of the commercially produced EFHW antennas).

SWR plot on real antenna vs. resistive load

(This image from K1RF 'Steve Dick')

- SWR plot looks very different from a resistive termination and typically improves when driving a real antenna!
- That's because if the antenna operates slightly above resonance, it looks capacitive. That capacitance series-resonates with unun secondary leakage inductance, effectively cancelling it out!



Look Ma! Typical SWR plot with No antenna tuner! Pretty nice!

Core Material Data from K1RF, Steve Dick

EFHW Single FT-240 Unun 3T different materials.xls [Compatibility Mode]

1 This EFHW core loss data generated by Steve Dick, K1RF based on on-line calculators available on owenduffy.net

2 Computations of EFHW UNUN using different toroid core materials, number of toroids, and number of primary turns (2 or 3)

3 Losses in the matching transformer are only part of the total system loss, and overall system efficiency will be lower than estimated here for the transformer alone

4 Using calculator at: https://owenduffy.net/calc/toroid.htm assumed 2pF Cs in the calculator

5 and an example of computing core efficiency at:

6 https://owenduffy.net/blog/?p=12578

7

8 This table was generated for a single FT-240 size toroid with 3 turn primary (for use with 21-24 turn secondary)

9 For a given material. The primary inductance for a three turn primary is 9/4 that if two turns, but Al is half that of two FT-240s.

10 Therefore primary indctance for a single core with 3 turn primary is only about 1.125 the unductance of a two turn primary with two cores.

11 However, the efficiency of a three turn primary has far lower core losses than two turns for the same number of cores and material.

12 A three turn primary should likely work fine even at 28 MHz for a single FT-240 core.

13

14 Core efficiency tables for a single DFT-240 size core with different core materials for a three turn primary:

15 This is assumed to be used for a 100 watt class transmitter. Assume 125 watts max and 44% duty on CW, or 55 watts average output power.

16 Green = efficiency >90% and core power dissipation <6.5 watts (assumption)

17

18 FT-240 parameters: A=OD-61mm, B=ID=35.55mm, C=width = 12.7MM

Type 43					
MHz	u'	u"	Gs	Core Eff	Core Pwr
3.6	470.2	224	0.00296	85.20%	[illegible]
7.1	332	228	0.00255	87.25%	[illegible]
14.2	201.2	204.3	0.00226	88.70%	6.215
21.2	135.3	179.4	0.00216	89.20%	5.94
28.5	97.5	158.4	0.00207	89.65%	5.6925

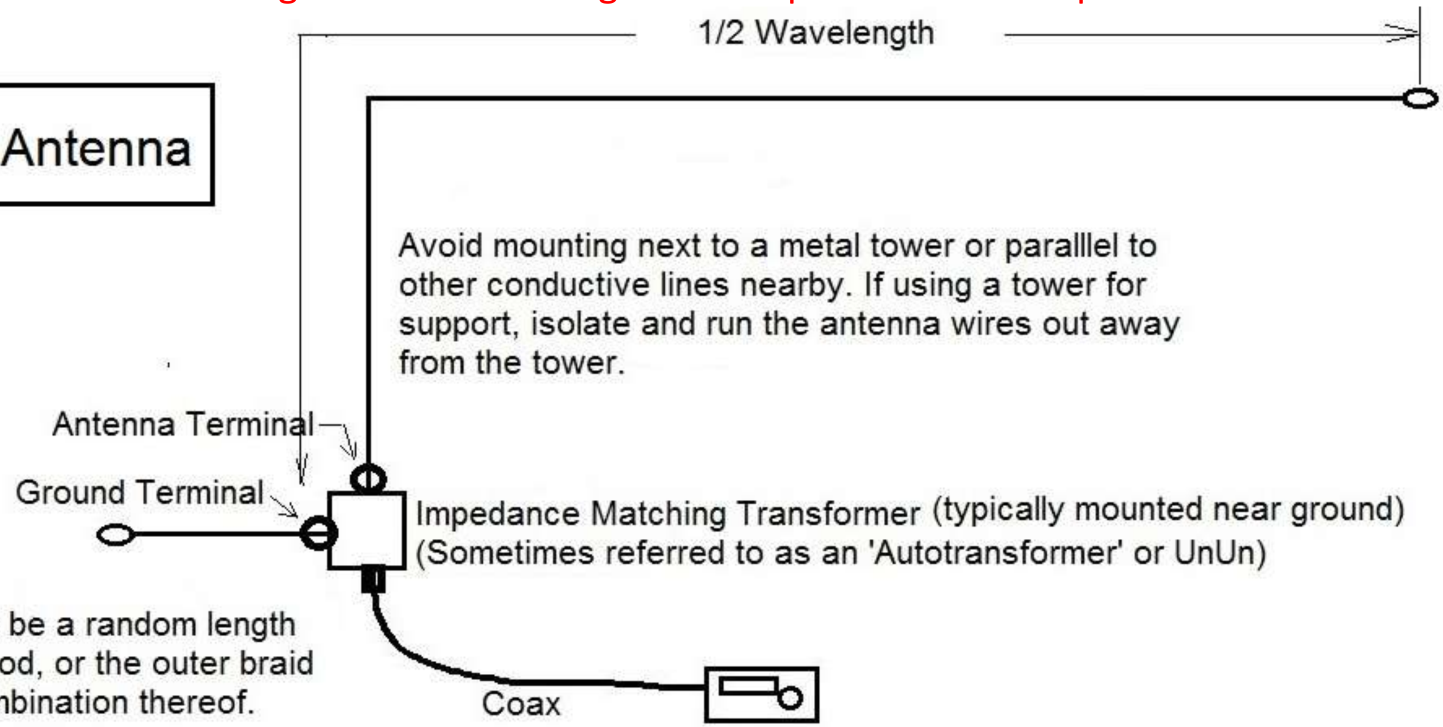
Type 52					
MHz	u'	u"	Gs	Core Eff.	Core pwr
3.6	278.7	7.8	0.000359	98.21%	0.98725
7.1	305.2	73.8	0.00136	93.20%	3.74
14.2	186.8	151.2	0.00238	88.10%	6.545
21.2	132.2	126.8	0.0023	88.50%	6.325
28.5	107.2	109.4	0.00211	89.45%	5.8025

Type 61					
MHz	u'	u"	Gs	Core eff.	Core pwr
3.6	120.6	0.6	0.000148	99.26%	0.407
7.1	123.4	1.2	0.000143	99.29%	0.39325
14.2	136.8	6.2	0.0003	98.50%	0.825
21.2	153.7	41.5	0.000996	95.02%	2.739
28.5	124.5	76.6	0.00162	91.90%	4.455

This is the clear winner!

The next few slides show some practical examples of EFHW antennas that I have experimented with over the past few years. My computer drawings are not the greatest but they will get the idea across. These antennas have worked surprisingly well and have gone a long way towards dispelling my initial misgivings about common mode currents on the coax and RFI concerns. I have operated some of these antennas from the townhouse at times running 400 watts into a wire that terminated in the attic of the townhouse with no adverse effects. And the antennas have performed with surprising efficiency. One of the primary benefits being able to feed the antenna near the ground with the high current points still well up on the antenna.

The Basic EFHW Antenna

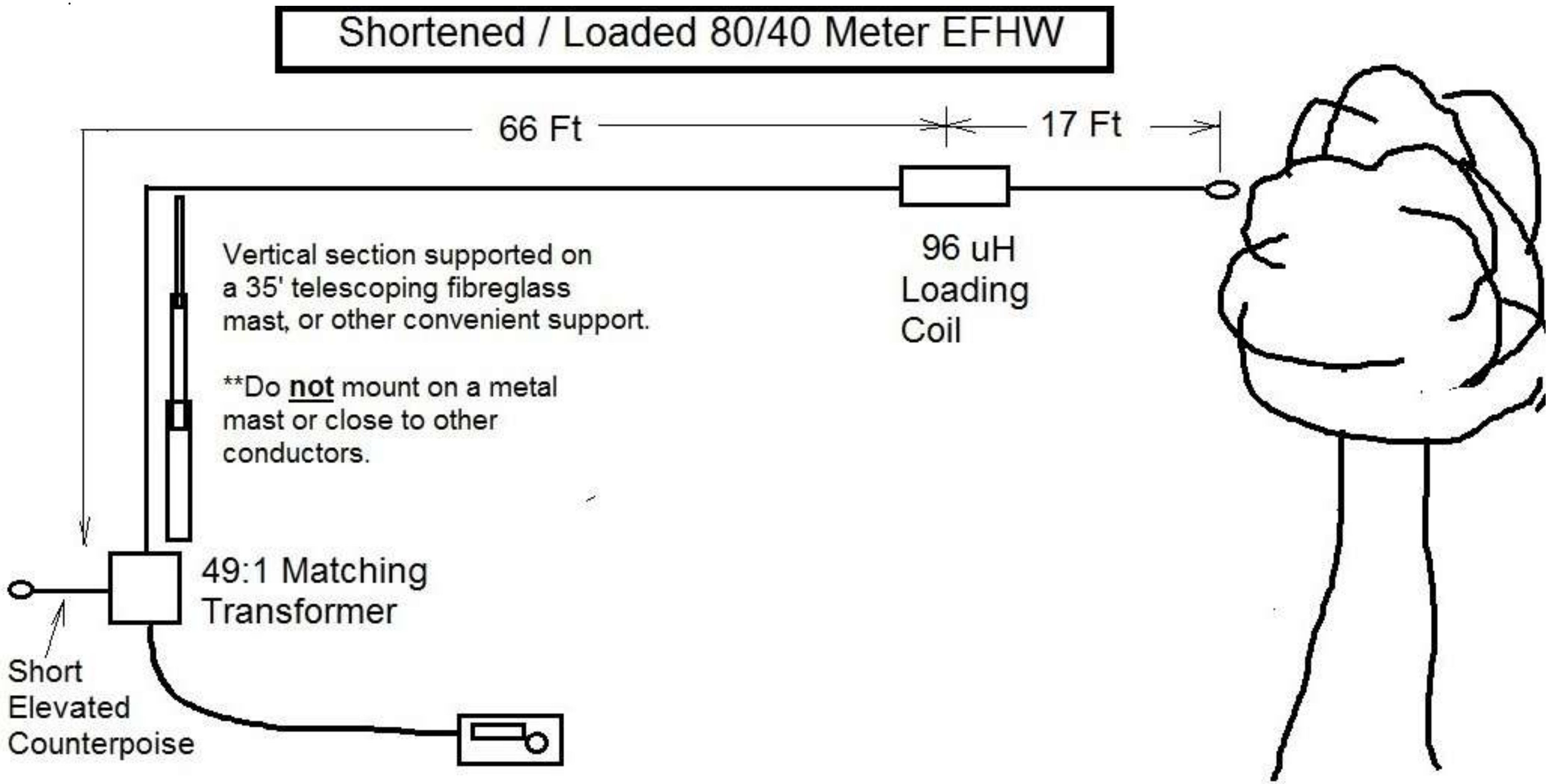


Ground Counterpoise - can be a random length short conductor, a ground rod, or the outer braid of the coax feed line or combination thereof.

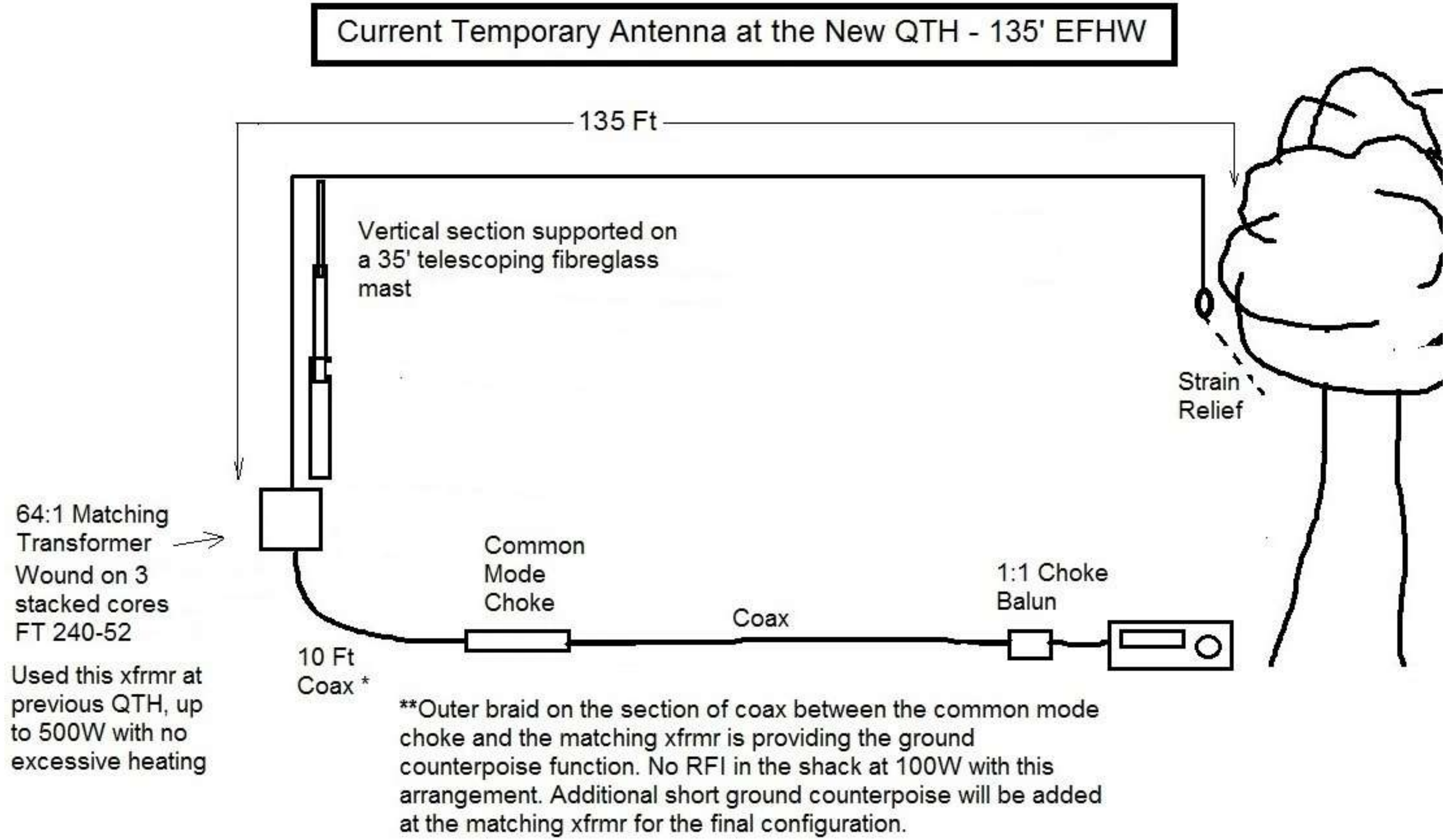
Note that there will be some small amount of ground current present and this will increase if the antenna is operated at other than multiple of the design 1/2 wavelength!

If you make no other provision for this ground current, it will travel on the outside of the coax feed line.

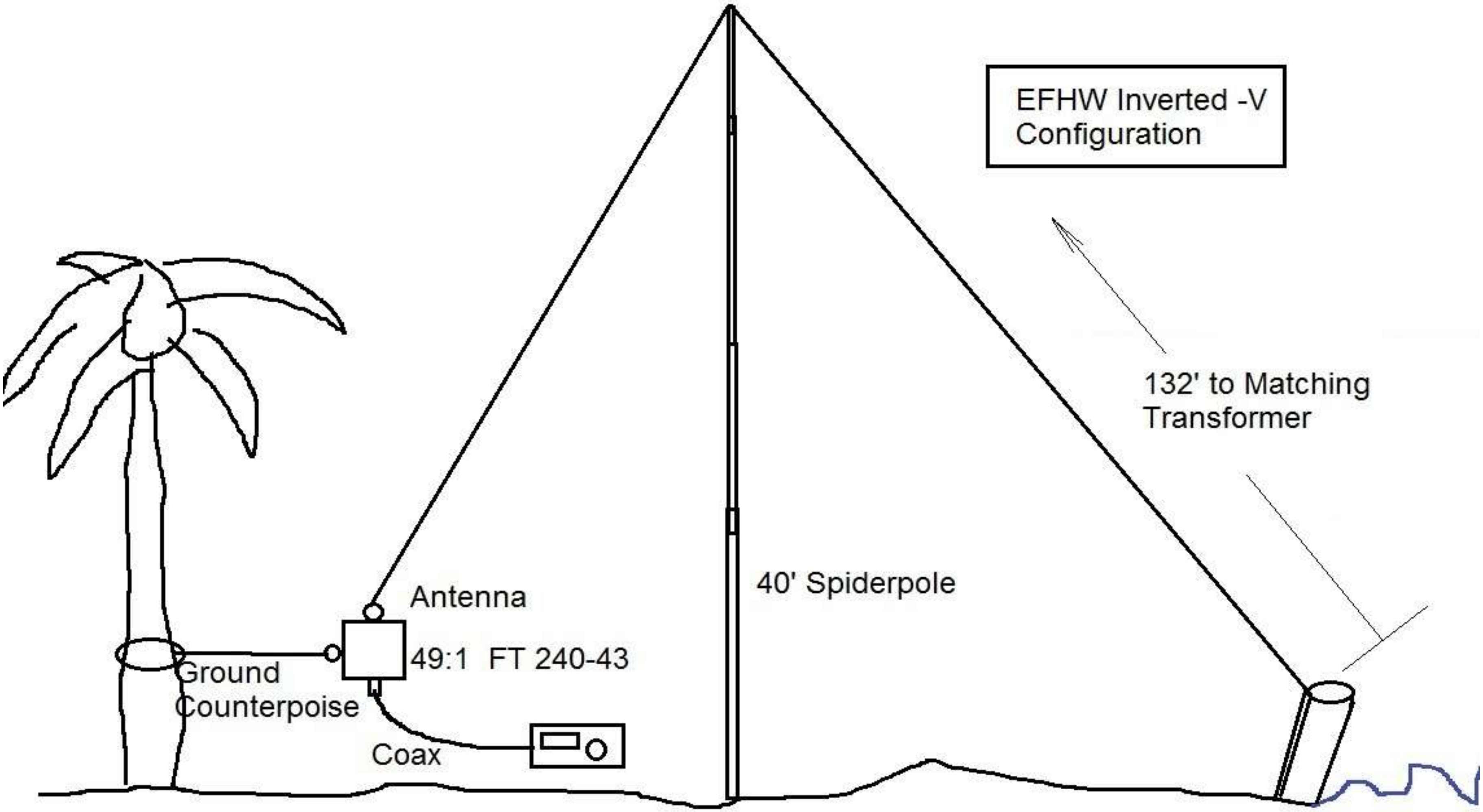
This antenna initially built and tuned as a 40m EFHW, then added a loading coil and short additional wire which was trimmed to resonance on the desired 80m frequency. High inductance of the loading coil effectively isolates the added 80m section from the original 40m antenna. It worked well on both bands.



This antenna is tuned for resonance just below the 80m band but it is exactly resonant over a good portion of the low end on 40m which was my primary aim. The transformer is wound on **3 stacked** FT240-52 cores to afford high power capability without excessive heating of the cores. The result is an SWR that is slightly high (3:1) at the bottom of the 80m band but less than 2:1 across the entire 40m band, and easily capable of handling 500 watts input with long duty cycles. The antenna is easily useable on the other bands with my antenna tuner and seems to be performing well in spite of its' low height above ground.



This is the configuration used extensively over 3 winters in Florida operating from the shores of Tampa Bay. The antenna was completely portable, and set up several times a week in various locations. I routinely checked into a weekly Olivia net running 50W and usually did well into Chino Valley AZ, Chance Harbor NB, Deep River ON, and Oakton VA. Also worked CW at 80W into Vancouver Is., Curacao, St. Barthelemy, Honduras, Spain and Switzerland, and much of the U.S. The nearby salt water probably helped, but I was very pleased with the operation of this antenna.



The telescoping Spiderpole mast mounted to a home brewed drive on base for portable operation. This photo taken at Fort De Soto park near Tierra Verde right on the inlet to Tampa Bay.

.Digital and CW mode operating from Ft De Soto Park, using a battery powered TS-570 at 60 watts to the EFHW antenna supported with the Spiderpole and nearby palm trees (which were not very high). But a great way to spend a winter day, with breaks from the radio to do some kayaking!

Another variation that I came up with while wintering in Florida, configured so that I could connect a ½ wave radiator to the matching transformer, or I could bypass the transformer and feed the radiating element directly and work it as a vertical antenna against a raised ground counterpoise.

I adapted this arrangement to our boat for last years' Field Day event and had a lot of fun working 206 CW contacts. The only time that my wife agreed to letting me set up a ham radio station in the boat. And it had to be removed immediately after FD.

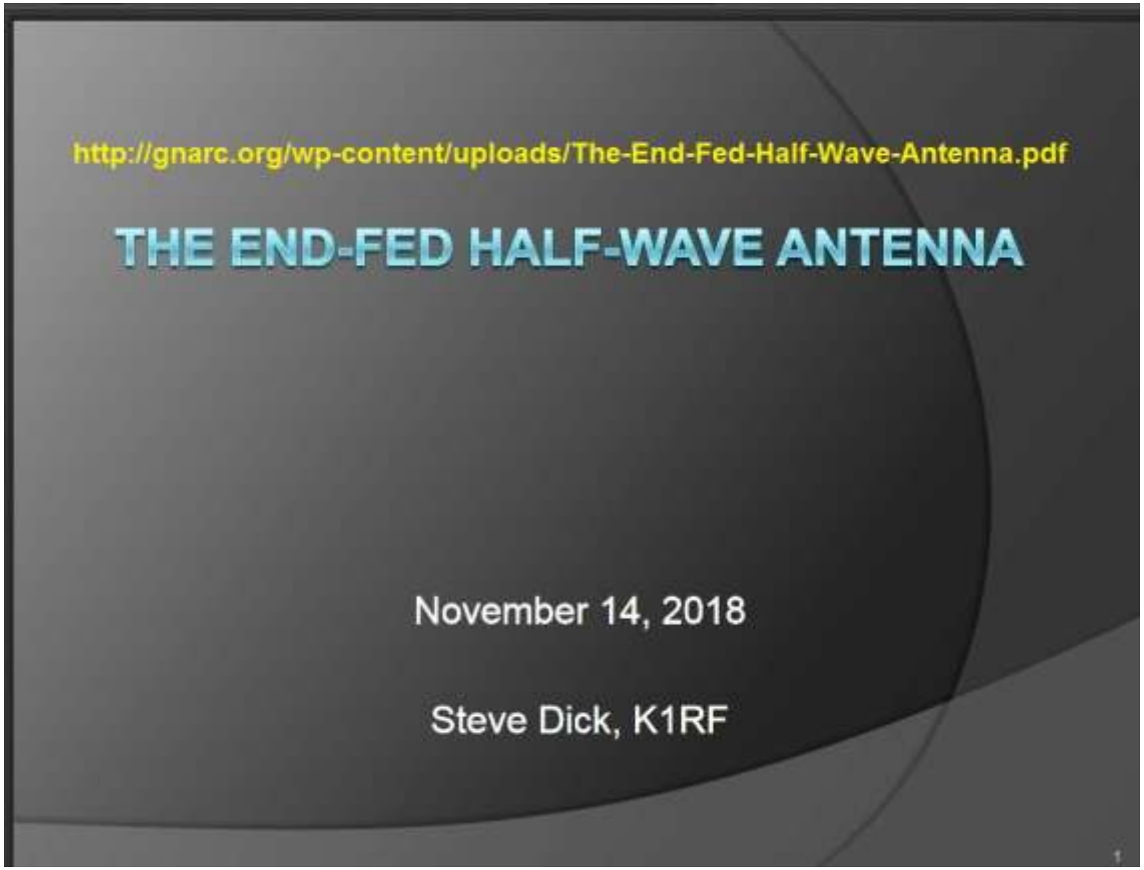
I've never been able to convince her that it would be beneficial to have ham radio on our Chris Craft.

I don’t understand why my wife would be opposed to leaving this set up in the boat!

Steve Dick, K1RF has an excellent PDF tutorial on EFHW antennas that is well worth reading for more information on these antennas.

Clicking on this URL should take you to the website…

http://gnarc.org/wp-content/uploads/The-End-Fed-Half-Wave-Antenna.pdf



Portable operating for the 40m Tuesday night Olivia net from a site at our Florida condo , using the EFHW antenna.

73 de Rick VE3ORY