MULTI-BAND END-FED ANTENNA

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Latest page update: March 2020 (restructured the page, expanded the intro section based on ref. 14, corrected transformer side-naming)
Previous updates: December 2019 (added ref. 13).

INTRODUCTION AND SOME HISTORY

As the name suggests, an "end-fed" antenna is just that: the radiating element is fed at one of its ends, instead of somewhere in-between its two ends (i.e., center-fed like a standard dipole, or off-center-fed). A special case of this, is the End-Fed Half-Wave (EFHW) antenna. Obviously, an EFHW antenna has a "half-wave" length only at one specific frequency. So, a "multi-band end-fed half-wave" antenna is actually a bit of a misnomer...

A "half-wavelength" radiator has a high impedance (= high voltage, low current) at the feedpoint. In fact, both ends of a such a radiator - so you need to keep them away from metal masts, walls, etc. However, this is also the case for an "*n* x half-wavelength" radiator. So, a radiator that is "half-wavelength" at one particular frequency (or in a particular band), will also have a high feedpoint impedance at harmonic *higher* frequencies (or, conversely, in harmonically related *lower* bands). Hence, an end-fed radiator that is dimensioned for the 80 meter band, can also be used for the 40, 20, and 10 meter bands. Or at least parts thereof, as the bands are not 100% harmonically related. As stated, the impedance at the resonance frequencies is high: on the order of 2500-3000 Ω, depending on the installation situation. Typically, a transformer is used to match this radiator wire to a 50 Ω coax cable. Transformers have an integer number of turns in their primary and secondary windings. The *voltage* transformation ratio is equal to the transformer's turns ratio. The *current* transformation ratio is the reciprocal of that turns ratio. Hence, the *impedance* transformation ratio is the square of turns ratio. So, with a 1:7 or 1:8 *voltage* transformation ratio (= ratio of the number of turns), an *impedance* transformation ratio of $1:7^2$ = 1:49, or $1:8^2$ = 1:64, is obtained. This transforms 50 ↔ 2450 and 50 ↔ 3200, respectively. **Note**: as with all antennas, the actual feedpoint impedance (and, hence, the actual transformer ratio that you need) will depend on installation height, etc.

N	M	Turns ratio	Impedance ratio
2	14	1:7	1:49
2	15	1:7.5	1:56
2	16	1:8	1:64
3	21	1:7	1:49
3	22	1:7.3	1:54
3	23	1:7.7	1:59
3	24	1:8	1:64

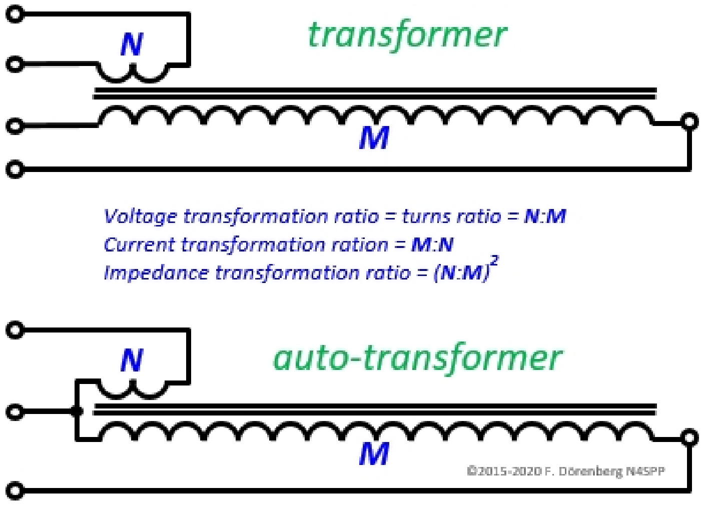


Figure 1: Transformer ratios (N and M are the primary & secondary turns-count)

There are (at least) two standard ways to match the end-fed radiator to the feedline:

- With an impedance transformer that has a variable capacitor across the antenna-side of the transformer. The resulting parallel-resonant circuit needs to be re-tuned when the operating frequency is changed. Here, the antenna is galvanically isolated from the feedline. This is also known as a "Fuchs" antenna, after OE1JF, Josef Fuchs (to be pronounced in English like "Foox") of Vienna/Austria, who patented it in 1927. In his original design, there are actually *two* variable capacitors: one across each side of the transformer. The parallel-resonant transformer circuit is called a Fuchs-circuit ("Fuchskreis" in German).
- With an impedance transformer that is configured as an auto-transformer. Hence, the antenna is not galvanically isolated from the feedline. Here too, one side of the transformer may have a fixed or variable capacitor across it.

Figure 2: The original "Fuchs" antenna

One way to make the Fuchs antenna multi-band, is to add selectable taps on the primary and/or the secondary side of the transformer. Further "tuning" can be done with a variable capacitor across the selected tap of the antenna-side winding of the transformer and the "bottom" of that winding. Ref. 1.

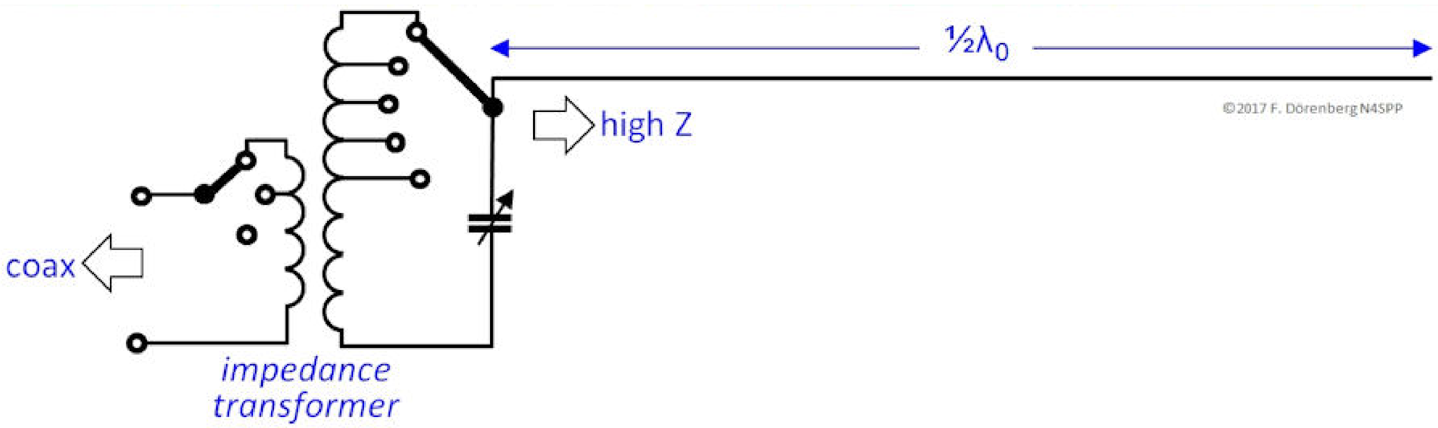


Figure 3: Multi-band "Fuchs" antenna with single tuning capacitor

Figure 4: Configuration with auto-transformer and a tuning trimmer-capacitor

In some implementations, the transformer can be switched between both configurations with a simple switch across the "bottom" of the transformer.

It might seem that an "end-fed" is a monopole antenna: there is no explicit "counterpoise" in most end-fed designs. Obviously the end-fed radiator does need something to "push against" (ref. 12), *just like all antenna radiators*. The need for expanding an End-Fed with such a "counterpoise" wire was already recognized well over a century ago! Example: the famous "Zeppelin" ("Zepp") antenna system. It was patented by Hans Beggerow of Berlin/Germany in 1909 (ref. 10B). The patent states that the purpose of the invention is to move the antenna's high-voltage points away from an airship's balloon, to reduce the risk of igniting the ever-present hydrogen leaks. The surface of the balloon and basket were often used as "counterpoise" for the antenna wire, or used to attach such a "counterpoise" to. So, Beggerow's application was for airships, such as the dirigibles designed and built by Ferdinand Count von Zeppelin. Hence the nickname "Zepp(elin)" antenna.

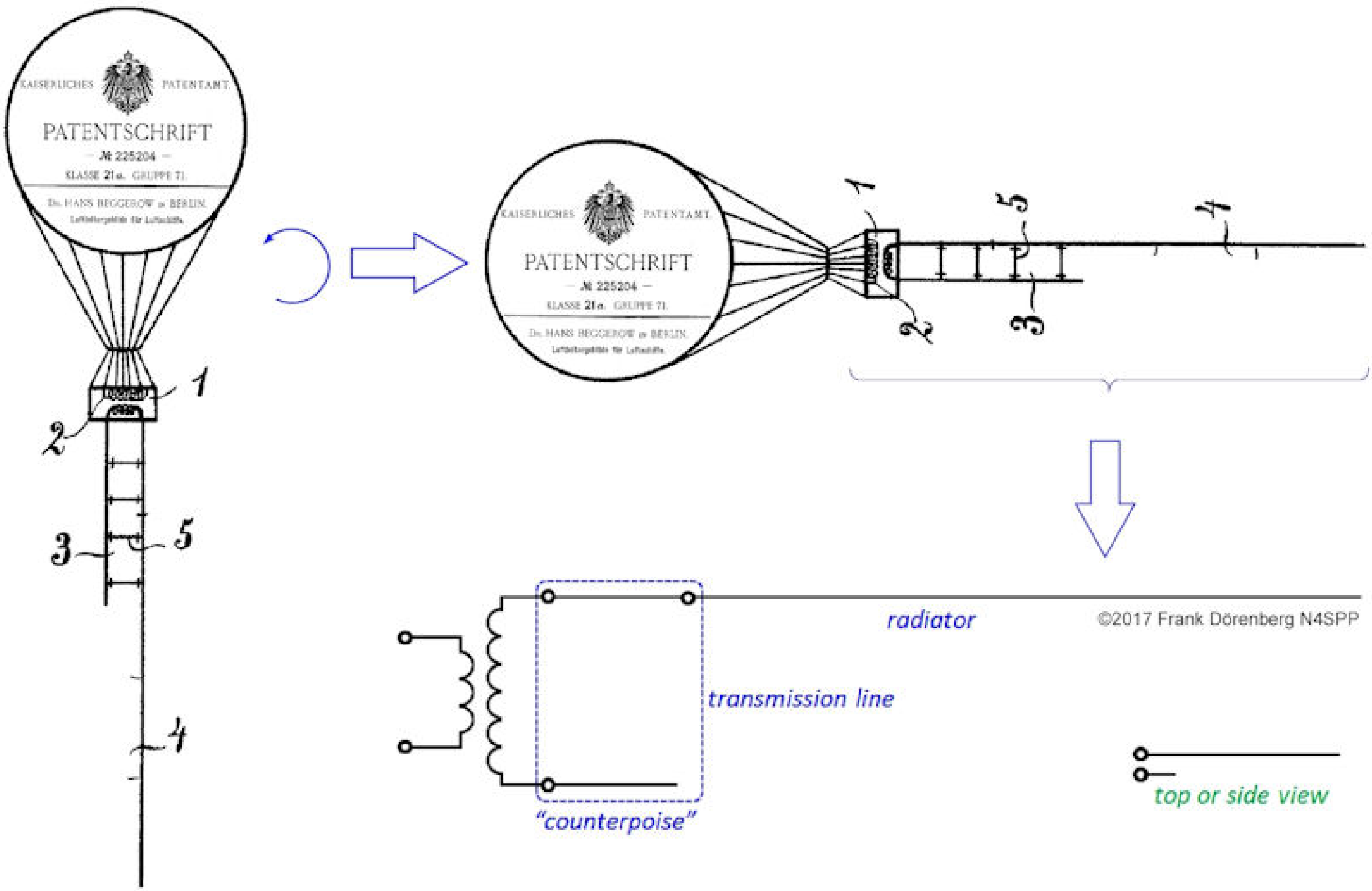


Figure 5: The original "Zeppelin" antenna
(adapted from the 1909 Beggerow patent, ref. 10B)

Beggerow's arrangement comprises a long antenna wire and a parallel-but-shorter "counterpoise" wire. The two parallel wires form a section of balanced transmission line. This is why the patent refers to it to as a "Lecher line", after the Austrian Ernst Lecher who used such an arrangement (with variable length) in the late 1880s to measure signal frequencies. The patent does not mention or suggest any dimensions for the wire lengths and their spacing, nor for the coupling transformer. It also does not suggest a tuning capacitor.

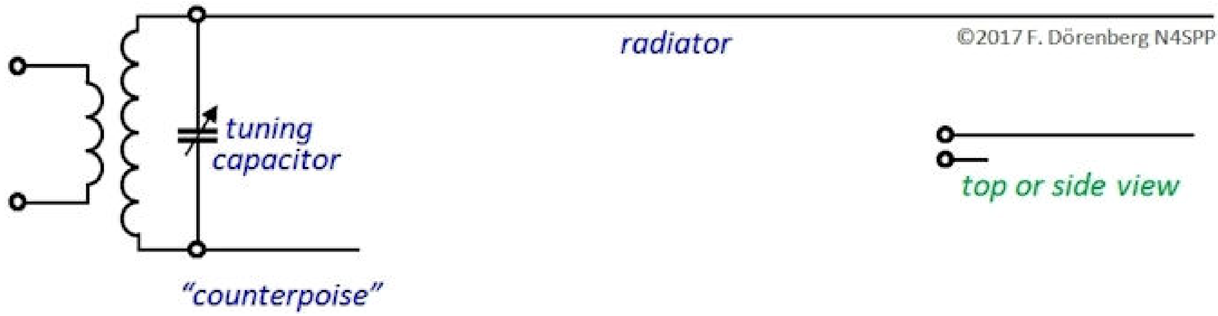


Figure 6: The Zepp antenna with "tuning" capacitor (Fuchs-circuit)

The transmission-line section of the original Zepp can be "sacrificed" by unfolding it, such that the antenna becomes an Off-Center Fed (OCF) doublet.

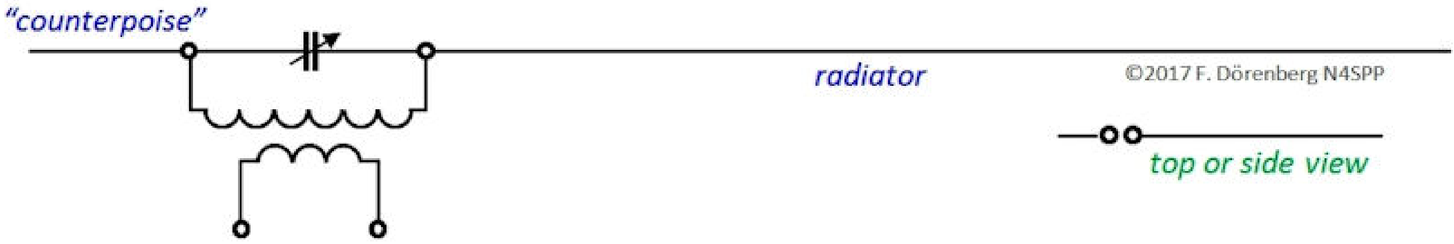


Figure 7: The Zepp antenna with tuning capacitor and unfolded transmission-line section

The first published amateur radio End-Fed appears to be the one by W3EDP from 1936. It is a regular multiband end-fed for 160-80-40-20-10m (there were no WARC bands in those days). The antenna was matched directly to the transmitter (= no feedline) with a parallel-resonant transformer circuit, i.e., a Fuchs-circuit as described in the Introduction section. The antenna wire had a length of 84 ft (25.6 m), and was installed at a height of 20 ft (6 m). A 17 ft (5.2 m) long "counterpoise" wire (6.5 ft for 20m) was connected to the bottom of the antenna-side of the Fuchs circuit's transformer. This wire was installed indoors, along the ceiling of his shack (probably about 7-8 ft off ground level), so it could not be installed in parallel with the antenna wire. An impedance-adjustment capacitor was placed across the antenna-side of the transformer, with unchanged setting on all bands. Ref. 10A.

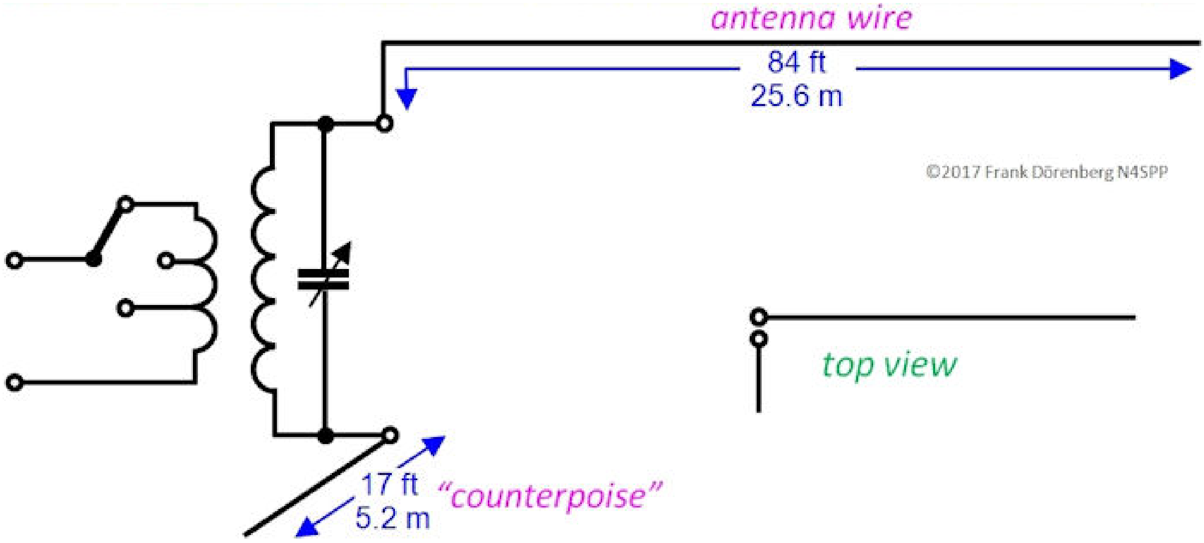


Figure 8: The original W3EDP antenna configuration

In many later versions of the W3EDP, the "counterpoise" wire is installed in parallel with the antenna wire. The original and the later versions of the this antenna can be looked at in several ways (ref. 10C):

- When the antenna and "counterpoise" wires are arranged in parallel, as in the "Zepp", it has a 67 ft long antenna wire (84 - 17 = 67 ft). This antenna wire is fed via a section of parallel-wire transmission line with 1/4 the length of the antenna wire (i.e., 67 / 4 ≈ 17 ft).
- An 84 ft long end-fed antenna wire, with a "counterpoise" wire of 1/5 the length of that antenna wire (i.e., 84 / 5 ≈ 17 ft).
- An Off-Center-Fed (OCF) dipole with total span of 84+17=101 ft, with the feed point at 1/6th of the total span (101 / 6 ≈ 17 ft = 17%) from one end (= 83 / 17 OCF). The dipole can be straight or bent.

The next figure shows a variation on the original W3EDP, by adding a variable *series*-capacitor to the transmitter side of the transformer:

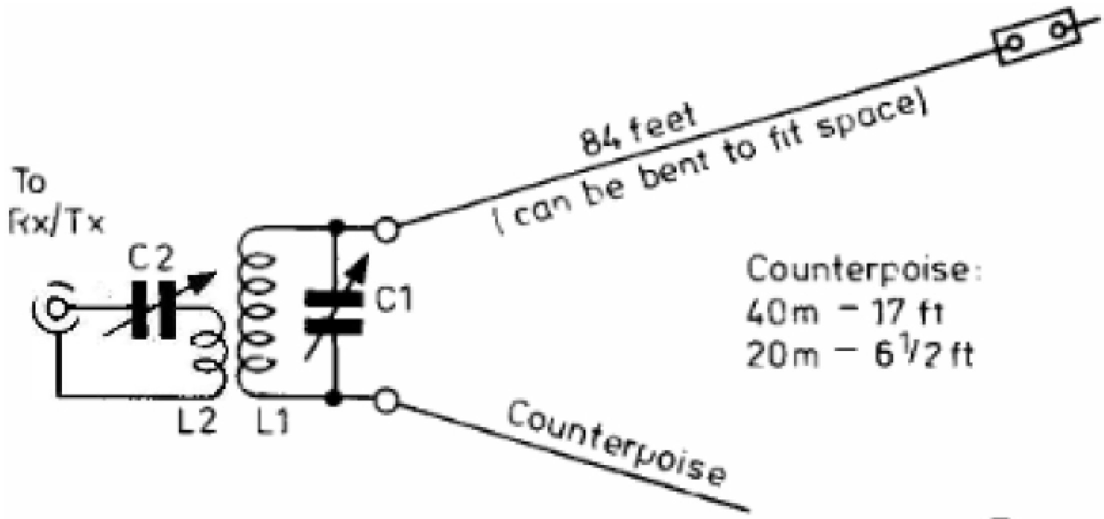


Figure 9: W3EDP antenna with ATU
(source: ref. 10H, 1981)

Many [modern versions of the W3EDP] use the transmission line configuration, with a section of open-wire ladder line or standard 300 or 450 ohm ribbon twin-lead. Note that 300 and 450 ohm twin-lead have a slightly different *velocity factor* VF, so slightly different length must be used. Instead of the Fuchs-circuit transformer, a 4:1 BALUN or 4:1 UNUN is used. The twin-lead is typically installed vertically, and the antenna wire horizontally. Of course, it can be installed completely vertically (as in the original "Zepp" patent, or upside-down), or in an inverted-V configuration, etc.

Shown below are various 80-40-20-10 end-fed configurations - the list is not exhaustive. They all have different characteristics and performance regarding common-mode issues (RFI, RX noise level,...) and current level in the antenna wire (radiated power).

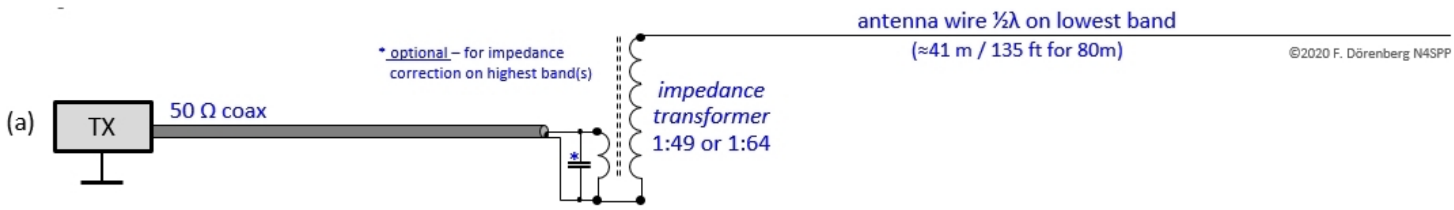


Figure 11: Baseline configuration with auto-transformer

In the baseline configuration above, the radiator will simply use the coax as counterpoise - the coax will have common-mode current on it and **will** radiate! Whether or not this is a problem (RFI, TVI, high receive noise level, etc.) at your specific location/QTH, depends on the the transmitter power level and inevitable coupling to "counterpoise" objects near the antenna and the (radiating) coax, and other sources of common-mode noise. There are three basic approaches for trying to eliminate (or at least sufficiently reduce) the common-mode current from the coax. See the next six configurations (adapted from ref. 14, publication by DC4KU).

The first option considered, is connecting the common point of the auto-transformer to real ground, with a wire and a ground spike. Note that there will now flow some current to ground. There will also stil be common-mode current on the coax. So, both the ground wire and the coax will radiate, and both may pick up electrical noise from all sorts of sources. The grounding point may also be connected to your "station ground" - directly or indirectly. This creates an undesirable ground loop.

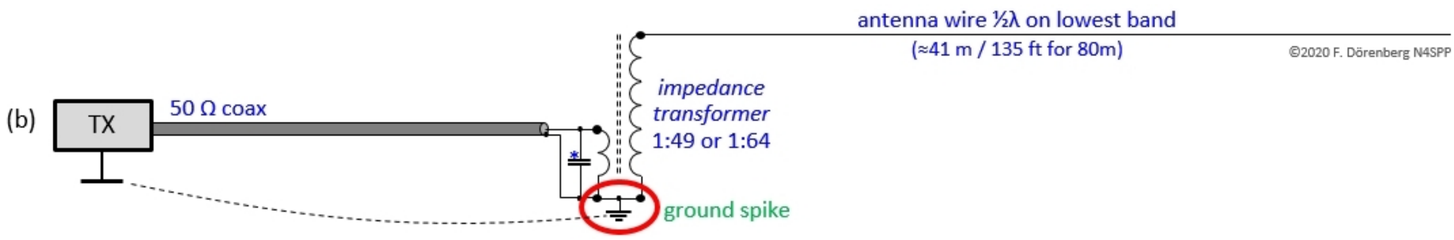


Figure 12: Baseline configuration with grounded transformer

We can also give the antenna radiator something to push against, by attaching a counterpoise wire to the common point of the auto-transformer. See figure 13 below. That wire does not have to be similar in length to the main radiator wire. A short wire is all that is needed: about 0.05 λ, that is ≈ 4.2 m or ≈14 ft for an 80 m (or 80-40-20-10) end-fed. See ref. 5, 13, 14. Some current will now flow into the counterpoise wire, and reduce the common-mode current on the coax. The counterpoise wire will radiate, which is OK.

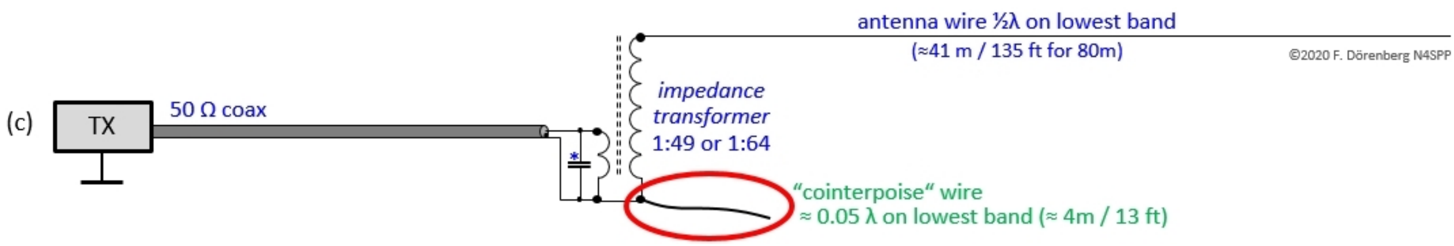


Figure 13: Baseline configuration with counterpoise wire at the transformer

To block the remaining common-mode current on the coax, we can add a common-mode choke (= 1:1 current balun) directly at the transmitter side of the transformer. See figure 14 below. However, this is not a high-current point of the antenna system. So, the choke will not be as effective as it could be...

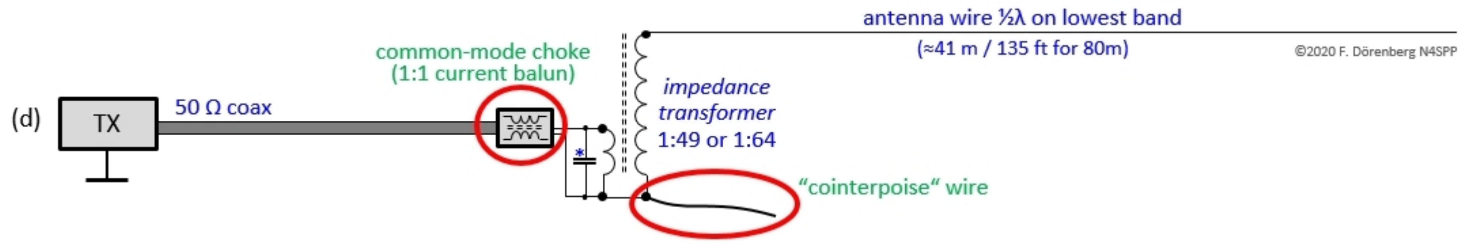


Figure 14: Baseline configuration with counterpoise wire and common-mode choke at the transformer

To make the choke balun more effective, all we have to do, is insert it at a point along the coax that is about 0.05 λ away from the transformer (the same as the length of the counterpoise wire in fig. 13). See figure 15 below - again, ≈ 4.2 m or ≈14 ft for an 80 m end-fed. Ref. 2A, 3, 14. Yes, the coax will radiate, but only the part of the coax between the transformer and the choke balun. It is part of the antenna! Effectively, the configurations of Fig. 14 and 15 are very similar.

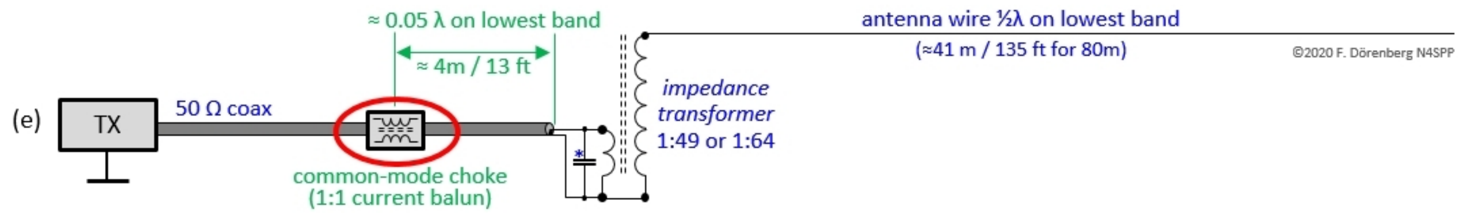


Figure 15: Baseline configuration with common-mode choke at some distance from the transformer

An other option for blocking common-mode current on the coax, is to not use an auto-transformer, but a "regular" transformer that provides galvanic isolation between the primary and secondary side. See figure 16. Fine. But without an explicit counterpoise, the radiator wire now has to push against something else in the area, for the antenna to be able to work well. Or not work at all, depending on what it can push against near the antenna (incl. stray/parasitic capacitance to the environment or between the antenna side of the transromer and the feedline).

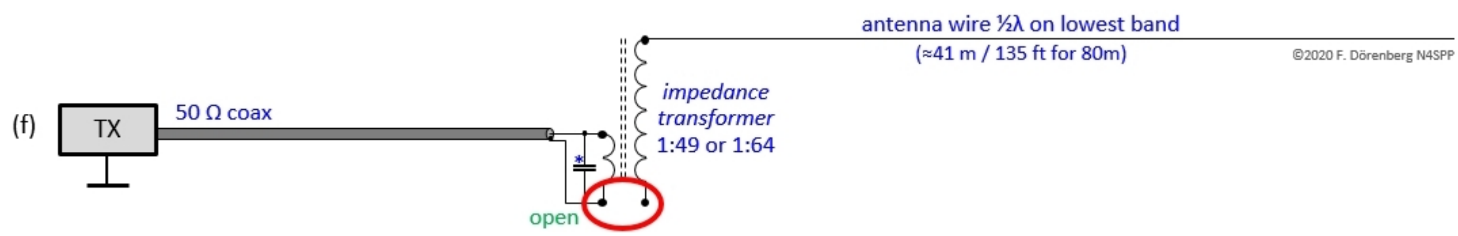


Figure 16: Baseline configuration with galvanically isolated transformer sides

The obvious solution for that, is adding a counterpoise wire, as discussed above:

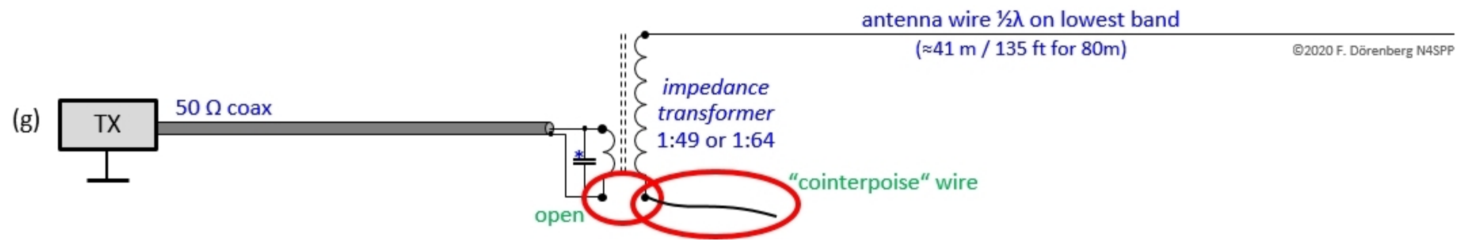


Figure 17: Baseline configuration with open transformer and counterpoise wire

You may want to bridge the bottom of the transformer with a 1 MΩ resistor, to bleed off static charges.

Whereas any of the above configurations may "work" at <u>your</u> particular location, the configurations in Fig. 14, 15, and 17 should result in the lowest common-mode current on the coax, and also the lowest receive noise level (especially the configurations in Fig. 14 & 15).

Not all of us have room to hang a full size end-fed (at least not in a straight line). However, a half-size version may be possible (as discussed further down on this page):

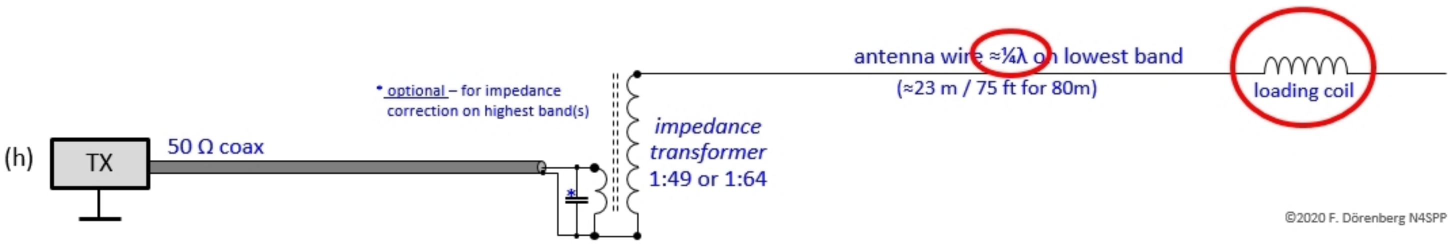


Figure 18: Half-size baseline configuration

There are several commercial suppliers of end-fed antennas (e.g., ref. 1, 2A/B/C/D). But the design is simple enough for home-building at a (much) lower cost (though the QRP end-fed transformer of ref. 2D is quite reasonable).

NOTE: for radiation patterns of an EFHW antenna on its fundamental resonance and harmonic frequencies (incl. 4NEC2 simulation model files), see ref. 12. Note that for an "*n* x half-wavelength" radiator, the radiation pattern will have (many) more lobes (and, hence, null) directions than a "one half-wavelength" radiator". I.e., with an 80-40-20-10 end-fed, the four bands will have significantly different radiation patterns!

NOTE: I have not completed measuring, tuning, and experimenting/playing with this type of antenna yet. So the discussion below is basically my current lab notes, and I cannot make any final conclusions yet. Also, at my location, I cannot install the antenna high enough (nor far away enough from the building), to get a low radiation angle for DX. **To be continued...**

NOTE: obviously, end-feds are not limited to HF frequencies. They can, e.g., be used to improve performance of VHF handheld transceivers, compared to using the "rubber ducky" antenna that is typically provided with such handhelds. Ref. 11.

COMMON 40-10 MTR OR HALF-SIZE 80-10 CONFIGURATION

> **NOTE**: I wrote the description below, before I added the discussion around Fig. 11-18 above. E.g., I did not use (or experiment with) a common mode choke (1:1 current balun) on the coax at the required distance from the transformer, nor a "counter poise" wire at the transformer.

I still need a **reduced-size** antenna for 80 mtrs that works acceptably well at my QTH. Scanning the "market" I came across advertizing, blogs, and forum threads about a half-size 80-10 multi-band end-fed (i.e., about 1/4 λ long on the lowest band). Based on its feedpoint location, an "end-fed" is easer to install at my QTH than a center-fed dipole (I can barely fit a 2x7 m dipole).

The basic antenna comprises:

- a wire that is about 1/4 wavelength on the lowest band,
- a loading coil,
- an extension wire beyond the coil,
- an impedance transformer, and
- a capacitor across the secondary side of the transformer.

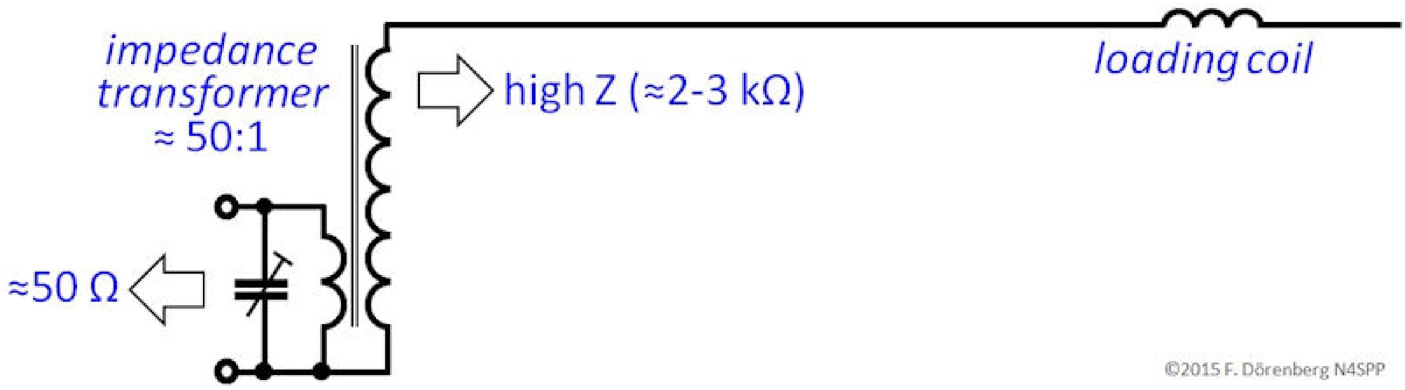
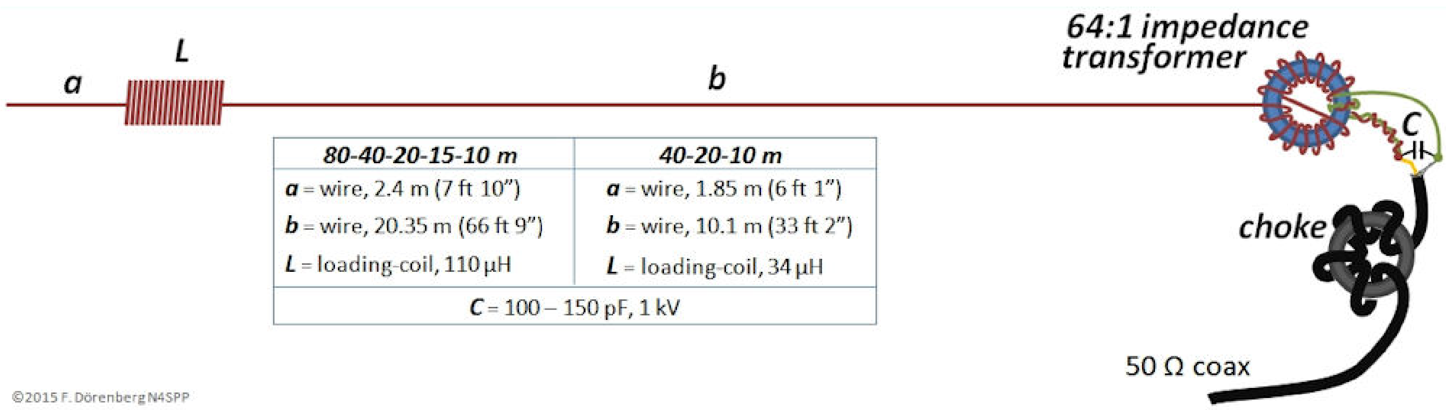


Figure 19: Principle circuit diagram

Nominal dimensions and component values for 80-10 and 40-10 end-feds are given below (also see ref. 7 for a discussion on lengths). I used multi-strand AWG #14 THNN wire (1.6 mm Ø) from the DYI store for the antenna, and AWG #20 (0.8 mm Ø) enameled copper wire for the transformer and the coil.



80-40-20-15-10 m	40-20-10 m
a = wire, 2.4 m (7 ft 10")	*a* = wire, 1.85 m (6 ft 1")
b = wire, 20.35 m (66 ft 9")	*b* = wire, 10.1 m (33 ft 2")
L = loading-coil, 110 μH	*L* = loading-coil, 34 μH
C = 100 – 150 pF, 1 kV	

Figure 20: Nominal dimensions of the multi-band end-fed antenna

The antenna generally has a high impedance (several thousand ohm) on most bands. So an *impedance* transformation ratio of about 1:50 to 1:60 is needed to get down to 50 Ω. I.e., a *turns* ratio of about 1:7 to 1:8.

Note that the feedpoint impedance depends on the ratio of length and diameter of the antenna wire! So, the transformer ratio that you actually need, depends on that wire-ratio, as well as on installation height, and the local environment.

Commercially-built multi-band end-feds (e.g., ref. 2A/B) use toroidal ferrite cores, such as the FT140-43 and FT240-43. These cores have an outside diameter of 1.40 and 2.40 inch respectively, and are made of material type nr. "43" (a nickel-zinc mix). However, the smaller one (FT140) has a slightly lower A_L value (inductance in μH per 1000 turns) than the larger one: 885 vs. 1075. Other companies use a toroidal iron-powder core (e.g., a T80-2 in ref. 1 (for QRP), and a T130-2 in ref. 2C).

Clearly, such transformers are not truly wide-band, covering 3.5 - 30 MHz (80-10 mtrs). If one prefers the lower bands (80/40), then a ferrite transformer with *N* = 3 on an FT**2**40-43 core (larger A_L value) would probably be best. Conversely, *N* = 2 on an FT**1**40-43 core, would be more suitable when concentrating on the higher bands (40-10 mtr). With this smaller core, 50-60 watt continuous should be OK. The larger core should be OK for at least twice that.

- Wind the transformer with enameled copper wire ("CuL", "magnetic wire") with a diameter of 0.8 - 1 mm (AWG # 18 - 20).
    - Note that when winding the transformer, each time you pass the wire through the core (i.e., including the first time**!**), counts as one turn. See the numbers in the photo below.

  The wire of the secondary winding is twisted onto the first turns of the primary winding, to get tighter coupling. The split-winding of the primary side (transition turn nr. 8 in the photo below) is supposed to reduce parasitic capacitance.
  - Enameled wire is never perfectly coated with enamel, and the enamel does not provide high voltage insulation. Consider using teflon coated wire.
- Note that iron powder cores such as the T-200-2 have an A_L that is 10-20% bigger than that of the above ferrite cores: 120 µH / 100 turns (be careful: A_L of iron powder cores is specified as inductance per *100* turns, but for ferrite cores it is inductance per *1000* turns!). However, the *permeability* of the ferrite core is about 80x larger than that of the iron powder core! Stick with the ferrite cores for this application.

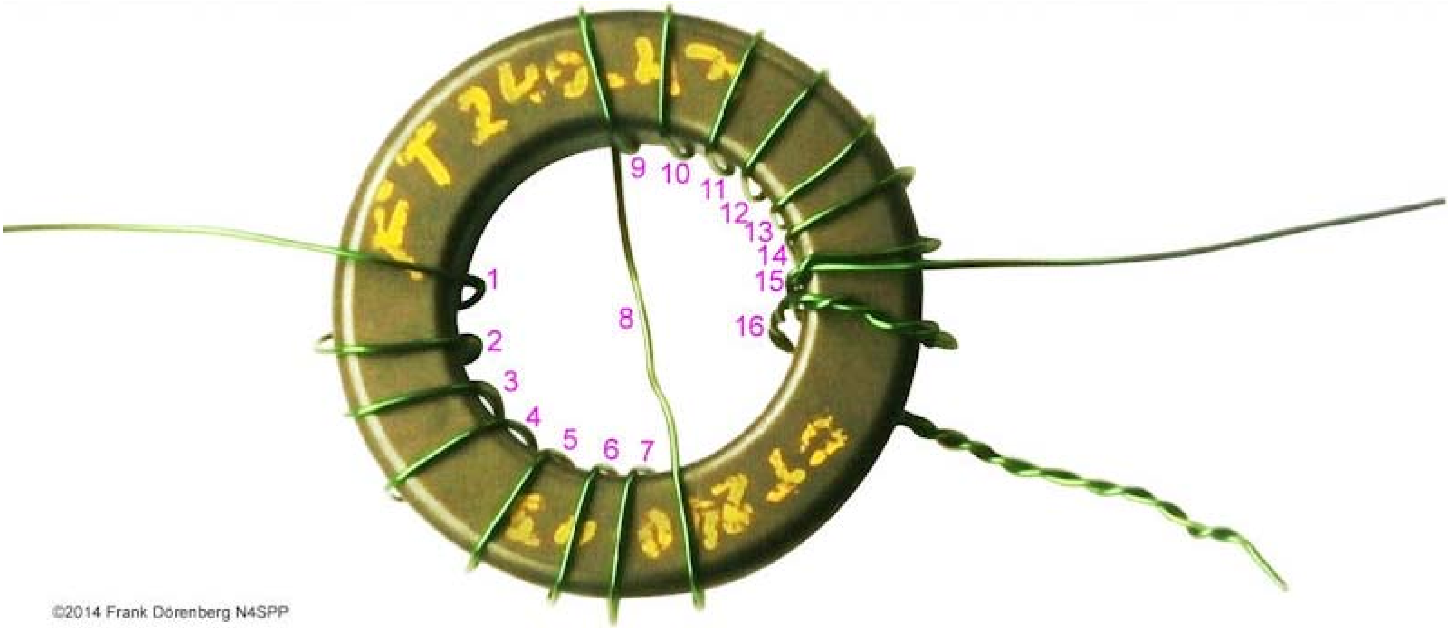


Figure 21: Impedance transformer with 2 primary (= transmitter side) turns and 16 secondary turns

(the 2-turn primary winding is bifilar-twisted with the first 2 secondary turns)

Figure 22: Components of the auto-transformer (ferrite core is an FT240-43)

Figure 23: The transformer fits nicely in a standard-size electrical junction box

A ceramic capacitor of 100-150 pF is placed across the primary (= transmitter) side of the transformer. Its purpose is to counteract the relatively high inductance of the transformer on the 15-10 mtr bands. The capacitor should have a rating of 500-1000 volt. A ceramic trimmer capacitor instead of a fixed capacitor makes adjusting for the highest band(s) easier.

The overall length of the 80-10 version of this antenna is about 23 mtrs (≈75 ft) - only about 1/4 λ on 80 mtrs. So a loading coil is added. The length of the wire *beyond* the coil has to be adjusted for the desired portion of the 80 mtr band (or of the 40 mtr band, if making the 40-10 antenna) and the local environment.

The nominal inductance of the loading coil is 110 μH for the 80-10 antenna, and 34 μH for the 40-10 version, see ref. 4. The 110 μH coil can be made with 260 turns of 1 mm Ø enameled copper wire (AWG #18) on a PVC core with a diameter of 19-20 mm (3/4 inch). Takes about 15.5 mtrs (50 ft) of that wire. Tightly wound, the core needs to be about 30-35 cm long, to allow for attaching strain-reliefs. As a sanity check and out of curiosity, I estimated the self-inductance of such a coil with on-line and other coil calculators (ref. 5A/B/C). The calculated inductance varied from 77 μH and 81 μH (with 0.112 mm (5 mils) turn-spacing and lump-sum equivalent calculation), 85 μH (zero turn-spacing, lumped-sum equivalent), 90 μH at 3.6 MHz, 119 μH at 7.5 MHz (effective series-resonance model). Actual inductance is indeed frequency dependent. The 34 μH requires only 90 turns.

Shrink tubing can be used for weatherizing (note that this changes the inductance slightly). For such a small diameter coil, the shrink tube opening on the highest side of the coil can be made watertight by stuffing it with hot-melt glue just before applying heat to the shrink tubing.

As I have a roll of AGW # 20 CuL (0.8 mm Ø), that's what I used. I wound my coil on a section of 50 mm Ø (2") PVC. Wire length is about 9.5 mtrs (31 ft). With 60 turns, coil height is 58.5 mm (2.3"). This suggests that my personal tight winding style results in a non-zero turn-spacing of 0.11 mm. I based the required number of turns on the same calculators mentioned above.

Figure 24: My 110 μH loading coil

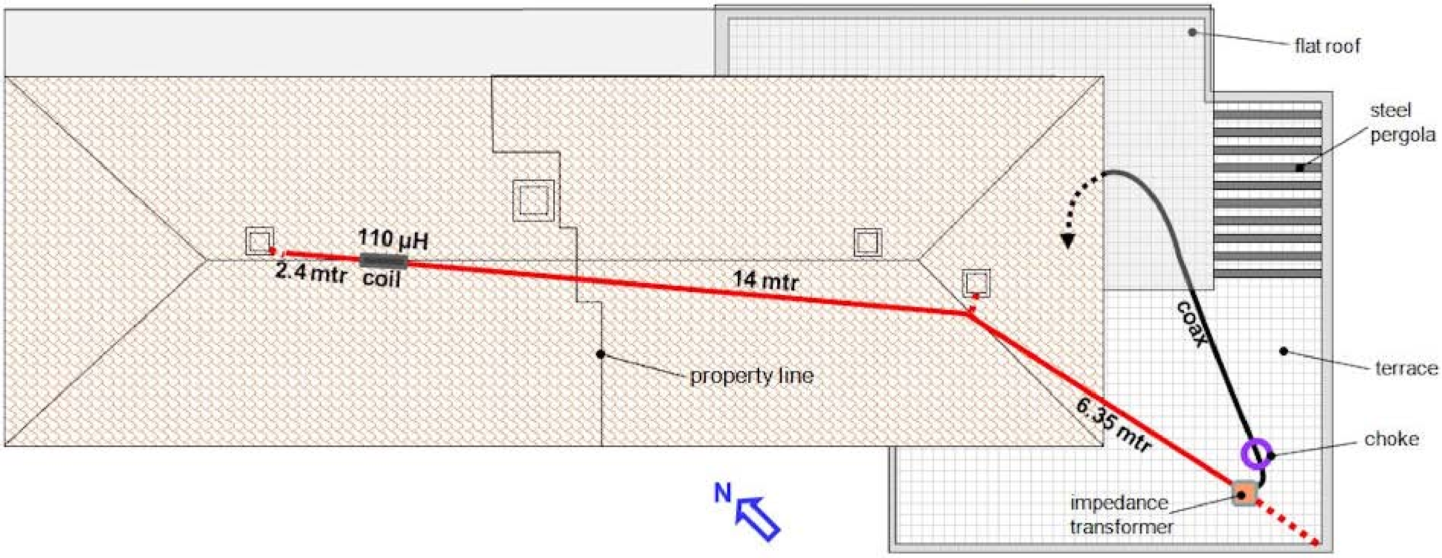


Figure 25: Top view of the installation at my apartment, just above the roof

One can "cut off" a piece of wire, but not "cut on" a piece. As stated above, the length of the wires has to be adjusted. So it is best to start out with wires that are definitely too long, e.g., by 1 mtr (3 ft). Just fold back the excess and attach it onto itself. See photo below. Standard approach for tuning-and-pruning the antenna is to start with the band where the antenna acts as a 1/2-wave end-fed (40 mtrs for the 80-10 antenna, 20 mtrs for the 40-10 version), rather than for the lowest band. Ref. 4. Measure the SWR in the portion of the 40 mtr band that is of interest. Without an antenna analyzer, this is doable but definitely not easy.... If the frequency of the SWR dip is above that band portion, then reduce the long wire by 5 cm (2") and repeat the measurement. Conversely, slightly increase the length of the extension wire if the dip is below the band portion of choice. Repeat until the minimum SWR is achieved. Then follow the same procedure for adjusting the length of the extension wire for minimum SWR on the portion of the 80 mtr band that is of (most) interest. Finally, adjust the capacitor across the coax for minimum SWR in the10 mtr band.

Figure 26: End of the extension wire attached with a bungee cord, excess wire is folded back

The SWR plot below shows an SWR sweep with my miniVNA antenna analyzer, directly at the transformer. Note that I did not have a capacitor installed across the coax at the transformer! This probably explains the rising SWR at the higher frequencies. Or: my transformer is not nearly as broadband as it should be? I have seen some SWR plots and reports of this type of antenna from other builders/users - low SWR on all bands. Whatever the transformer, there should still be multiple resonance peaks as in my plot.

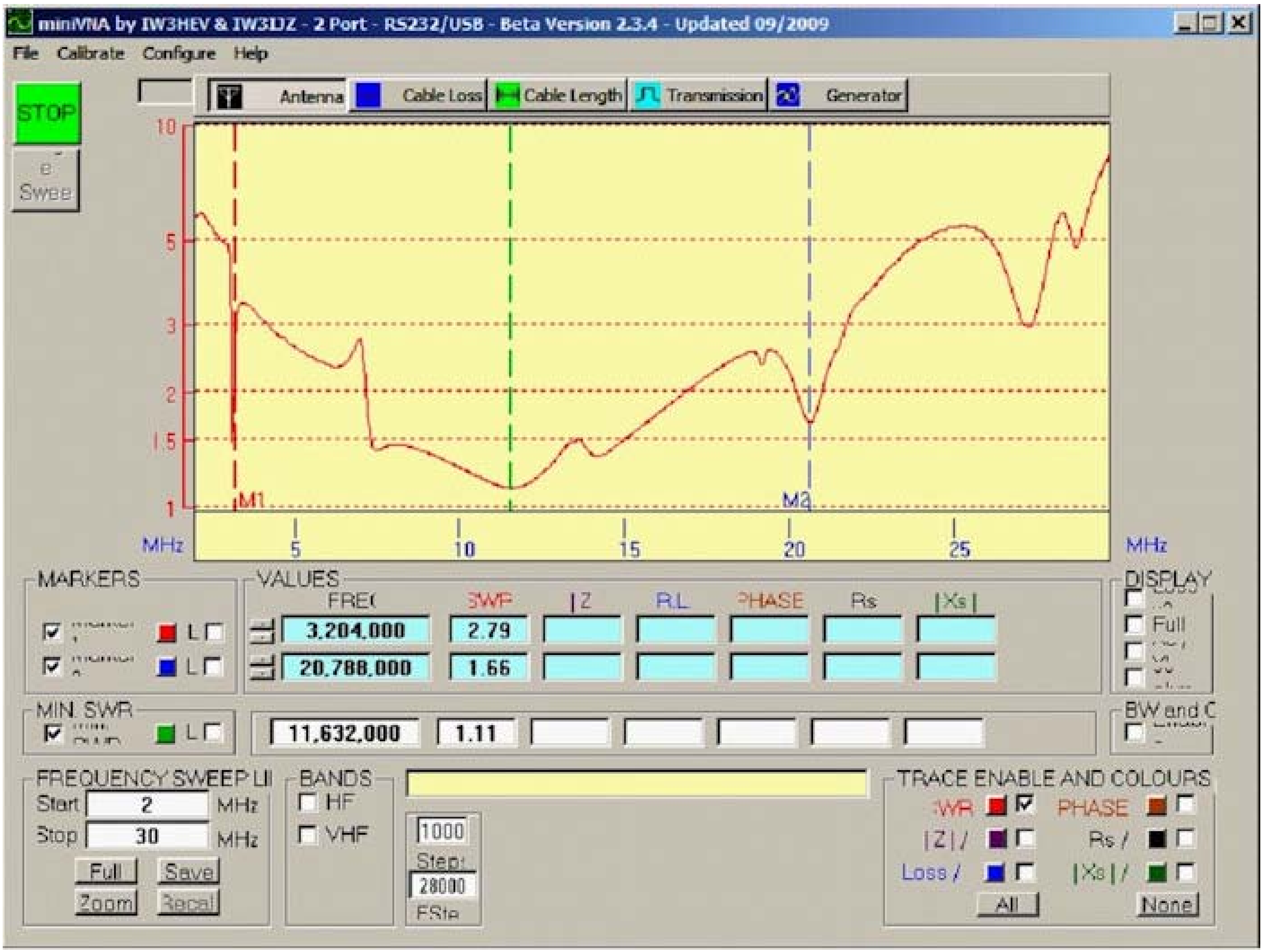


Figure 27: 2-30 MHz SWR sweep with 64:1 transformer and 60-turn loading coil
(no shunt capacitor across the coax)

At some point during my experiments (for some reason that I can no longer remember), I decided to reduce the number of turns of the coil from 60 to 53. The resulting SWR plot for the 80 mtr band is shown below:

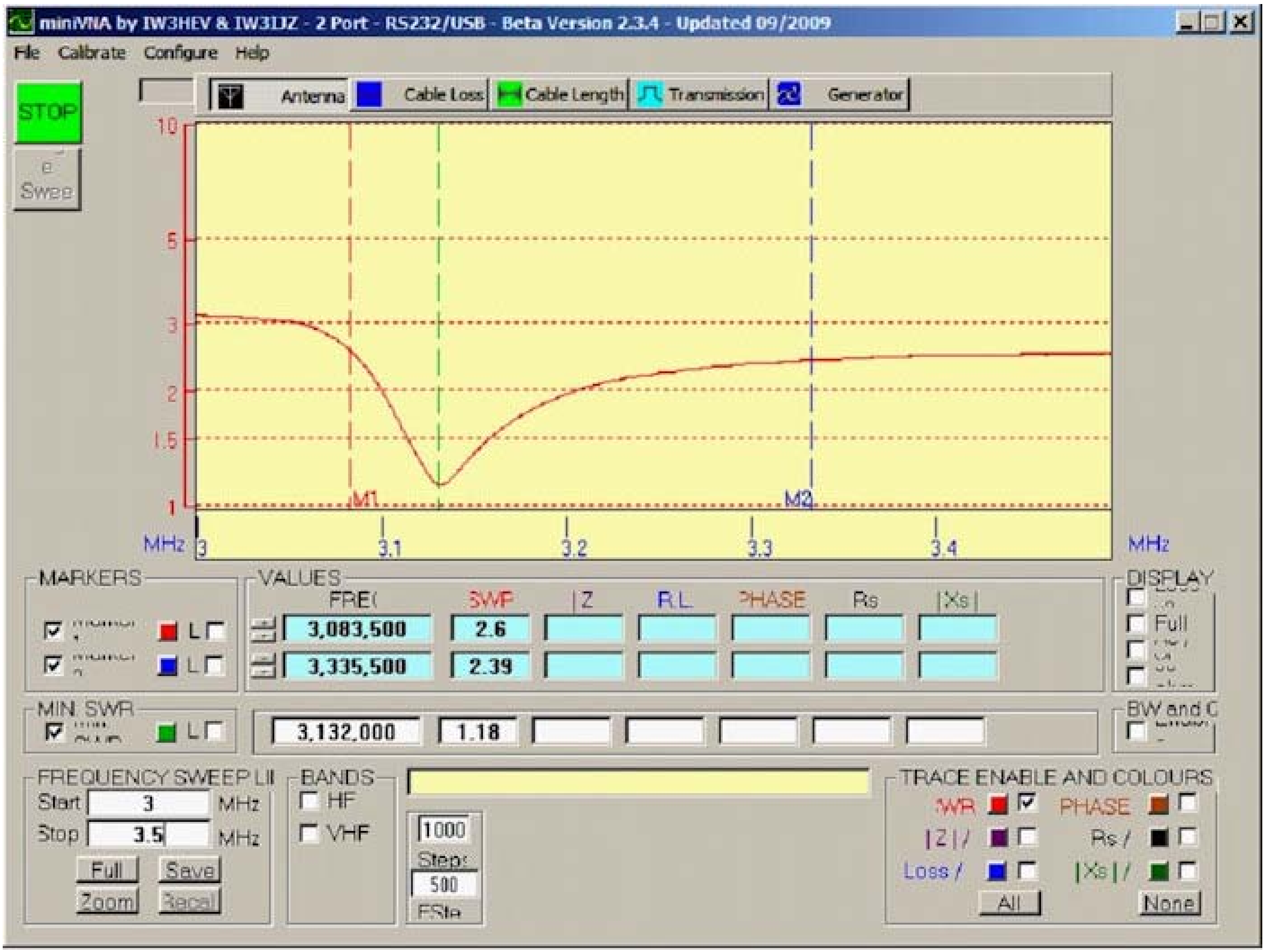


Figure 28: 3-3.5 MHz SWR sweep with 64-1 transformer and 53-turn loading coil

Some operators use a 4:1 BALUN, others a 4:1 UNUN, some in combination with a 1:1 current choke, some without. I have done some measurements with a 4:1 BALUN and a 4:1 UNUN.

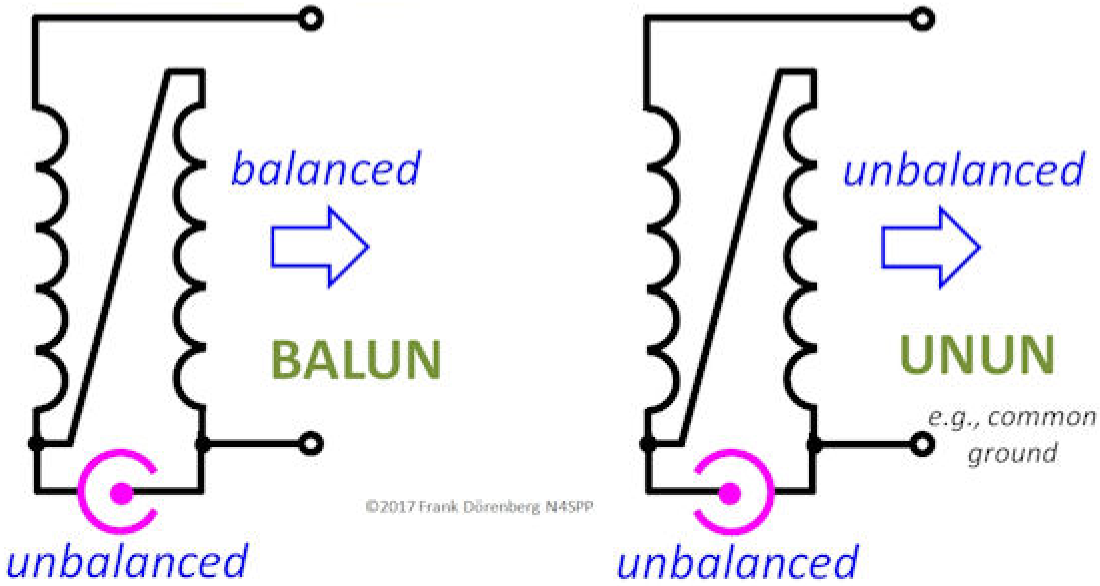


Figure 29: 4:1 BALUN and UNUN wiring diagram
(note: the only difference is the inverted coax connection!)

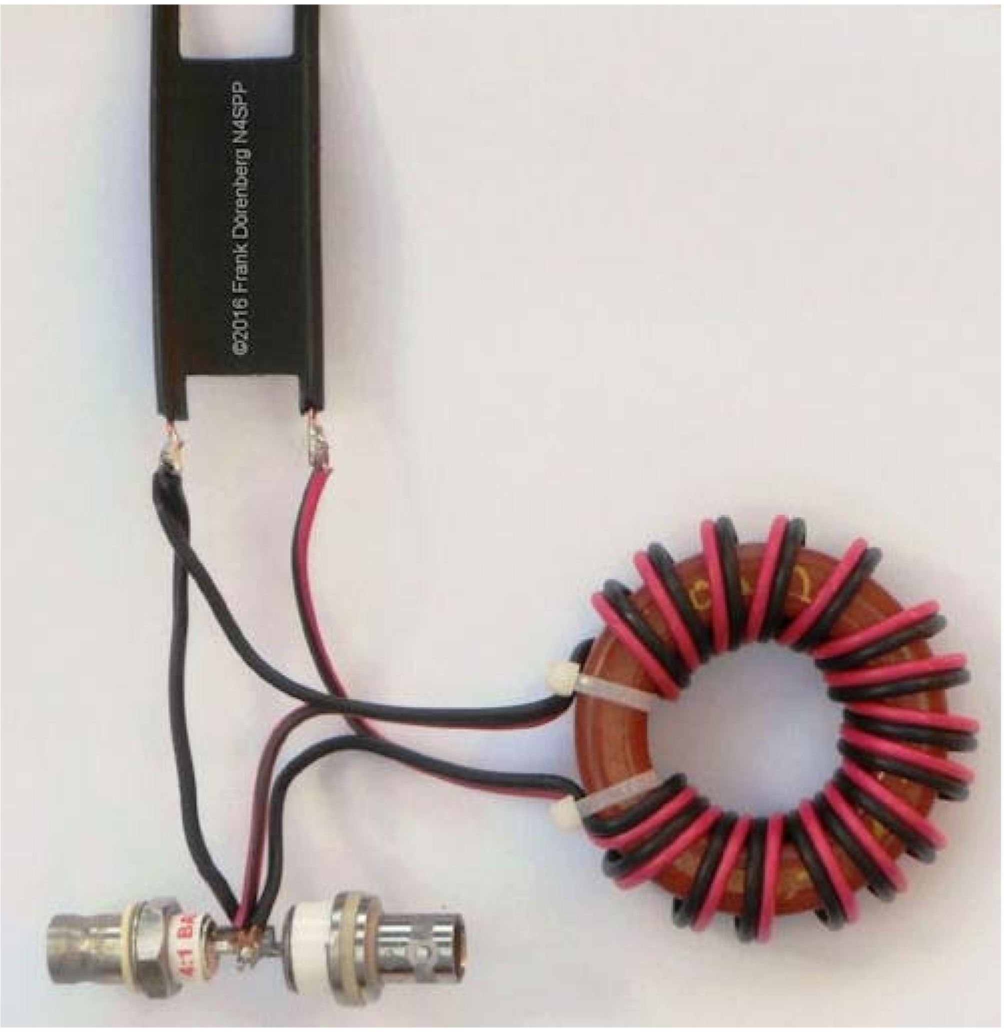


Figure 30: The experimental 4:1 BALUN/UNUN of my W3EDP antenna

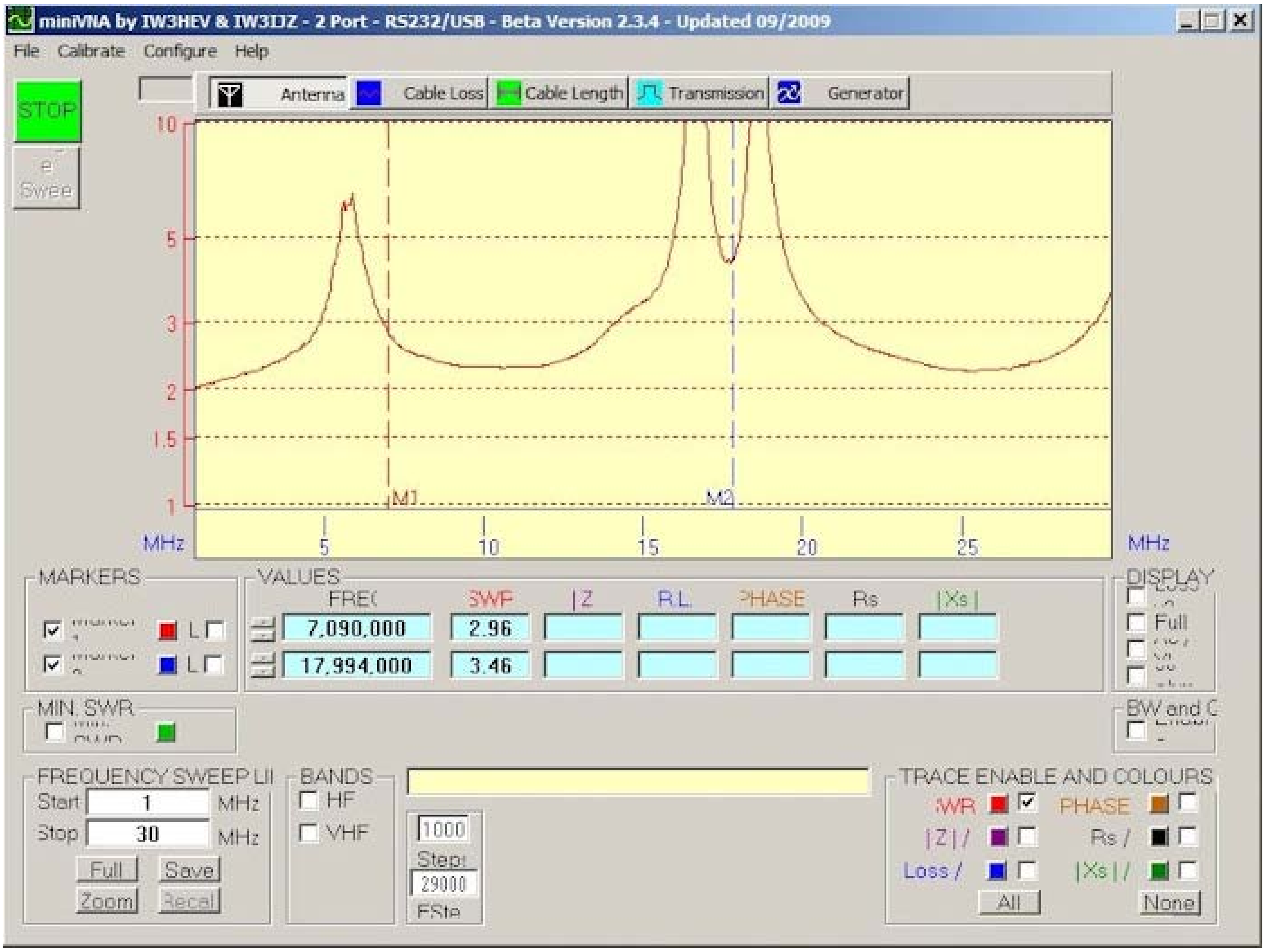


Figure 31: SWR sweep at my QTH of the W3EDP antenna with a 4:1 BALUN
(antenna analyzer directly at the BALUN; no 1:1 current choke between BALUN and coax)

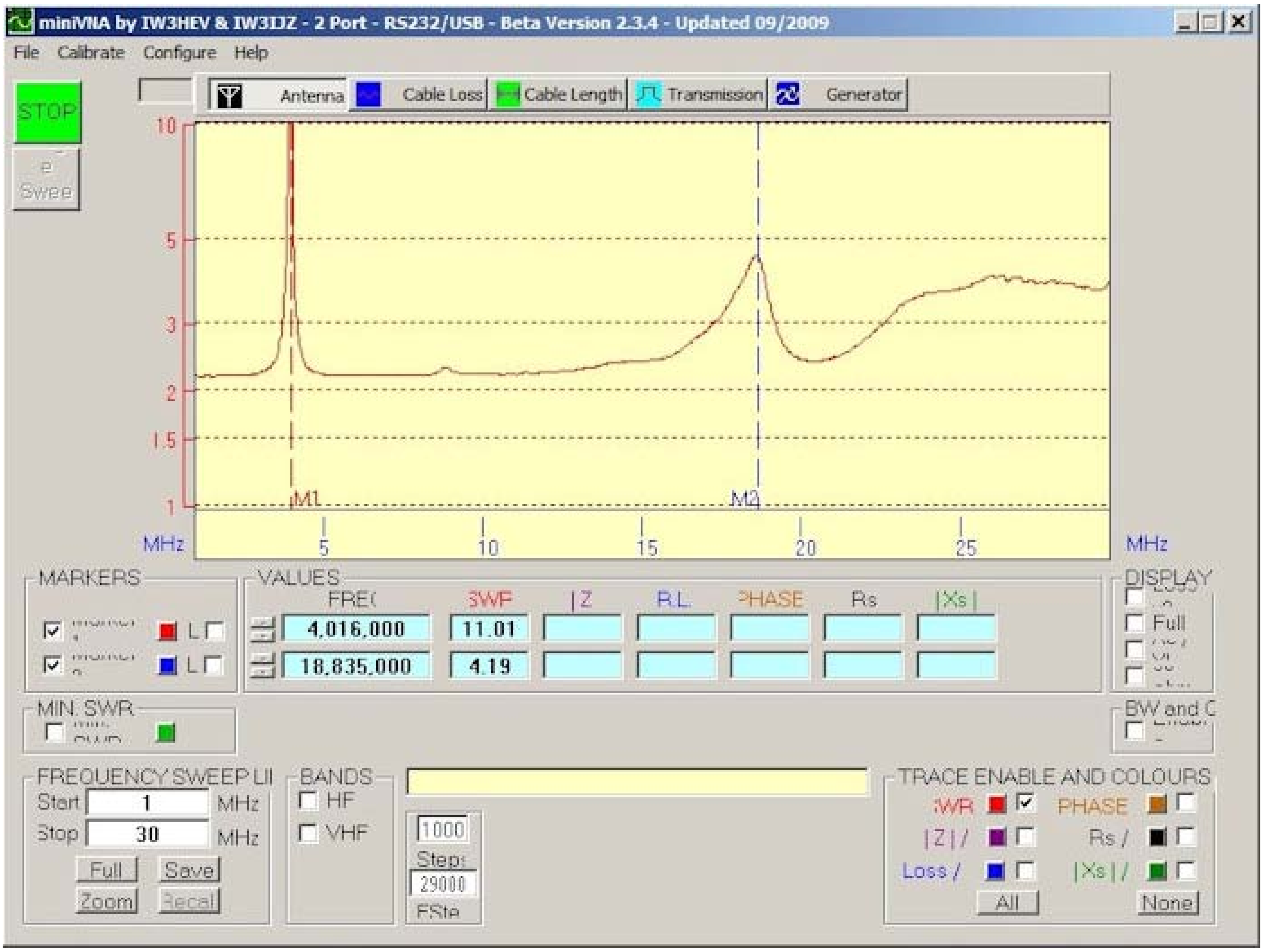


Figure 32: SWR sweep at my QTH of the W3EDP antenna with a 4:1 UNUN
(antenna analyzer directly at the BALUN; no 1:1 current choke between BALUN and coax)

Figure 33: My W3EDP antenna is very portable

6-40 MTR CONFIGURATION BY EARCHI

Ca. 2011, the Emergency Amateur Radio Club of Hawaii (EARCHI) marketed a matchbox-kit for a 6-40 mtr multi-band end-fed antenna. See ref. 9A, which includes the parts list and building instructions.

Configuration and operation (per ref. 9A):

- Recommended antenna wire length: 24-30 ft (60 ft max), e.g., 18 AWG. Length to be adjusted for best SWR and based on desire to operate on frequencies below the 40 m band. Longer wire will result in a radiation pattern with very many side-lobes in the higher frequency bands.
- Impedance transformer: UNUN (unbalanced-to-unbalanced) transformer with a 9:1 impedance transformation ratio
    - The transformer has 3x9 turns. This results in a 27:9 = 3:1 voltage ratio. Hence, a 9:1 impedance ratio. For low SWR, the antenna impedance would have to be close to 9x50=450 ohm. Therefore, the antenna wire length (accounting for its velocity factor) should not be close to ½λ on any operating frequency, otherwise the antenna impedance will be several kohm. E.g., 2.7 kohm / 9 = 300 ohm or SWR=6.
    - The transformer is trifilar (= "3 wires") wound on an iron-powder toroid of type T130-2 (1.3 inch outside diameter, material type "2"), limiting transmitter power to 100 W at best.
    - The manual says "...the transformer will match the high input impedance of the end fed antenna into the range where most antenna tuners can produce good performance...."
    - No tuning or compensation capacitors.
- Recommended coax length: at least 16 feet; no current choke balun. Also see ref. 9B.
- Counterpoise: not required (hence, there is a recommended coax length), but the matchbox has a hookup lug for a counterpoise wire.

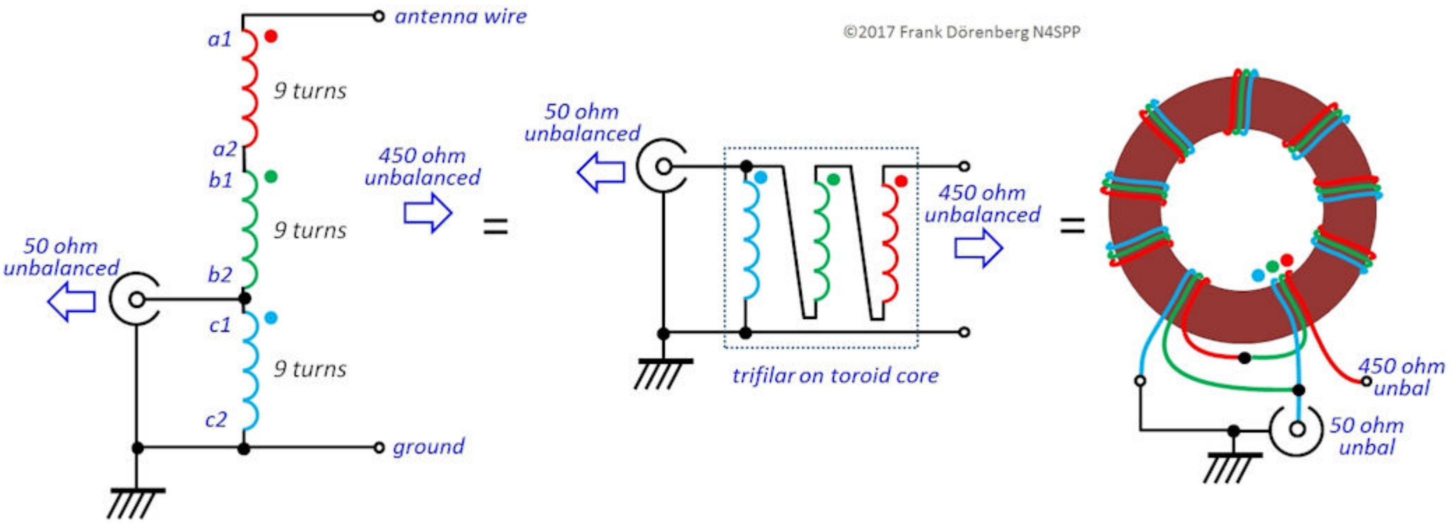


Figure 34: 9:1 UNUN

Check ref. 9A for parts list and building instructions. I made the UNUN using wires with different colors, to make it easier to connecting them correctly. Note: sometimes the color of the enameled wire indicates which temperature is required for removing the enamel with a soldering iron. Note: enameled wires do not have a very high breakdown voltage, and the enamel insulation coating may not cover the fulll 100% of the wire surface. It may be necessary to use PFTE/teflon insulated wires.

Figure 35: My trifilarly wound transformer on a T130-2 core, ready for installation

Figure 36: My transformer, mounted in a small project box
(the black project-box measures 5x5x2 cm = 2x2x3/4 inch)

VARIATIONS ON THE W3EDP

Below are some more variations on the good old W3EDP "Zepp".

José Campione (VA3PCJ) has built and assed several versions of the modern W3EDP. He used 300 ohm twin-lead and a 4:1 UNUN, with a 1:1 current choke between the UNUN and the coax to the tuner and transceiver:

- The full-size "flimsy" (ref. 10C) for the 10-80 m bands, or even 6-160 m: 17 ft (5.2 m) of twin-lead and 68 ft (20.7 m) of antenna wire (i.e., standard dimensions).
- The half-size "junior" (ref. 10D) for the 6-80 m bands: 8.5 ft (2.6 m) of twin-lead and 33.5 ft (10.2 m) of thin antenna wire. Vertically, this fits nicely on a standard 43 ft mast or pole.

- The quarter-size "mini" (ref. 10E) for the 10-20 m bands: 3.5 ft (1.1 m) of twin-lead and 16.75 ft (5.1 m) of thin antenna wire.

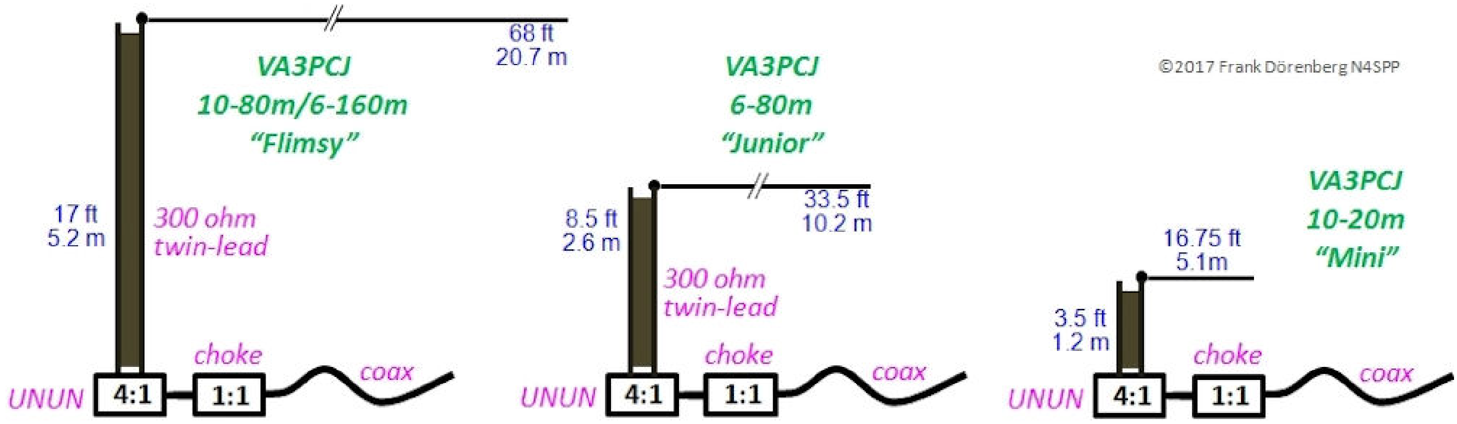
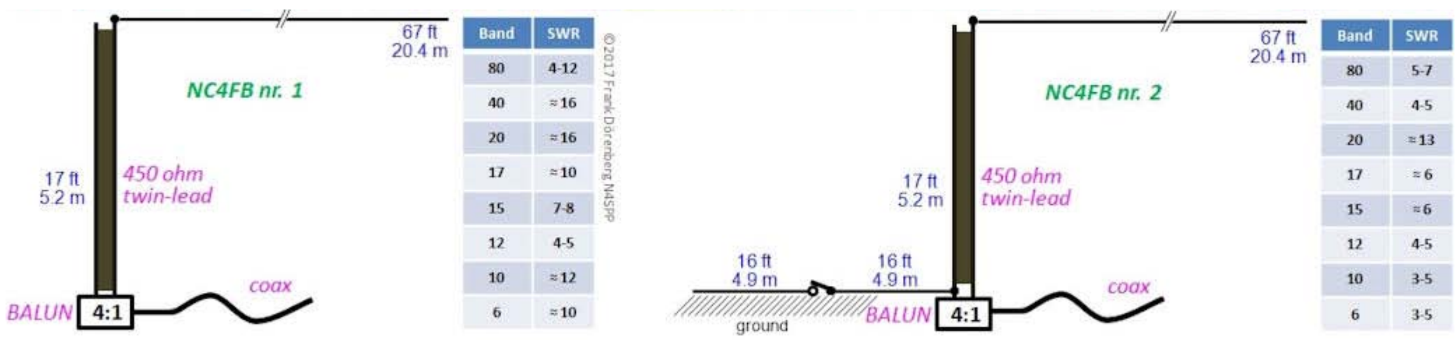


Figure 237: Versions of the W3EDP antenna by José Campione (VA3PCJ)

Frederic Benson (NC4FB) has done extensive experiments with four versions of the W3EDP (ref. 10F). He used 450 ohm twin-lead and a 4:1 voltage BALUN (though he recommends a current BALUN). For most configurations, a tuner with wide-range impedance matching capability is required.

- The full-size for the 6-80 m bands: 17 ft (5.2 m) of twin-lead and 67 ft (20.4 m) of antenna wire (i.e., standard dimensions). The antenna wire slopes upward from 20 to 25 ft above ground.
- Same, but with an additional "counterpoise" wire that is connected to the high-impedance side of the BALUN (on the side that is not connected to the antenna wire). The wire is 32 ft (9.8 m) long for the 80-40m bands. It has a switch half way, to reduce the length of the wire to 16 ft (4.9 m). The wire is simply laid on the ground, pointing away from the direction of the antenna wire.
- No transmission line. The antenna wire is in an inverted-L configuration of 17+67=84 ft (25.6 m). There are two selectable "counterpoise" wires, connected to the BALUN. The wires are strung in parallel, spaced 2 inch (5 cm), and about 3 ft (1 m) off the ground. I.e., a zig-zag OCF dipole. The wire is 14 AWG THHN insulated stranded copper wire from the DIY store.
- Same, but instead of separate "counterpoise" wires, a steel roll-up tape-measure is used (33 ft x 1 inch = 10 m x 2.5 cm). The length of the tape is adjusted to optimize SWR for each band. Solely based on SWR, this has the best results. In order of decreasing length of the "counterpoise" wire: 40 m band (33 ft = 10 m), 20 m (19.5 ft = 6 m), 80 m & 6 m (13 ft = 4 m), 17 m (12 ft = 3.7 m), 15 m (9 ft = 2.8 m), 12 m (6.5 ft = 2 m), 10 m (5 ft = 1.5 m).



NC4FB nr. 1:

Band	SWR
80	4-12
40	≈16
20	≈16
17	≈10
15	7-8
12	4-5
10	≈12
6	≈10

NC4FB nr. 2:

Band	SWR
80	5-7
40	4-5
20	≈13
17	≈6
15	≈6
12	4-5
10	3-5
6	3-5

Figure 38: Versions 1 and 2 of the W3EDP antenna by Frederic Benson (NC4FB)

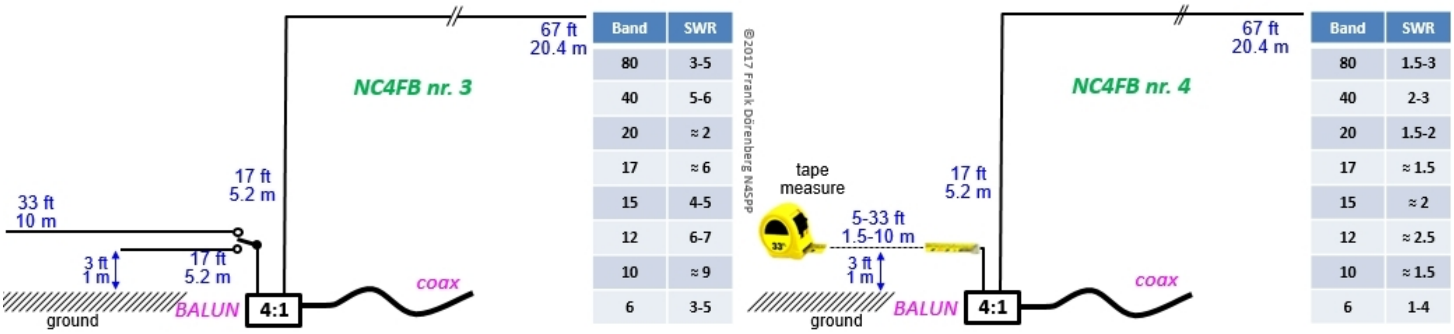


Figure 39: Versions 3 and 4 of the W3EDP antenna by Frederic Benson (NC4FB)

Nick Toparcean (AE5VV) used the standard dimensions for 10-80 m, and an 85 ft long wire radiator for 10 -160 meters. Richard Marris (G2BZQ) made a compact version by configuring the radiator wire as a spiral (ref. 10G).

REFERENCES

- **Ref. 1:** "Lambda/2 no Counterpoise: Fuchs Antenna matching unit", DL-QRP-AG, 6 pp. [pdf]
- **Ref. 2:** Commercially-built multi-band end-feds are available from manufacturers such as the ones listed below. Note that I do not endorse these products, as I have no experience with them (though I welcome any manufacturer who will provide me one for trials).
  - **Ref. 2A:** HyEndFed.
  - **Ref. 2B:** PAR End-FedZ.
  - **Ref. 2C:** EARC END FED 6-40 Meter Multiband HF Antenna [incl. parts list and building instructions]. [pdf]
  - **Ref. 2D:** QRPGuys Portable Multi-Band End Fed Antenna 40/30/20 [schematic and build instructions], QRPGuys Portable No Tune End Fed Half Wave Antenna 80-10m [schematic and build instructions].
- **Ref. 3:** Some blogs and forum threads about this type of antenna:
  - **Ref. 3B:** "End fed matching – PA3HHO design review", Owen Duffy (VK1OD) blog. [pdf]
  - **Ref. 3C:** "Multiband PAR End-fedz nabouwen" zendamateur.com blog (in Dutch), through March 2011. [pdf]
  - **Ref. 3D:** "Multiband end fed antennas 3.5 - 30 MHz", John Scheepers (PD7MAA), April 2012. [pdf]
  - **Ref. 3E:** "End Fed Half Wave Antenna Coupler", MØUKD Amateur Radio Blog. [pdf]
- **Ref. 4:** "Une antenne end-fed réellement multiband" ["A real multiband end-fed antenna"], Guy Marchal (ON5FM), QSP, Nr. 41, June 2014, pp. 18-23.
- **Ref. 5:** "The End Fed Half Wave Antenna", Steve Yates (AA5TB), October 2014. [pdf]
- **Ref. 6:** Some on-line coil calculators:
  - **Ref. 6A:** "Helical coil calculator" on pages of the Tesla Coill webring
  - **Ref. 6B:** "ON4AA Single-layer Helical Round Wire Coil Inductor Calculator".
  - **Ref. 6C:** "Turns-length calculator for ferrite and iron powder core toroids".
- **Ref. 7:** "Taming the end-fed antenna", Alan Chester (G3CCB, SK), in "Communications Quarterly", Spring 1998, pp. 17- 22. [pdf]
- **Ref. 8:** "A 3- or 5-band end-fed antenna", Jos van den Helm (PA1ZP), RadCom (RSGB), Vol. 92, No. 2, Feb. 2016, pp. 54, 55, 58, 59. *See note 1 at bottom of page*.
- **Ref. 9:** EARCHI end-fed

- **Ref. 9A:** EARC END FED 6-40 Meter Multiband HF Antenna [incl. parts list and building instructions]. [pdf]
- **Ref. 9B:** "Fine Tuning the EARCHI End Fed Antenna", pp. 59-61 of "Some Serious QRPp Work and Some Serious QRP Antennas", by Cam Hartford (N6GA), in "CQ Amateur Radio", January/February 2015. [pdf]

- **Ref. 10:** W3EDP end-fed
  - **Ref. 10A:** "An Unorthodox Antenna", by Yardley Beers (W3AWH), in "QST", March 1936, pp. 32, 33. [pdf]
  - **Ref. 10B:** "Luftleitergebilde für Luftschiffe" ["Antenna arrangement for airships"], Dr. Hans Beggerow, Patenschrift Nr. 225204, Kaiserliches Patentamt (Empirial Patent Office), 19 September 1909.
  - **Ref. 10C:** "A “Flimsy” W3EDP Portable Antenna (“la Manquita”)", by José Campione (VA3PCJ), 22 May 2016. [pdf]
  - **Ref. 10D:** "A 42′ Portable Endfed Multiband HF Antenna with no Wire on the Ground: the “W3EDP Jr.”", by José Campione (VA3PCJ), 15 August 2016. [pdf]
  - **Ref. 10E:** "The MINI (1/4th) W3EDP – A Special Design for a Balcony Down South", by José Campione (VA3PCJ), 27 September 2016. [pdf]
  - **Ref. 10F:** "W3EDP Multi-band Antenna" [pdf], and "Optimizing the W3EDP Antenna" [pdf]; in "NC4FB - Amateur Radio" weblog by Frederic Benson (NC4FB), September 2013.
  - **Ref. 10G:** "Compressing the W3EDP", by Richard Marris (G2BZQ), pp. 20, 22, 24 in "73 Amateur Radio Today", September 1993. [pdf]
  - **Ref. 10H:** "A Simple Aerial", G.C. Dobbs (G3RJV), in "Short Wave Magazine", vol. XXXIX, nr. 6, August 1981, p. 304.
- **Ref. 11:** "Home-brew end-fed antennas for handhelds" [VHF], Pat Hawker (G3VA), "Technical Topics" column in RSGB "Radio Communication", Vol. 67, Nr. 1, January 1991, p. 29. [pdf]
- **Ref. 12:** Radiation patterns of an EFHW antenna when operated on the fundamental resonance frequency and its harmonics; configurations: straight, sloping, inverted-V, and inverted-L, incl. 4NEC2 files), Dick Reid (KK4OBI); retrieved 9 July 2019. [pdf straight, sloping, inverted-V, inverted-L]
- **Ref. 13:** "End-fed 1/2 wave matching system end feed", Tom Rauch (W8JI), 2005; retrieved 26 July 2019 [pdf]
- **Ref. 14:** "Optimaler Betrieb einer endgespeisten Halbwellenantenne" [Optimal operation of an end-fed halfwave antenna], Werner Schnorrenberg (DC4KU), pp. 341-345 in "Funkamateur", Vol. 68, nr. 4, April 2019. Accessed March 2020.

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