A Portable 7-Band End-Fed Half-Wave (EFHW) Antenna

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Figure 1: A typical inverted-L EFHW antenna setup with one bypassable loading coil

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1 Summary and Purpose of this Document

This document is about a multi-band shortwave (HF) amateur radio wire antenna that does not need an antenna tuner. The described antenna is based on the widely used end-fed half-wave (EFHW) dipole antenna design, improved for a bigger variety of bands, maximum efficiency and optimized for portable QRP communication.

The antenna system consist of a 20m-long radiator wire with one bypassable loading coil that in sum is resonant on the 60-, 40-, 30-, 20-, 17-, 15- and 10-meter bands, which I have never seen before. A small and efficient broadband transformer is used to match the impedance of this EFHW antenna to a 50Ω coaxial cable.

The document starts with the definition of the described EFHW antenna system, the author's personal portable antenna requirements, the history of choosing and developing the described antenna system and then continues with antenna experiments and their conclusions.

Further, it gives some hints on how to build the proposed antenna system, as well as its compact backup antenna, and shows how to add additional bands to both of them. Practical technical tips and references to other EFHW websites and documents complete the document.

My suggestions are not intended to be a ready-made solution but should give the experimenter hints and tips for building a practical and efficient EFHW antenna system that is tailored to their personal needs.

Please note that I am not an antenna expert and therefore mainly focus on the practical aspects, supported with measurements conducted in the field. The basic information was compiled from other sources and ideas, all of which are referenced in this document.

I created this document to live the ham spirit and in the hope that my ideas will be valuable to other like-minded hams. Your mileage may definitely vary!

Special thanks goes to R.S. for editing my English.

2 Definition of the Described EFHW Antenna

In this document, I refer to an EFHW antenna that is a resonant half-wave dipole, fed from its (near) end, and consists of a single radiator wire. The length of this radiator is about 0.5λ on its fundamental frequency. A "counterpoise" in the form of an attached coaxial cable shield, a short wire, or even by stray capacitance, is employed.

Compared to a center-fed half-wave dipole, the EFHW feed impedance is much higher, somewhere in the 2kΩ to 5kΩ range.

To enable a good impedance match to a 50Ω coaxial cable, different matching techniques exist. For HF multi-band no-tune operation, the high impedance of the antenna can be matched with a broadband transformer. Usually, this transformer is wound as an autotransformer on a ferrite toroid core and employs a small shunt capacitor on the primary side for frequency compensation for the higher bands. In the rest of this document, when I use the term "coupler", I am referring to this setup.

Combining these building blocks, the radiator is resonant on all odd and even harmonics of the fundamental frequency and can be used as a multi-band antenna, directly fed by a 50Ω coaxial cable.

For more background information and technical details about this and other EFHW antenna systems, please see Links to Other EFHW Antenna Articles.

3 Analyzer Measurements

All the measurements described in this document were done with the *RigExpert Stick 230*[1] antenna analyzer. It is a compact and robust analyzer, easy to carry for portable operation. Its e-ink display is easily readable in the sunlight, and I find the usage intuitive.

I like the hardware, but not the software that was created by this company, but I will keep my rant brief:

- AntScope Android app (up to version 2.27 with firmware version 1.10):

  Bluetooth connection problems, app crashes, app does not save the data, and more.

  I had to carry a second Android device with an older Android version with me, but even then, when I used a certain app version with the latest firmware, it was sometimes just impossible to take measurements.

- AntScope2 Windows application (up to version 1.2.0):

  After upgrading to a newer version, the printout VSWR values suddenly did not correspond with the reality: they were higher. Further, the printed Smith chart was skewed, and the band highlighting was missing, along with other annoyances. There was no reaction for months after submitting bug reports, both on GitHub and groups.io. Reverting to an earlier version fixed some of the newly introduced bugs, but some features were missing.

  Because of all the above-mentioned reasons, the charts in this document are not always uniform in appearance.

When possible, the measurements were conducted directly at the coupler, using a 5m-long counterpoise wire. When the coupler with the attached 5m-long RG-174 A/U coaxial cable was used, the length of the cable was subtracted by the software.

1 https://rigexpert.com/products/antenna-analyzers/stick-230/

4 Portable Antenna Requirements

When I go portable with my HF rig, I usually do a SOTA[2] activation, but I am sure that most of my requirements will also apply to GMA[3], WWFF[4] or POTA[5], just to name a few other portable award schemes.

For SOTA activations on HF in IARU region 1, I was looking for a portable antenna system with the following requirements (in this order):

- Light and small enough to be carried inside a backpack for several hours.
- Quick and easy to setup on most summits (except for very space-restricted ones), whether in a dense forest or above the tree line.
- Self-supporting, and needing a maximum of 20m of horizontal space.
- Resonant and therefore with no need for a tuner.

  Several older and newer rigs (e.g., FT-817/818, IC-705 or TX-500) do not contain an internal antenna tuner, and I want to keep the number of items I carry to a minimum.
- Supports multiple bands that are quick to switch between, with no or minimal operator action.

  At least the 20-meter and the 40-meter bands plus at least one WARC band, which allows contacts during contests, should be supported.
- If possible, no separate counterpoise wire should be necessary.

  Only a 5m-long coaxial cable and a radiator wire that can be attached to a tree or a telescopic pole should suffice. Avoiding radials simplifies the setup and, on busy summits, removes the danger that other people trip over the wires.
- As efficient as possible and usable for both NVIS and DX contacts.
- The antenna system should easily handle 10W of continuous power (e.g., when using a digital mode) on a hot summer day.

2 https://www.sota.org.uk/
3 https://www.cqgma.org/
4 https://wwff.co/
5 https://parksontheair.com/

5 Initial Antenna Evaluations and Experiments

Every portable ham operator evaluates different antenna systems that meet their personal needs. I outlined my requirements in Portable Antenna Requirements after doing a couple of SOTA activations in different locations. The following paragraphs describe my personal experiences and thoughts about some commonly used antenna types for SOTA activations.

First, I read about portable magnetic loop antennas that can be handy on space-restricted summits, but I decided against them. This was mainly because a bulky tripod has to be brought along; they need re-tuning for even small frequency changes; and they have poor efficiency on the lower bands. This applies especially if they are built for portable use, e.g., when using a 1m-diameter LMR400 coaxial cable[6] or similar.

Then, I looked at loaded whip antennas that are directly attached to the rig, along with a counterpoise, which can sometimes be seen in videos taken on space-restricted summits. I tried this setup myself and needed a lot of time to tune the radiator and counterpoise to get an acceptable VSWR on one band. Using a rig with an internal antenna tuner would definitely speed this up. Unfortunately, this antenna setup did not result in any contacts using 6W of SSB output power. During this test, a contest was occurring, and the feed point of the attached antenna was just above ground level. This was the only practical setup I could think of at that moment because I need one hand to log the QSOs and the other to hold the microphone.

Next, another similar small "wonder" antenna was also tried. It employs an integrated L-matching unit, driving a 1.4m-long telescopic whip, together with a tunable counterpoise. When I tested this antenna with WSPR, my station was heard around the world, even in Antarctica, using only 2.5W on the 20-meter band. Unfortunately, when I tried this antenna on a summit on the 20-meter band using 6W of SSB output power, I could hear the activators that were calling me for a summit-to-summit (S2S) contact, but they could not hear me at all.

Furthermore, there are commercial portable antenna packs that mostly employ adjustable loading coils to tune the antenna for resonance. After I saw their steep price, I experimented with the vertical-L[7] "Up and Outer" antenna using links and a tapable loading coil for the lower bands. The main disadvantages I found is that they need an elevated radial which people can trip over and the links or coil needs re-tuning when changing

6 https://www.sotabeams.co.uk/blog/how-try-a-mag-loop-before-you-buy-a-mag-loop/

7 https://www.qsl.net/dk7zb/Wire-Antennas/Vertical_L.htm

bands. Also, since the radial is close to ground, the ground conductivity has an influence on the resulting VSWR, and so the fine-tuning needs to be repeated on most summits.

Then, another vertical antenna possibility could be to use an automatic antenna tuner at the antenna feed point with some non-resonant radials lying on the ground. I would like to experiment with such an antenna system in the future, but only if it is small, water-resistant, uses its own power source and is universally applicable, i.e., supports quick auto tuning with any QRP rig without further control wires. The *ATU-10*[8] design by N7DDC could provide a good starting point for such a DIY project.

Finally, the widely used linked dipole is another viable candidate, but it has the disadvantage of being center-fed. Therefore, it needs a more robust but heavy(er) mast and a long(er) coaxial cable. Further, the links need to be changed when changing bands. A multi-band off-center-fed dipole could avoid this step. I decided not to go this route; however, it is second on my list of interesting, simple antennas.

8 https://github.com/Dfinitski/ATU-10-10W-QRP-antenna-tuner

6 Putting Theory into Practice

After all these evaluations and experiments, I realized that a resonant multi-band end-fed half-wave antenna with a broadband coupler fulfills my personal requirements best, and I started to look at different designs, both commercial and home-made.

First, I bought the *Par EndFedz® EFT-10/20/40 Trail Friendly*[9] antenna, consisting of a coupler with a BNC connector and about a 12m-long radiator. After a 10m length of wire, a loading coil for the 40-meter band that acts as a choke for the 20- and 10-meter bands is inserted. After adding about 2.7m of wire to the end of this antenna, it was also usable on the 60-meter band.

Then, I built a portable EFHW antenna according to the very well described instructions from HB9BCB[10][11], consisting of a QRP coupler with an FT-50A-43 toroid using a 3:24 winding ratio and shunted with a 100pF silver mica capacitor over the primary winding. The radiator is about 20m long and resonates on the 40-, 20-, 15- and 10-meter bands.

After tuning the length of the radiator wires for minimum VSWR, both antennas worked perfectly well and resulted in many SOTA contacts. Even a summit-to-summit DX contact with 5W of SSB output power during a solar sunspot minimum was possible.

After these experiments, my typical portable setup now consists of the following:

- The EFHW antenna is usually configured as a kind of inverted-L. The end of the radiator is insulated and attached to a cord, which is fastened to a tree, some kind of support or an extended walking pole.
- A 5m-long RG-174 A/U coaxial cable that connects the transceiver with the coupler allows the operator to move to a comfortable place, e.g., to be protected from wind and sun.
- A 6m-long glass-fiber telescopic pole that fits inside my backpack when collapsed, e.g., the *Tactical Mini*[12] from SOTABEAMS that packs down to 56cm. For me, this pole has a good balance between length, weight and robustness for these kinds of end-fed antennas. Using a mast allows the radiator wire to be erected without trees or other supports.

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9 https://www.vibroplex.com/contents/en-us/p3410.html

10 https://hb9sota.ch/wp-content/uploads/2018/01/Slim-EFHW-Koppler.pdf

11 https://docplayer.org/103995874-Slim-efhw-koppler-qrp-und-qro-version.html

12 https://www.sotabeams.co.uk/tactical-mini-compact-ultra-portable-6-m-19-6-ft-mast/

- A bright fishing rod holder, e.g., the cheap one from *DECATHLON*[13][14][15], alone supports the mast with the antenna on most summits. On windy or more rocky/sandy/muddy soil summits, two guy wires may be used to support the mast from the opposite side of the sloping radiator.

13 https://www.decathlon.co.uk/rod-rest-spike-25-cm-id_8127195.html

14 https://www.decathlon.ch/ch_de/rutenablage-erdspie-25-cm-suewasserangeln-de-sx8127195.html

15 https://www.decathlon.de/p/rutenablage-erdspie%C3%9F-25-cm-su%C3%9Fwasserangeln/_/R-p-X8127195

7 Refining the EFHW Antenna Radiator

These two previously described EFHW antennas were a good first solution. What I was missing was the possibility to quickly switch to at least one WARC band since, when contests happen, it is sometimes nearly impossible to find a free frequency on a popular HF band for more than a couple of minutes.

Since I currently do not practice CW, it had to be a WARC band allowing phone operation, and the 17-meter band seemed the most promising one to me. Like HB9BCB and other antenna builders have done, I considered adding traps to the radiator, but because they make the construction more brittle, I was looking for a simpler and more robust solution. I am aware that a high-Q trap does not incur much loss for the lower bands, while improving the antenna radiation pattern on the higher bands. But in a dense forest, where bulges along the radiator may get trapped in tree branches, I want to have as few bulges as possible.

Antenna links would be a possibility as well, but I felt the need to also be QRV on the 60-meter band for closer stations, so I had already planned to add a loading coil to the radiator wire, while keeping the wire at its maximum length of 20m.

For this purpose, a simple but effective solution is to insert a loading coil with a certain inductivity at a certain position on the radiator wire. When bridging the coil (i.e., the coil is bypassed or short-cut), the antenna is resonant with its full 20m length on the 40-, 20-, 15- and 10-meter bands. When the coil is in use, the antenna is resonant on the 60-meter band (0.5λ, electrically extended by the loading coil), on the 30-meter band (about 0.5λ, the coil is a choke at this frequency) and on the 17-meter band (about 1λ, the coil is a choke at this frequency). In my case, the coil is tuned on the 60-meter band for about 5.36 MHz. In Switzerland and the surrounding countries, only 15 kHz is allocated. Therefore, the narrow bandwidth of this antenna on the 60-meter band is not a problem.

Instead of putting the coil after 0.5λ on the 17-meter band, I decided to go for a 1λ length, which is roughly 16m after the coupler, mainly because accessing the coil towards the end that is sloping down is easier and usually avoids the need to lower the mast. Moreover, having the coil at this position additionally allows a 0.5λ-resonance on the 30-meter band.

8 Building an Efficient Coupler

During my experiments with the coil inductance and its optimal position, I researched how to maximize the efficiency of the QRP wide-band transformer.

One can find vast amounts of information about building such couplers on the web, but a lot of information is repeated, misleading and not backed by data. To me, it seems that many hams just follow and repeat advice without experimenting and drawing their own conclusions, so over time, myths and legends become "facts".

Basically, the article, *Small efficient matching transformer for an EFHW*[16]*,* by Owen Duffy, together with some measurement videos by *Evil Lair Electronics*[17], opened my eyes and paved the path for the following coupler experiments.

Since I did not find a reliable source of detailed EFHW data, and I did not trust my 4nec2 models, I ordered a number of Fair-Rite 2643625002 toroid cores and different silver mica capacitors from 47pF to 150pF with ±5% tolerance, and experimented with different coupler configurations.

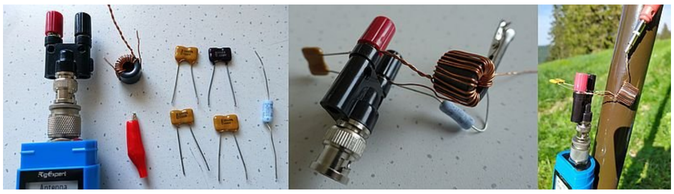

Figure 2: Coupler experiments

During my experimentation phase, whenever I went for a SOTA activation, I spent some time measuring the different combinations of coupler/coil/radiator/environment using the portable antenna analyzer described in Analyzer Measurements.

To easily measure different coupler aspects on a hill top, I also built a test coupler, which allowed me to switch the transformer ratios (1:36, 1:49, 1:64 and 1:81) as well as the primary shunt capacity (0pF=none, 82pF and 120pF). The measurements from one summit are shown in Test Coupler VSWR Measurements in the Field.

Figure 3: Test coupler with open enclosure

Figure 4: Test coupler in action

16 https://owenduffy.net/blog/?p=12642

17 https://www.youtube.com/channel/UCfxfVg2TM_pTb8Bf5dKGPZQ

9 EFHW Antenna Experiment

9.1 Experiment Setup

Because there are so many variables, after the initial couple of experiments, I decided to keep some settings constant, mainly to make the measurements more easily comparable, while adhering to my proven and practical portable/SOTA configuration:

- A broadband coupler that is optimized from the 60- to the 15-meter bands:
  - A small 43-material core from Fair-Rite with P/N 2643625002[18].
  - An auto-transformer with 3 primary and 24 secondary windings, using 0.63mm of CuL enameled wire, and resulting in an impedance transformation ratio of about 1:64. This leads to about 3.2kΩ impedance at the feed point, when using a 50Ω coaxial cable on the primary side.
  - The primary winding is shunt with a silver mica capacitor of 100pF (±5%, 1kV) for better VSWR on the higher bands.
- The radiator is a 0.22mm² tinned annealed copper wire. I used the *lightweight antenna wire*[19] from SOTABEAMS. To see the wire well outdoors, I favor the highly visible yellow color.
- To reduce the antenna wire bend at the suspension point, I built a small “top radiator wire support” made of a banana socket plastic cover attached by a cord to a slightly curved 20mm PVC tube that reduces the bent angle and lets the wire slide easily (see Figure 5).
- A 6m-tall telescopic glass-fiber mast, using its full length.
- When measuring directly at the coupler, I added a 5m-long counterpoise wire, most of which was lying on the ground. This corresponds closely to the configuration with the 5m-long coaxial cable (RG-174 A/U) that I use when making contacts with my rig.

Figure 5: Top radiator wire support

18 https://www.fair-rite.com/product/round-cable-emi-suppression-cores-2643625002/
19 https://www.sotabeams.co.uk/antenna-wire-lightweight-100m/

- The antenna configuration: inverted-L, or more accurately, an inverted-7 (see Figure 6). In this figure, wires 1 and 2 are in total the 20m-long radiator (with optional loading coil), and wire 3 is the 5m-long coaxial cable that acts as a counterpoise. The direction of this counterpoise may change, depending on the environment and possibilities at the summit.

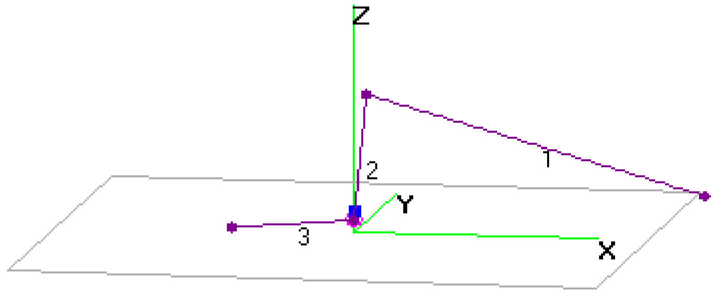

Figure 6: The geometry of the 20m-long inverted-L EFHW antenna

The feed point of the coupler is located at about 0.5m above ground. Then, the radiator runs nearly vertically up for about 5.5m and slopes down the rest of the about 14.5m to about 2m above the ground, where the end is attached to an insulator and cord. If there is no tree or other high support available, a fully extended 1.5m-tall walking pole is used instead.

Most of the summits that I have visited have limited how I can set up the antenna. For example, they determine the direction of the antenna radiator or the direction of the coaxial cable that acts as a counterpoise.

9.2 Experiment Observations

Following are my general experiment observations:

- The thinner the antenna wire, the higher the impedance.
- The higher the harmonic band, the lower the impedance.
- The closer the antenna to the ground, the higher the impedance and the lower the resonance frequency.
- Changing the antenna configuration from an inverted-L to an inverted-V slightly lowers the resonance frequencies on all bands.
- Increasing the transformer impedance ratio, e.g., from 1:49 to 1:64, decreases the usable bandwidth and increases the resonance frequency (see Test Coupler VSWR Measurements in the Field).
- Increasing the primary shunt capacitor, e.g., from zero to 82pF, increases the resonance frequency (see Test Coupler VSWR Measurements in the Field).
- Varying the coupler feed point height, e.g., from 0.5m to 1.7m, slightly influences the antenna resonance frequency and impedance, most prominently on the higher bands. Unfortunately, a uniform pattern over the measured bands could not be detected.

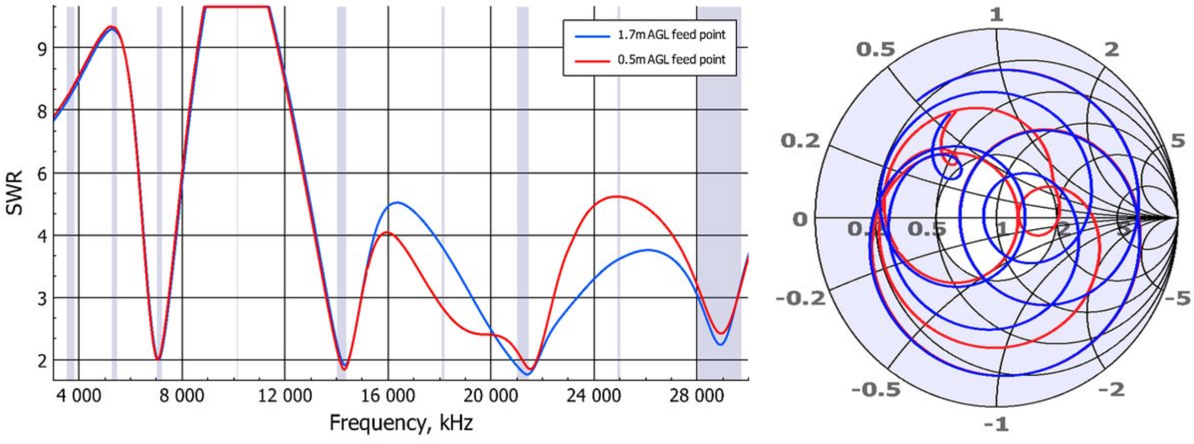

Figure 7: Resulting VSWR and Smith chart with 50cm and 170cm feed point height (20m-long radiator wire, configured as an inverted-L)

- Since the current at the feed point is very low but not zero, a small amount of current pushes from the radiator against the ground terminal, the so-called "counterpoise". Depending on the counterpoise configuration, the resulting antenna feed point measurement changes on certain frequencies.

  Following are some different counterpoise configuration experiments, ordered from higher to minimal variation. The charts that are shown contain the resistance (red line), the reactance (green line) and the impedance (blue line), in function of the frequency. Both the coaxial cable and the counterpoise wire were lying on the ground. The counterpoise wire had the same quality as the radiator wire. Note that each experiment series was executed on the same summit. Some experiments happened at summit A (DM/BW-239 with wet soil after days of rain), and others happened at summit B (DM/BW-284 with overgrown heather).

  - Counterpoise wire length (summit B):

    When changing the counterpoise length, a variation in the measurements could be clearly observed, although the variation at or near the resonance frequency was rather small. This also depended on the band; on the higher bands, there was more variation than on the lower bands.

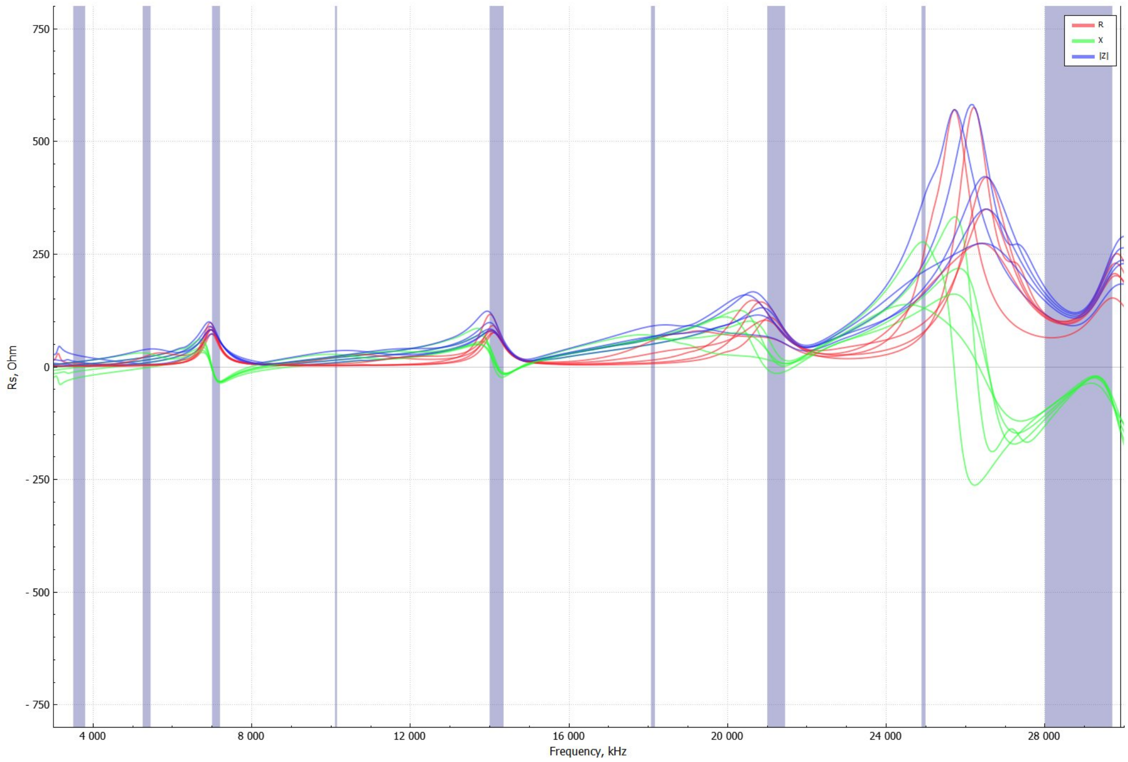

Figure 8: Counterpoise wire length: 1m, 2.5m, 5m, 10m and 20m

The biggest variation happened between no counterpoise at all and a short counterpoise of 1m in length. The following figure also includes a measurement with no counterpoise (best seen with the single bolded lines) that should be compared with the previous Figure 8.

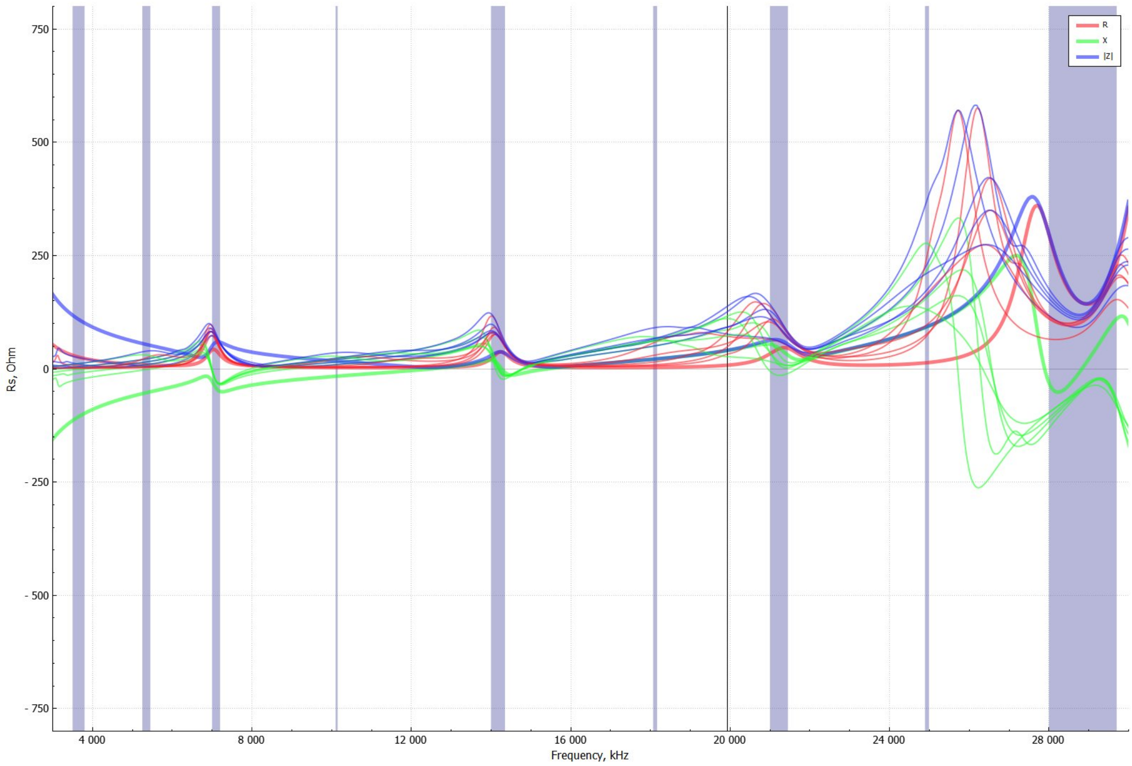

Figure 9: Counterpoise wire length: zero, 1m, 2.5m, 5m, 10m and 20m

Again, the biggest variation could be seen around the 10-meter band, but also the 40-meter band showed some variation. The least variation happened on the 20-meter band.

After reading the article, *Of end-feds and feed-lines*[20], I expected a bigger variation around the 20-meter band for the 5m-long counterpoise that corresponds to about 0.25λ.

20 https://www.hamradio.me/antennas/of-end-feds-and-feed-lines.html

- Coaxial cable with added counterpoise wire (summit A):

  When I added a counterpoise wire of a certain length to the 5m-long coaxial cable, by connecting the counterpoise wire to the ground socket of the rig, the resulting measurements changed only slightly at the resonating frequencies.

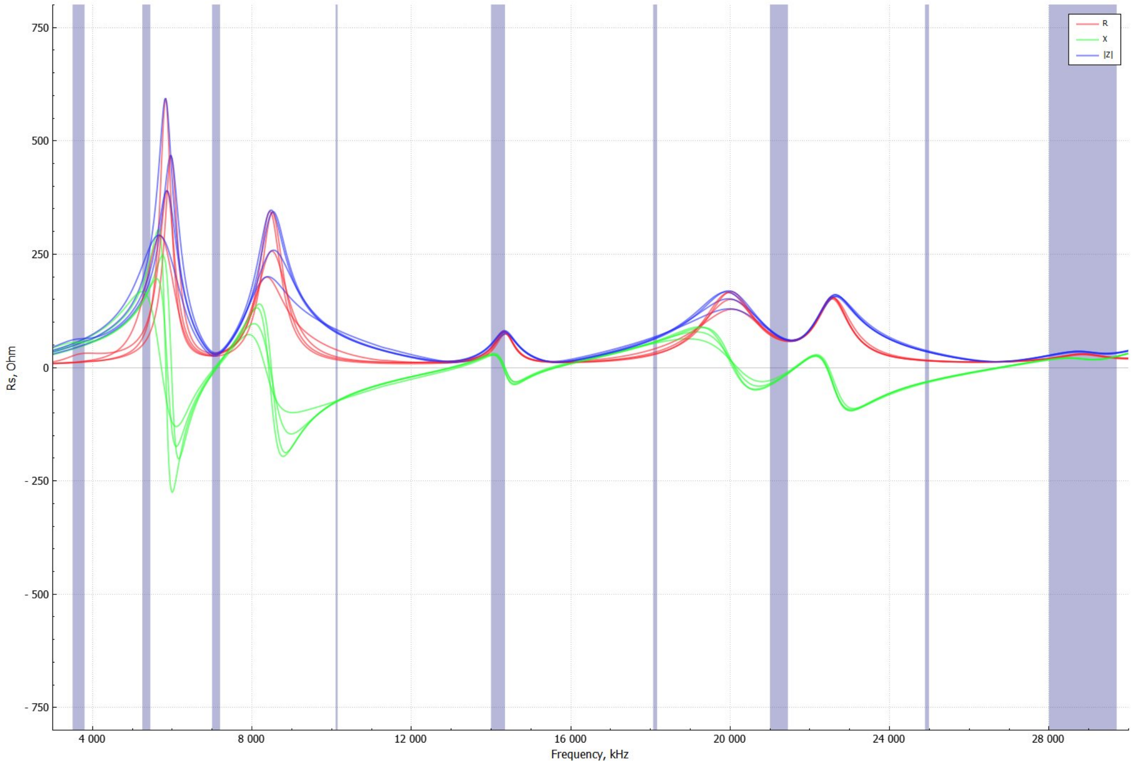

Figure 10: Coaxial cable with counterpoise wire length: zero, 5m, 10m and 20m

Note that the resulting total counterpoise lengths in this experiment were 5m, 10m, 15m and 25m long.

Again, because I had read the article, *Of end-feds and feed-lines*[21], I expected a bigger variation around the 20-meter band for the 5m-long coaxial cable that corresponds to about 0.25λ, or the combination of coaxial cable and counterpoise wire that adds up to 15m of length, corresponding to about 0.75λ.

21 https://www.hamradio.me/antennas/of-end-feds-and-feed-lines.html

- Counterpoise wire shape (summit B):

  Instead of laying the 5m-long counterpoise in a straight line, one can also lay it in a U-, O-, or S-shape. All these different shapes, or a combination thereof, may happen when doing an activation when the coaxial cable extends beyond the feed point of the antenna. There was some small variation, mainly on the non-resonant higher frequencies. On the resonant frequencies, the variation was very small.

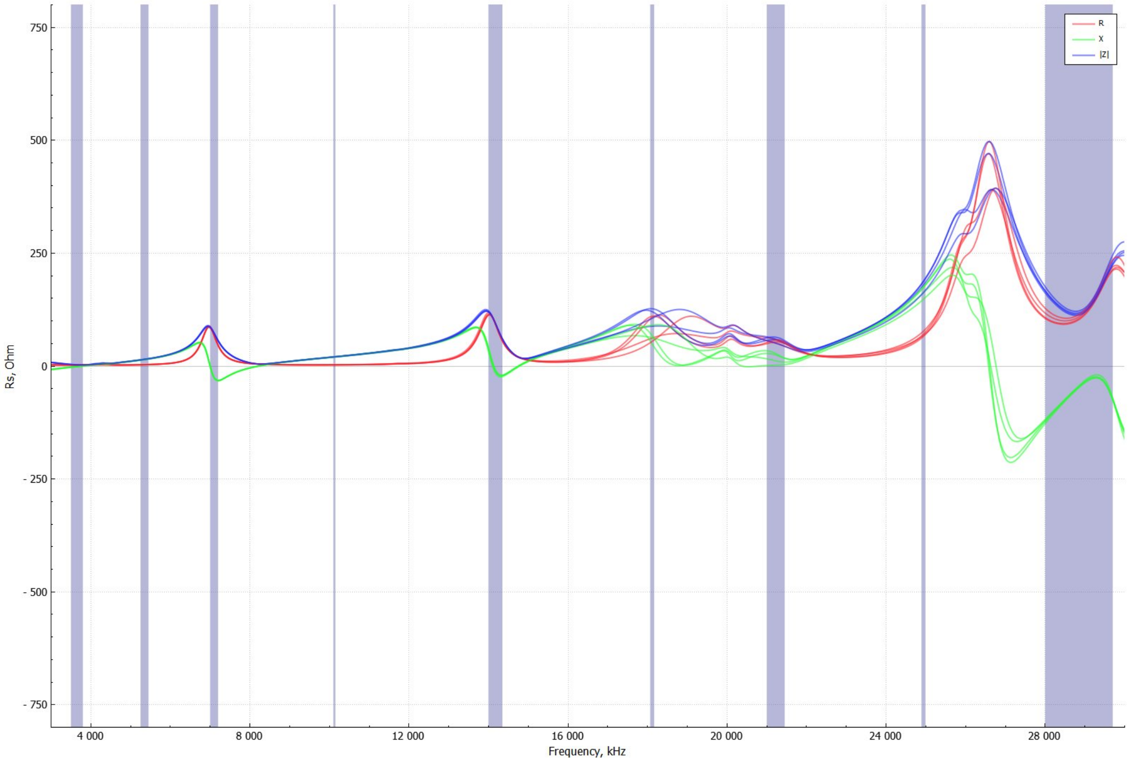

Figure 11: Counterpoise wire shapes: straight line, U-, O- and S-shapes

- Counterpoise wire direction (summit A):

  When laying the 5m-long counterpoise wire in different directions, i.e., laying the wire at 0°, 90° or 180° in relation to the antenna wire direction, there was a minor variation, mainly on non-resonant frequencies. On the resonant frequencies, the variation was negligible.

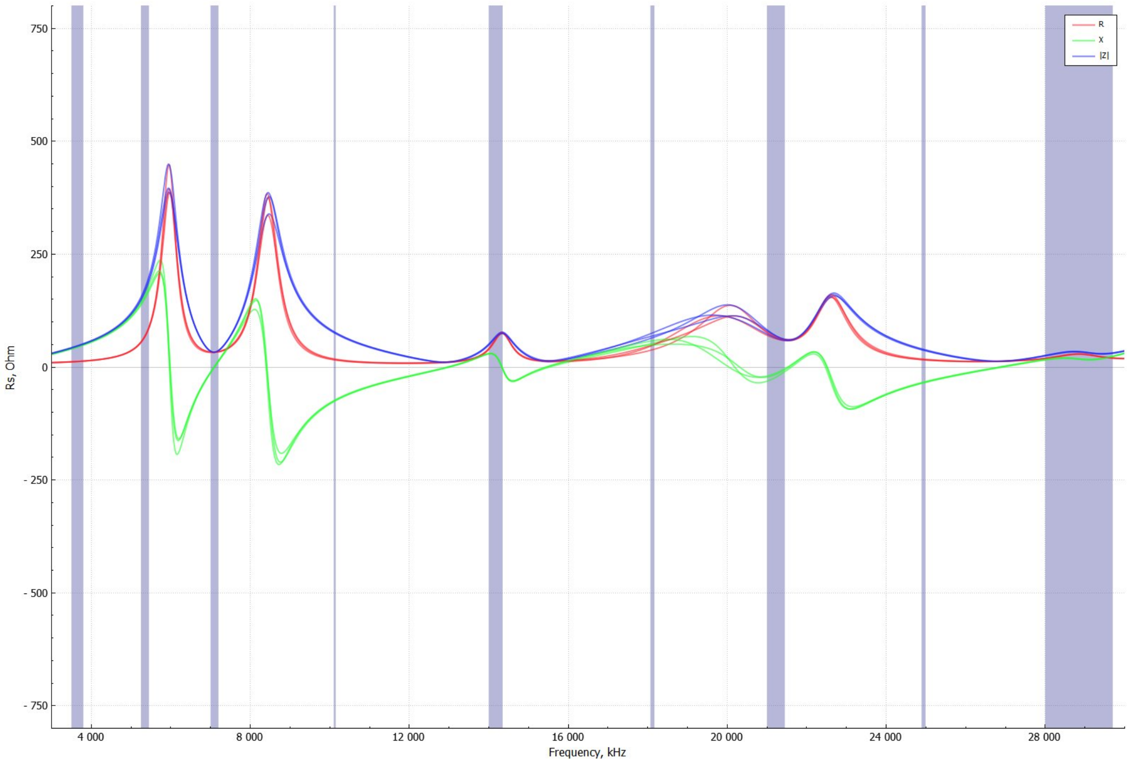

Figure 12: Counterpoise wire directions: 0°, 90° and 180°

- Counterpoise wire with grounding rod (summit A):

  When the ground of the coupler was directly connected with a ground rod (18cm-long aluminum guying peg in dense and wet soil), adding a counterpoise wire of any length showed a negligible variation.

- On the 20-meter band and upwards, a transformation ratio of 1:49 instead of 1:64 improves the VSWR since the EFHW impedance tends to be lower on higher bands. Similarly, from the 15-meter band upwards, two instead of three primary windings leads to a better match, most likely due to lower primary inductance. According to calculations done with Owen Duffy's ferrite core calculator[22], this also results in less transformer efficiency when using two instead of three primary windings, down to about 84% from about 93% at 28MHz. Note, however, that more losses may also mask a bad VSWR.

- When aiming for a low VSWR, the primary shunt capacitor of about 100pF is only necessary above the 20-meter band. If you use only the lower bands, this capacitor can be omitted. Inserting this capacitor will slightly lower the resonance frequency.

- The resonance frequency, where the reactance is zero, and thus current and voltage are in phase, corresponds very well with the minimum VSWR, but only up to the 15-meter band. From this band upwards, the antenna configuration (e.g., vertical, inverted-L or inverted-V) and the ground conductivity plays a bigger role than on the lower bands.

- To lower the resonance frequency, a simple but effective trick is to add a short wire immediately after the antenna coupler, which increases the antenna capacitance. For example, on the 20-meter band, a 25cm-long wire connected at the antenna terminal of the coupler will lower the resonance frequency by about 200kHz.

- How much power can the coupler handle? My current portable HF rig delivers a maximum of 6W of continuous output power. When using 5m of RG-174 A/U coaxial cable with a VSWR below 2, at 28MHz about 5W, and at 5.3MHz about 5.5W of RF power will be present at the coupler.

  To detect if the core warms up, I ran several practical power tests at about 20°C in the shade for five minutes, using the resulting 5-5.5W continuous input power at 28MHz, 7MHz and 5.3MHz. After running these tests, I noticed almost no temperature increase when putting my hand on the coupler that is protected by shrink tubing. Owen Duffy measured, directly at the coupler, a 5°C temperature increase at 3.6MHz over two minutes applying 20W of continuous power at 20°C ambient temperature.

  Therefore, I conservatively estimate that the coupler should be able to handle at least 10W of continuous power during a hot summer day.

22 https://owenduffy.net/calc/toroid.htm

- When using a carbon mast, the radiator wire should not run too closely parallel to the mast, otherwise some RF will be absorbed, the resonance frequency will be lowered, and the radiation pattern will change. Therefore, it is better to aim for an inverted-V antenna configuration where the radiator wire does not run parallel to the partly conductive mast.

9.3 Experiment Conclusions

After many measurements under different summit conditions, my conclusions are the following:

- In general, end-fed antennas are quick to set up and adaptable to different environmental conditions. This is probably also the reason why they are such a popular choice with portable operators[23].

  After having done more than 150 SOTA activations using an EFHW antenna with the previously described inverted-L setup, I find it fast and easy to erect on most of the summits I have visited so far in Europe, even in the deep winter snow. When only using the fishing rod holder, I usually need less than five minutes to set up the whole antenna. If guying is necessary, it may take up to ten minutes.

  Further, the nearly vertical part of the radiator has a pretty flat and omnidirectional radiation pattern which works well for DX on the higher bands, and the sloping nearly horizontal part of the radiator works well for NVIS on the lower bands.

  This 20m-long EFHW antenna really shines on the busy 40-meter band, where the pattern, compared to the higher bands, is nearly omnidirectional (see Antenna Radiation Pattern).

  Note that, on the 40-meter band, the high current part of the radiator, which does most of the radiating, is a quarter wave away from the feed point, which is close to the highest antenna point. In theory, the antenna radiator should not be bent here, but I hope that my antenna wire support keeps it from bending too sharply.

- Although the described coupler is called a broadband transformer, its usable bandwidth is limited. If you need a wide range of bands, e.g., from the 80- to the 10-meter bands, this antenna will be most likely a compromise for the end bands, mainly because the transformer is not as broadband as one might think. You will still make many contacts with such an antenna system, but if you want to further optimize, you will have to use two different couplers for two different band segments, for example, one for the 80- to 20-meter bands and one for the 17- to 10-meter bands.

23 https://www.sotabeams.co.uk/efhw/

- If we do not only focus on the coupler, but look at the whole antenna system including the antenna radiation pattern, it would be better to use two different antennas for a lower and a higher band segment, e.g., a standard 20m-long radiator with a switchable coil for the 60- and 40-meter bands and a compact 10m-long radiator for the 20- to 10-meter bands. The main reason is that a 0.5λ- or 1λ-long radiator has a more uniform pattern compared to a 1.5λ- or 2λ-long radiator (see Antenna Radiation Pattern). Unfortunately, swapping antennas takes time and effort, which is something a typical SOTA activator tries to avoid. In practice, I did several sporadic E contacts on the 10-meter band transmitting with only 5W even on FM and using the inferior 2λ-long radiator. Its pattern looks like a cloud burner (see Figure 16), but when the 10-meter band is open, even a mediocre antenna works pretty well. For the sake of simplicity, I stick to one main antenna and accept its limits on the higher bands. When focusing for an extended time on the higher bands, one can still choose the compact 12m-long antenna (see below) with its better radiation pattern especially on the 10-meter band (see Figure 17). It can also be used on the 40-meter band, albeit with less efficiency.

- There is no one-size-fits-all EFHW antenna system. Especially for SOTA activity, each summit has a different environmental condition, and one has to cope with size and wind restrictions. That is why I finally built two different EFHW antennas: the standard 20m-long one and a shorter 12m-long one, which has fewer bands to choose from, for limited space summits. Since both antennas, including cord and winder, weigh so little, I always carry both antennas with me. If one antenna wire breaks, I still have the other antenna as a backup.

  In case the coaxial cable or the coupler, which is attached to the cable, breaks, I built a similar coupler in a small enclosure, which I carry as a spare with me (see Figure 13). If need be, I can connect its BNC connector with a male-to-male adapter directly to the rig.

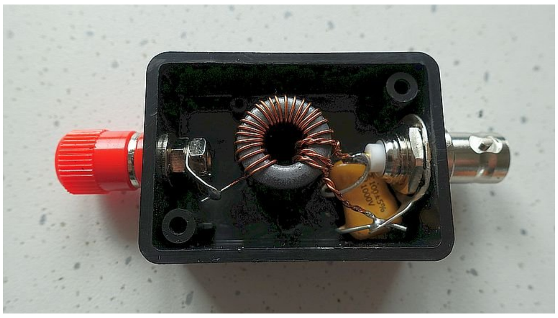

Figure 13: A compact coupler as backup

  As a counterpoise, I would use a few meters of wire from one of the spare EFHW antennas, connecting it to ground of the rig.

An even more practical backup solution that adds only a little more weight is to carry a second coaxial cable with an attached 1:49 coupler, which is already connected to the compact 12m-long EFHW antenna. Then, if I have space restrictions, I simply use the compact antenna with the coupler that is better suited for the higher bands, and I do not have to switch the coaxial cable with attached coupler from one radiator wire to the other. If one of the two coaxial cables or couplers breaks, I still have a spare one that is very usable for both radiator wires.

- For QRP power levels, all my experiments showed that it is fine to (mis)use the coaxial cable as the counterpoise. If you have problems with noise or too much RF on the coaxial shield, which is more pronounced when the antenna is not resonant, try using a common-mode choke. When doing so, make sure you insert the choke at least 0.05λ away from the antenna feed point for the lowest band. A 5m-long coaxial cable works fine as the counterpoise down to the 80-meter band (0.05λ@3.5MHz≈4.3m).

  In any case, even without an explicit counterpoise wire, as long as there is a rig connected and an operator holding the microphone or CW key, any of these conductive parts will form a kind of counterpoise by providing stray capacitance.

- Most EFHW couplers I found on the web use a 1:49 transformation ratio (Z≈2.4kΩ) and, to a lesser degree, 1:64 ratio (Z≈3.2kΩ). These suggested couplers mostly use toroid cores with different geometries, different winding techniques and sometimes different ferrite materials, resulting in different behaviors, e.g., a different inductance per turn at a certain frequency.

  As already stated, the actual impedance of the antenna depends on several factors. In general, on the lower bands, I measured a higher impedance, where I got good matches even with a 1:81 transformer corresponding to about 4kΩ of impedance (see Test Coupler VSWR Measurements in the Field). My experiments suggest that the reason for this high impedance is most likely to do with my antenna system that is optimized for portable use, i.e., using a thin wire and deploying the antenna relatively low above the ground.

- The bands do not match exactly harmonically. Instead, on each higher band, the resonance frequency changes a bit. This could be optimized by inserting a small inductance after the first two meters of the radiator or adding a short stub wire in the middle of the radiator to create an additional end effect[24] for 1λ and above. Since the VSWR on all bands, except the 10-meter band, is below 2, I decided to omit these possible improvements, to keep the design simple and robust.

- The primary windings on the coupler are tapped and not bifilarly wound, as most published designs suggest. My measurements using bifilar windings (see Figure 13) showed a difference below measurement tolerance, also on the higher bands.

  Further, the windings are tightly wound to minimize flux leakage with no crossover. Owen Duffy[25] and Evil Lair Electronics[26][27] seem to agree with this approach. When I can choose, I strive for the simplest solution.

- Changing bands by staying on the same band segment is possible without operator intervention; not even pressing a tune button is necessary.

  When the coil is in use, one can instantly change between the 60-, 30- and 17-meter bands. When the coil is bypassed or short-circuited, one can choose between the 40-, 20-, 15- and 10-meter bands. My default band segment is the latter, since most SOTA contacts happen on the 40- and 20-meter bands, and therefore, my sought-after summit-to-summit contacts are more likely to happen there. To change the band segment, one needs to get up and bridge the coil, in my case, by pressing a button on the downward-hanging coil. This is also good physical exercise, after one has been sitting in the same spot for a while, hopefully after working a long pile-up.

24 https://www.dj0ip.de/ricki-leaks/ocfd-end-effect/

25 https://owenduffy.net/blog/?p=11727

26 https://www.youtube.com/watch?v=On_n1fhp4sI

27 https://www.youtube.com/watch?v=1urC7O_Kyf4

10 Antenna Radiation Pattern

While I did not measure the antenna radiation pattern, my antenna models (see Figure 14 ff) and other people's models show clearly that the radiation pattern changes according to the band one operates and hence the number of harmonics the antenna actually radiates (for example, see the KK4OBI “bent dipole” website[28]). As the number of harmonic bands increases (e.g., from 0.5λ to 1λ), the radiation pattern changes with additional lobes forming. Mostly, this is a disadvantage compared to a single-band EFHW or a center-fed half-wave dipole that is operated on only one band.

Keep in mind that when portable on a summit, the environment may have a big influence on the resulting pattern. Therefore, the following radiation patterns are just for reference and assume a real ground type of *medium hills and forest* with 4 mS/m of ground conductivity.

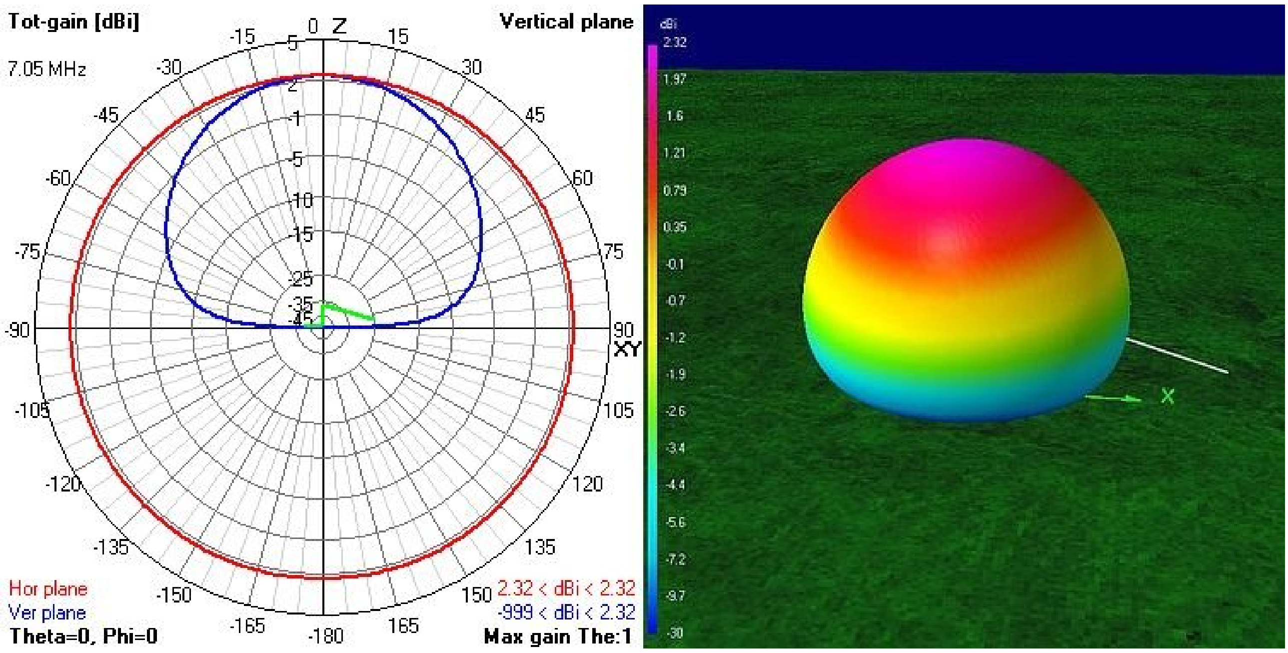

Figure 14: 40-meter-band radiation pattern (0.5λ)

28 https://www.qsl.net/kk4obi/EFHW%20inverted%20L.html

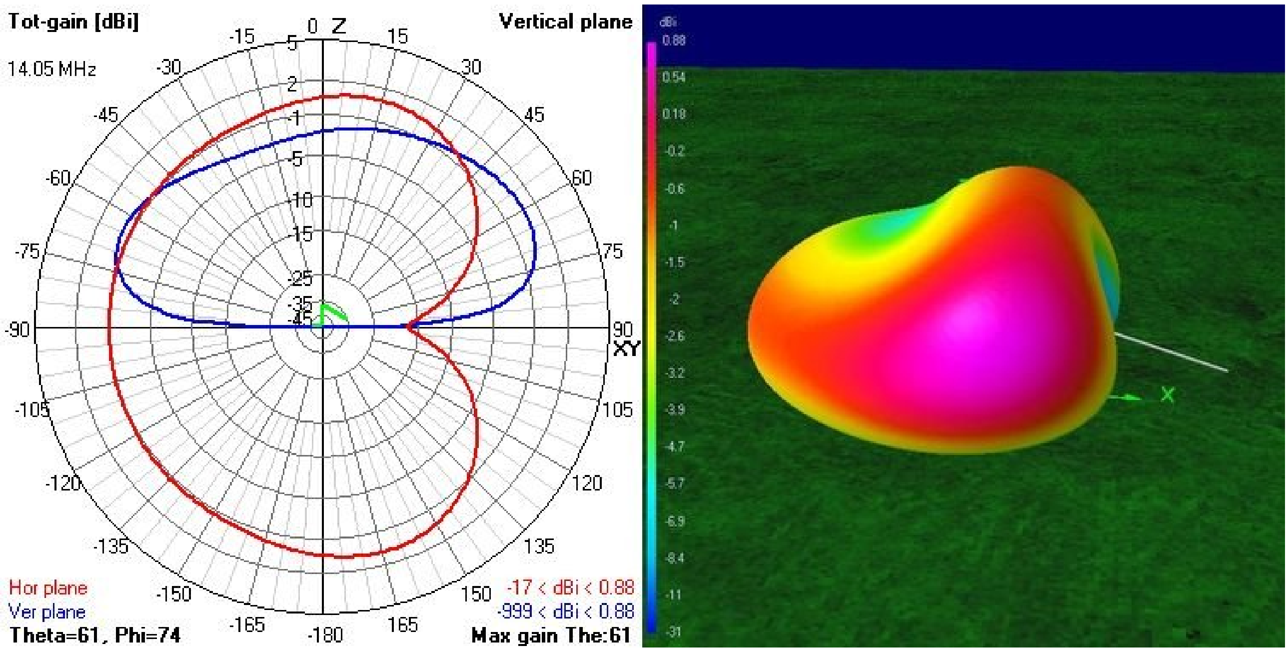

Figure 15: 20-meter-band radiation pattern (1λ)

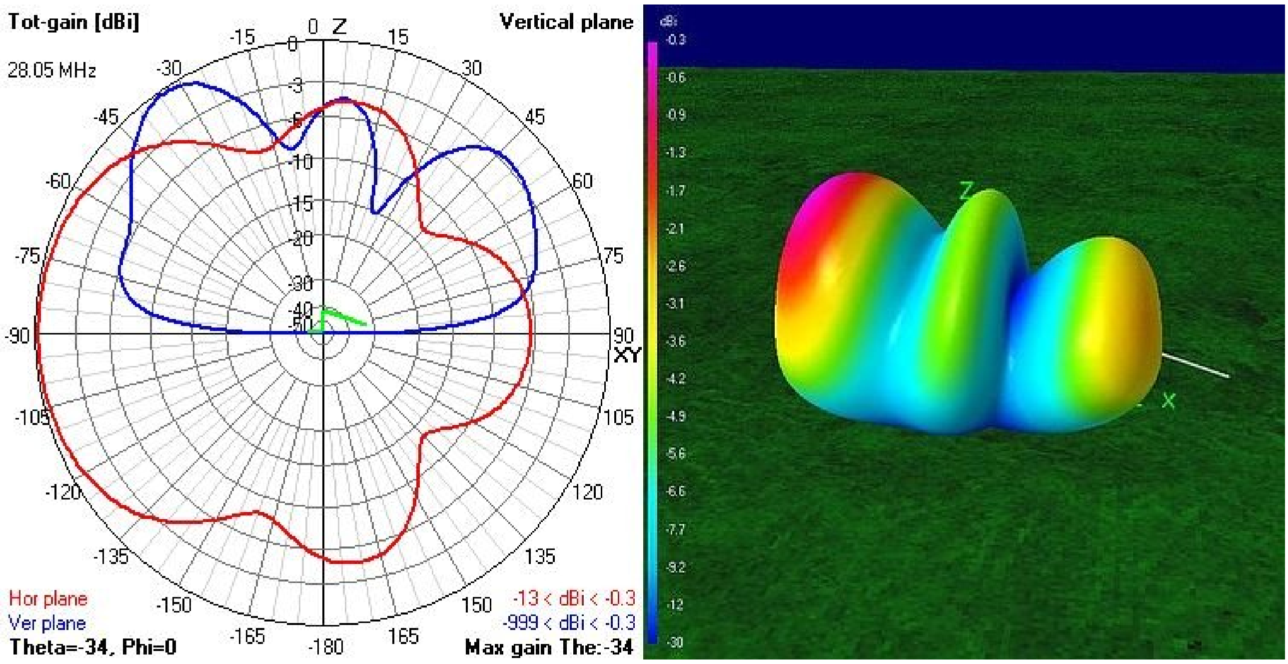

Figure 16: 10-meter-band radiation pattern (2λ)

For comparison, the following image is a pattern of a compact EFHW antenna radiator that, instead of 20m (2λ), is only 10m (1λ) long, but otherwise adheres to a similar antenna configuration (see Figure 19).

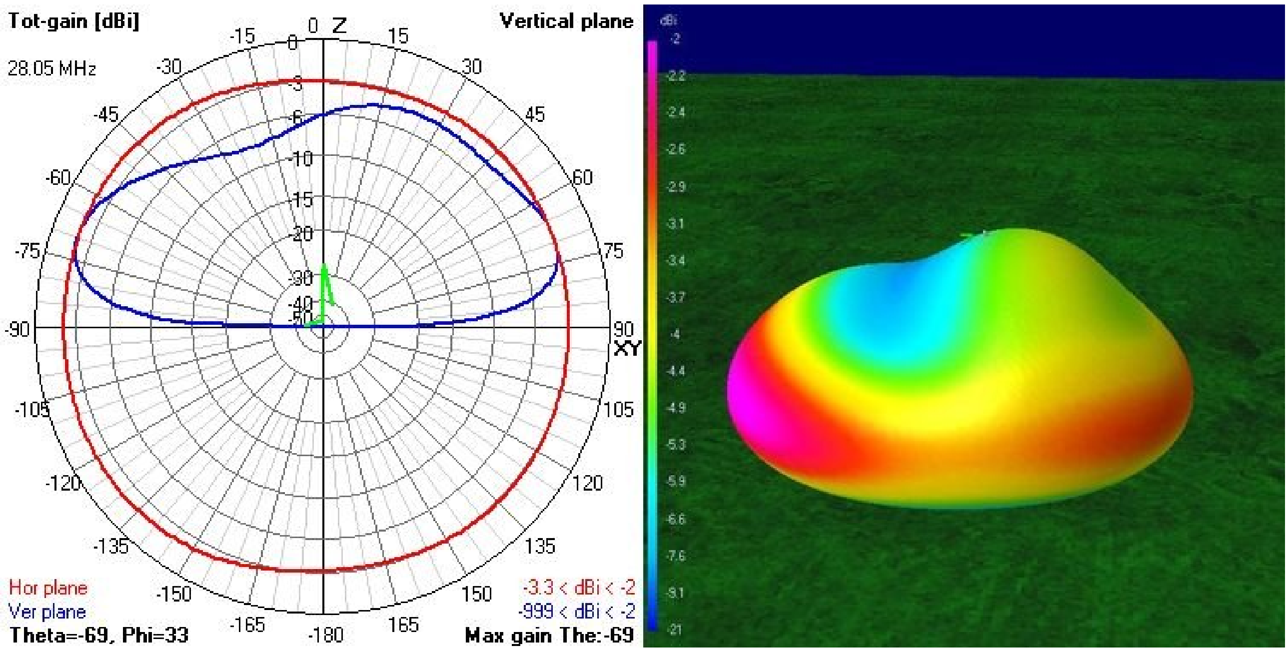

Figure 17: 10-meter-band radiation pattern (1λ) of the compact EFHW antenna

11 Test Coupler VSWR Measurements in the Field

The following VSWR measurements reflect the combinations of transformer ratios (1:36, 1:49, 1:64 and 1:81) and a primary silver mica shunt capacitor (0pF=none, 82pF and 120pF, each with ±5% tolerance) used with the test coupler (see Figure 3) under real conditions.

The attached radiator wire was about 20m in length and was configured according to the Experiment Setup. The measurements were taken at the BNC connector of the coupler, and a 5m-long counterpoise was used.

When looking at the 10-meter band, it seems that the optimal shunt capacity is somewhere in the 100pF range. This is the reason why this value was chosen for both the 1:49 and the 1:64 couplers.

The following graphs are meant to show the general trend of the VSWR depending on the chosen winding ratios in combination with a selected shunt capacitor. Please keep in mind that these measurements were recorded at one summit location in a dense forest and that other places may show slightly different results.

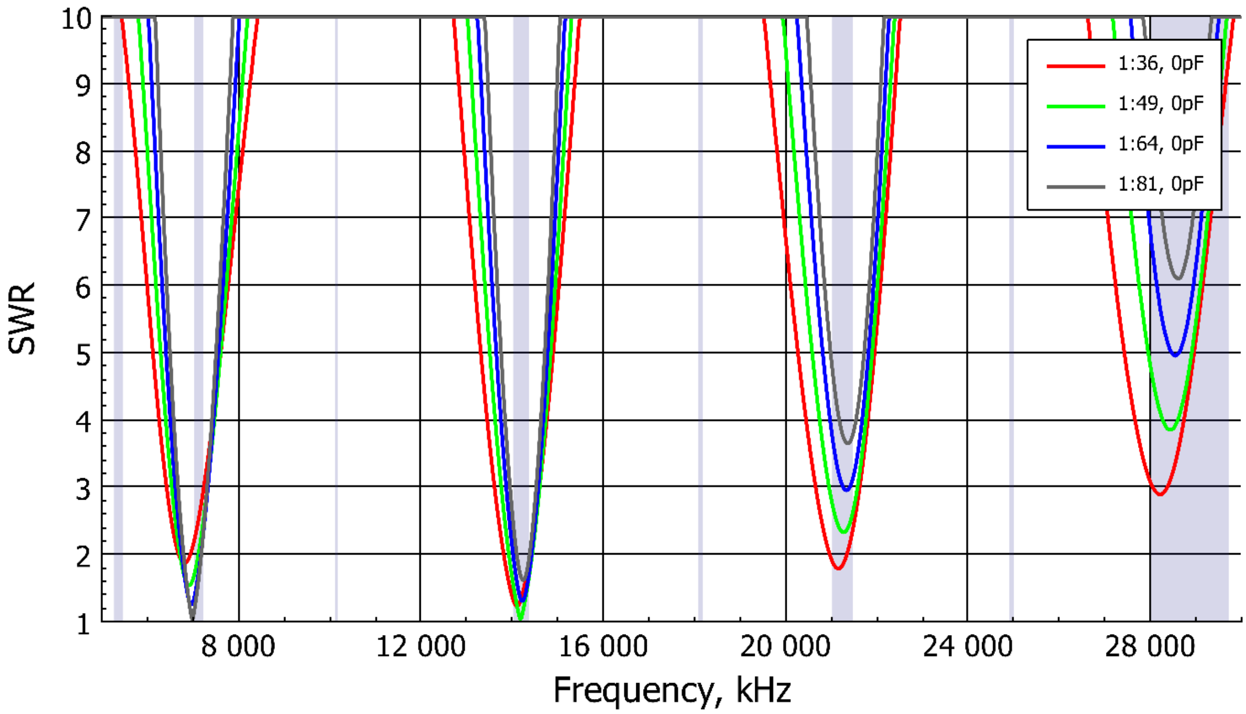

Figure 18: Measured VSWR without a primary winding shunt capacitor

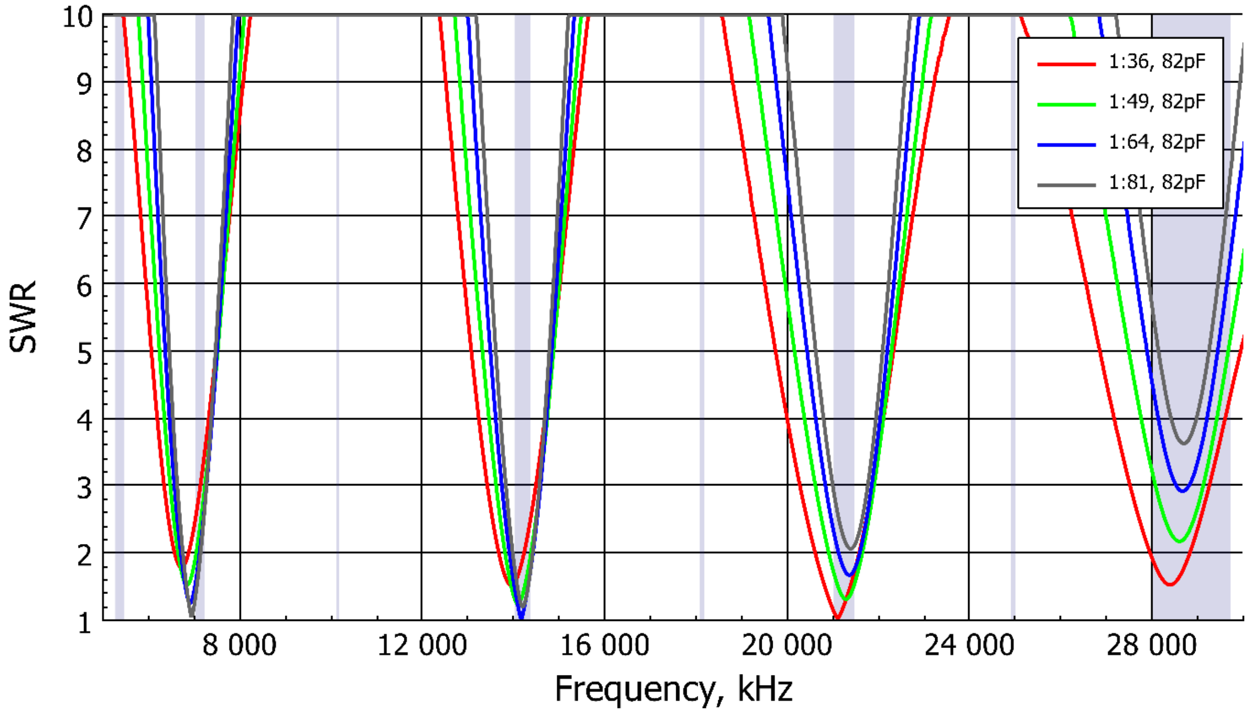

Figure 19: Measured VSWR using an 82pF primary winding shunt capacitor

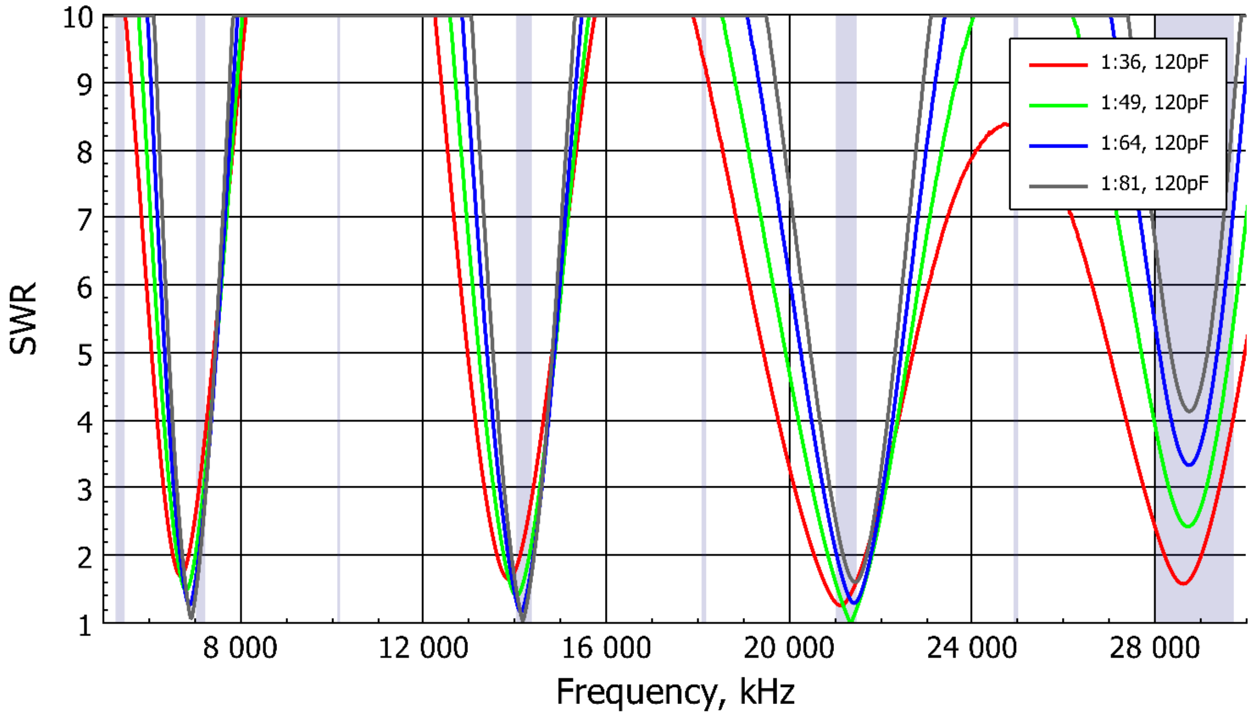

Figure 20: Measured VSWR using a 120pF primary winding shunt capacitor

12 Building the EFHW Antenna

12.1 Building Overview

The following figure shows the typical EFHW antenna building blocks.

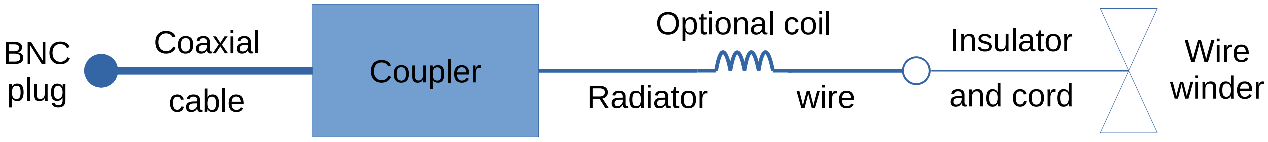

Figure 21: Typical EFHW antenna building blocks

The coupler may be connected directly to the transceiver, by omitting the coaxial cable that acts as the counterpoise (its shield). In this case, as previously noted, some sort of counterpoise should be added.

The radiator wire may contain a loading coil, links, traps, or a combination thereof.

When using low power, instead of an insulator, one can also just use a nonconductive synthetic cord that does not soak water or humidity. But remember that, at the beginning and the end of a resonant EFHW antenna, the voltage is at its maximum.

The following figure shows all the outlined building blocks, conveniently wound on a wire winder.

Figure 22: Complete standard EFHW antenna on wire winder

12.2 Building the Coupler

I built couplers that are directly attached to the coaxial cable or are contained in a small enclosure.

If the coupler is attached to the coaxial cable, one can keep it directly wound on a winder and save some weight, as well as some antenna setup time, because the whole antenna including its coaxial cable can be unwound from one winder.

By putting the coupler into an enclosure, one has more possibilities, either by swapping the coupler for different band segments, or by creating different coupler configurations, e.g., by switching the primary shunt capacitor or switching the transformation ratio (see Figure 3). Moreover, one can analyze the antenna directly at the coupler, without calibrating the analyzer for the additional coaxial cable.

When attaching the coupler directly to the coaxial cable, I basically followed the well described building instructions from HB9BCB (see Initial Antenna Evaluations and Experiments). Since the Fair-Rite 2643625002 toroid core has a slightly bigger diameter than the FT-50-43 core (16.3mm vs. 12.7mm diameter), the board shown in Figure 23 has 5mm of added length, compared to HB9BCB's original design. Further, the shrink tubing needs a larger diameter for the taller toroid core.

When designing the coupler for 10W of continuous power, let us assume this corresponds to about 40W PEP. The peak working voltage of the shunt capacitor for 40W PEP is calculated with $\sqrt{2 * P * R}$ and corresponds to about 64V. After applying a generous safety margin that also accounts for mismatches, a capacitor specified for 250V or more would be fine. It is important to choose a stable and low-loss capacitor for this application. Good candidates are silver mica or ceramic class 1 capacitors.

To connect the radiator with the coupler, the readily available banana plug works very well (diameter: 4mm, length: 20mm). The banana plug connects firmly with the coupler and allows the radiator wire to be quickly changed. When the wire tension gets too high, it will let go, hopefully well before the thin radiator wire breaks.

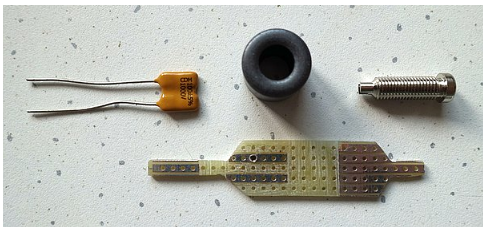

Figure 23: Preparing the coaxial cable attached coupler components

In Figure 24, a 3:24 winding ratio is used, resulting in a 1:64 transformer ratio or about 3.2kΩ of antenna feed point impedance.

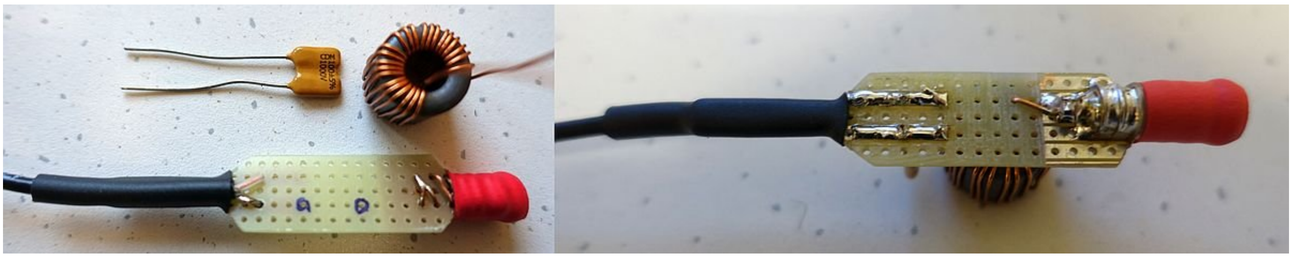

Figure 24: Building the coaxial cable attached coupler

To protect the coupler from water ingress and make it more robust in the field, I propose applying a final layer of adhesive-lined heat shrink tubing (see Figure 25).

Figure 25: 1:64 coupler after more than 150 SOTA activations

12.3 Building the Standard EFHW Antenna

The following drawing shows the dimensions of the built antenna that is used with the previously described coupler.

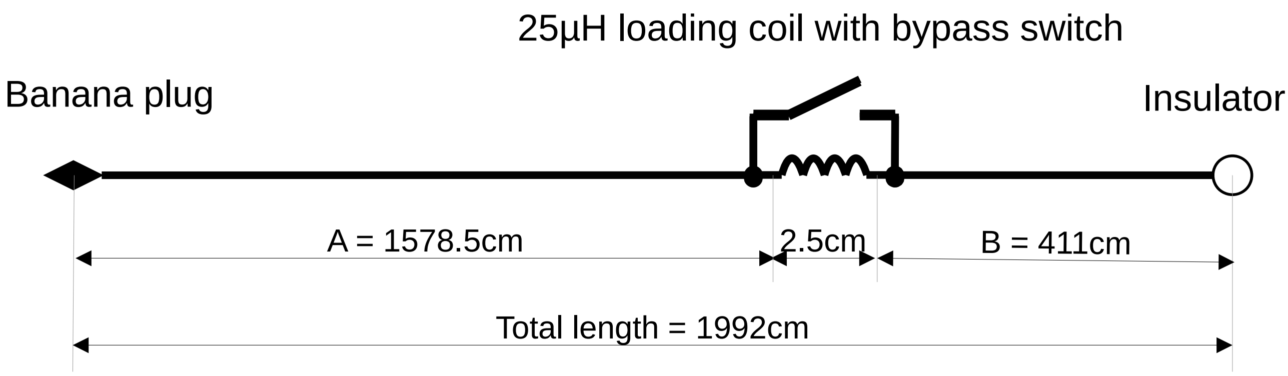

Figure 26: The standard antenna dimensions

The wire that is used has a velocity factor of 0.97 and is described under Experiment Setup. It is advisable to add 3-5% of wire length to account for the final tuning. Apart from the velocity factor of the wire, the height and configuration of the antenna, as well as the chosen coupler, also play a role when tuning the antenna for minimum VSWR. Therefore, one should tune the whole antenna system with all the parts and configured in the way that it is most likely to be used in the future.

To optimally tune the antenna, I needed several SOTA activations to find a) the optimal length of A and B and b) the optimum coil inductance.

First, I started with wire A that corresponds to 1λ for the 17-meter band. Then I attached wire B and tuned for 0.5λ on the 40-meter band. Because I knew that I would have to fine-tune these wires after inserting the loading coil, I intentionally kept the resonance frequency a bit below the target.

After I cut the wire lengths, I inserted the loading coil and removed windings until I got resonance at 5.36MHz, while still slightly optimizing the length of wire A and B to fit the other bands.

The matching 60-meter-band loading coil contains 45 windings, using 0.5mm of CuL wire on a 20mm-diameter PVC tube. This calculates to about 25µH when tightly wound.

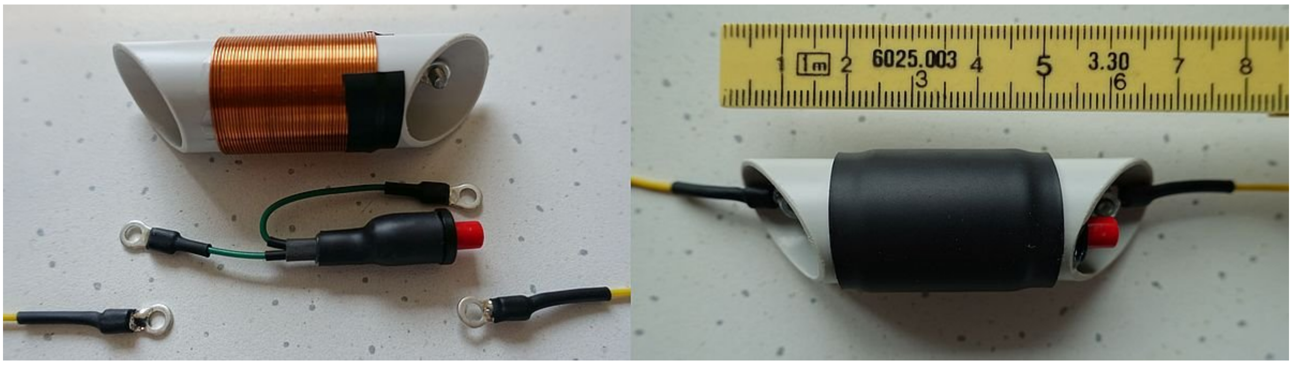

Figure 27: Building the switchable loading coil

As one can see in the above figure, I used a small push-button[29] to bypass the loading coil. To protect the button from water, I sealed the rear part of the button with heat shrink tubing, but a waterproof button would be preferable. Finally, I glued the button into the coil using a two-part epoxy glue.

Initially, the wire was directly attached to the coil without any strain relief, but after about 50 activations, one of the attached wires broke. Good thing that I carry a backup antenna with me!

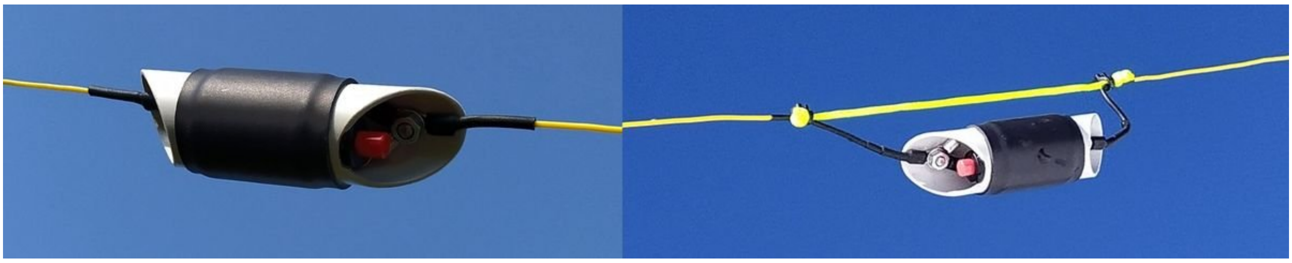
Figure 28: Loading coil without and with strain relief

After this incident, I built a simple strain relief with more layers of heat shrink tubing that has been working well so far.

From time to time, I like to try lower bands, while keeping the basic antenna configuration. To connect another radiator wire or coil to the end of the existing radiator, I use 2mm gold plated bullet plugs and sockets that are cheaply and readily available in Chinese online shops. They do not corrode, have a low contact resistance and are very light, but have to be soldered to the antenna wire. Of course, other connectors, like the hermaphroditic *Anderson Powerpole®*[30] connector might be viable alternatives, but I did not try them.

29 https://secure.reichelt.com/en/pushbutton-0-2a-60vdc-1x-on-non-illuminated-rt-s-9151-rt-p44441.html
30 https://powerwerx.com/anderson-power-powerpole-sb-connectors

With my non-hermaphroditic connectors, I always use a socket type at the end of a radiator wire and a plug type at the beginning of an additional radiator wire or coil. To protect the plug or socket with its soldered wire from mechanical stress, I always use at least one layer of heat shrink tubing.

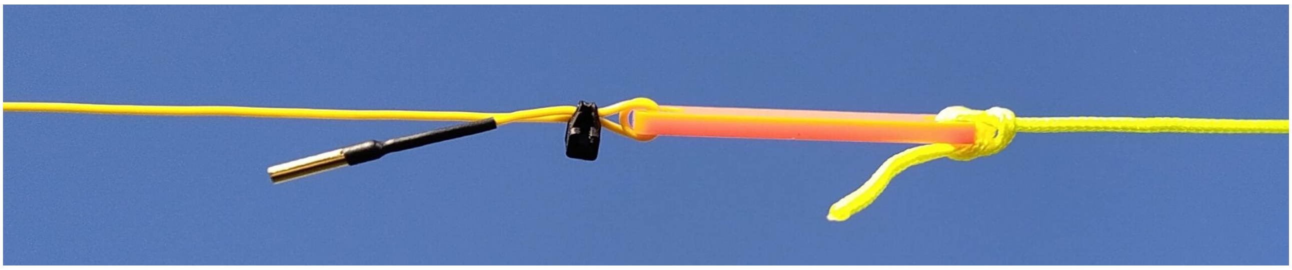

Figure 29: Antenna wire with 2mm gold plated socket, insulator and rope

Following are some typical VSWR measurements that were taken at different locations with different environments, using the antenna configuration described under Experiment Setup with a 5m-long RG-174 A/U coaxial cable.

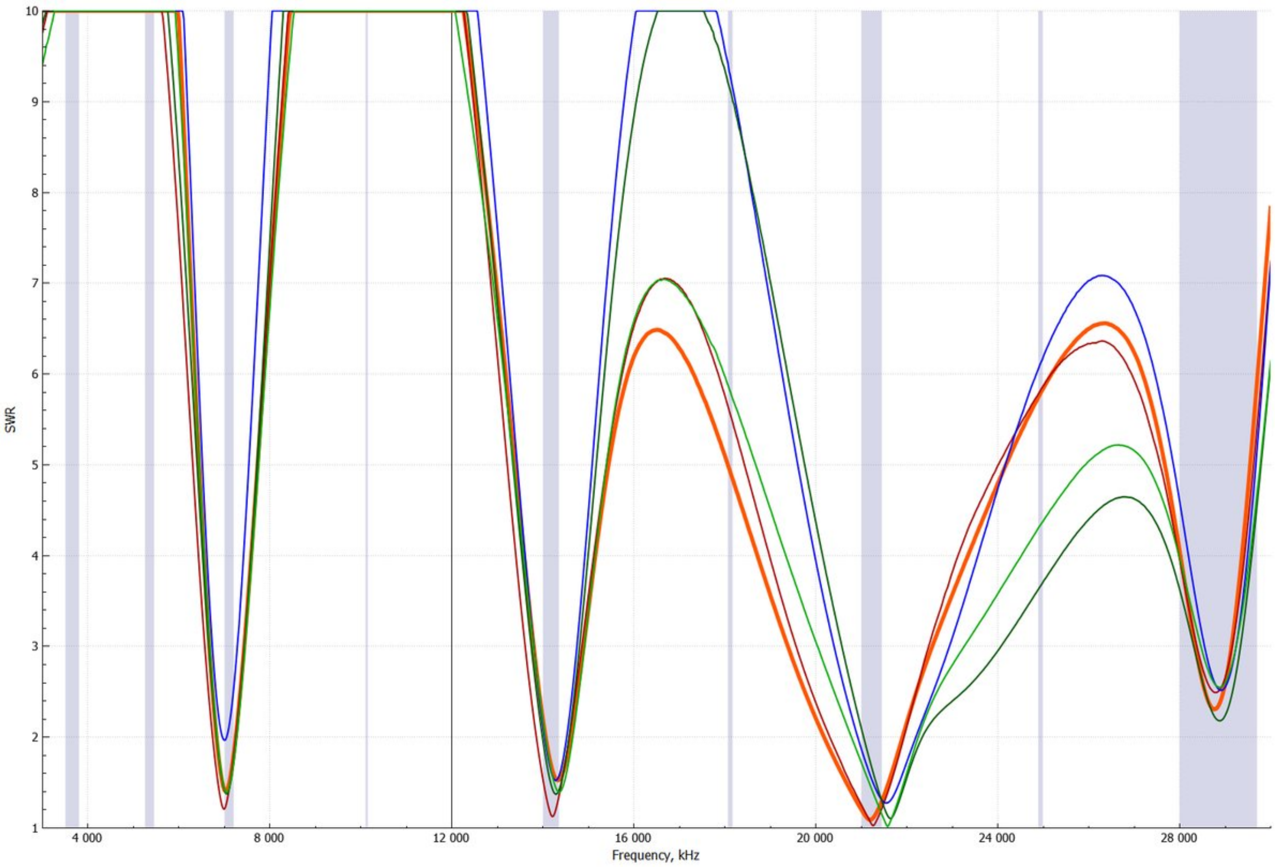

Figure 30: Typical VSWR measurements with bypassed loading coil

As one can see in Figure 30, the 10-meter band, compared to the lower bands, is not that well matched. This corresponds with the observations made under Test Coupler VSWR Measurements in the Field.

Please note that when these measurements were taken, the 5m-long coaxial cable that was used as the counterpoise had different directions in relation to the radiator and was not always fully straight, but was always lying on the ground.

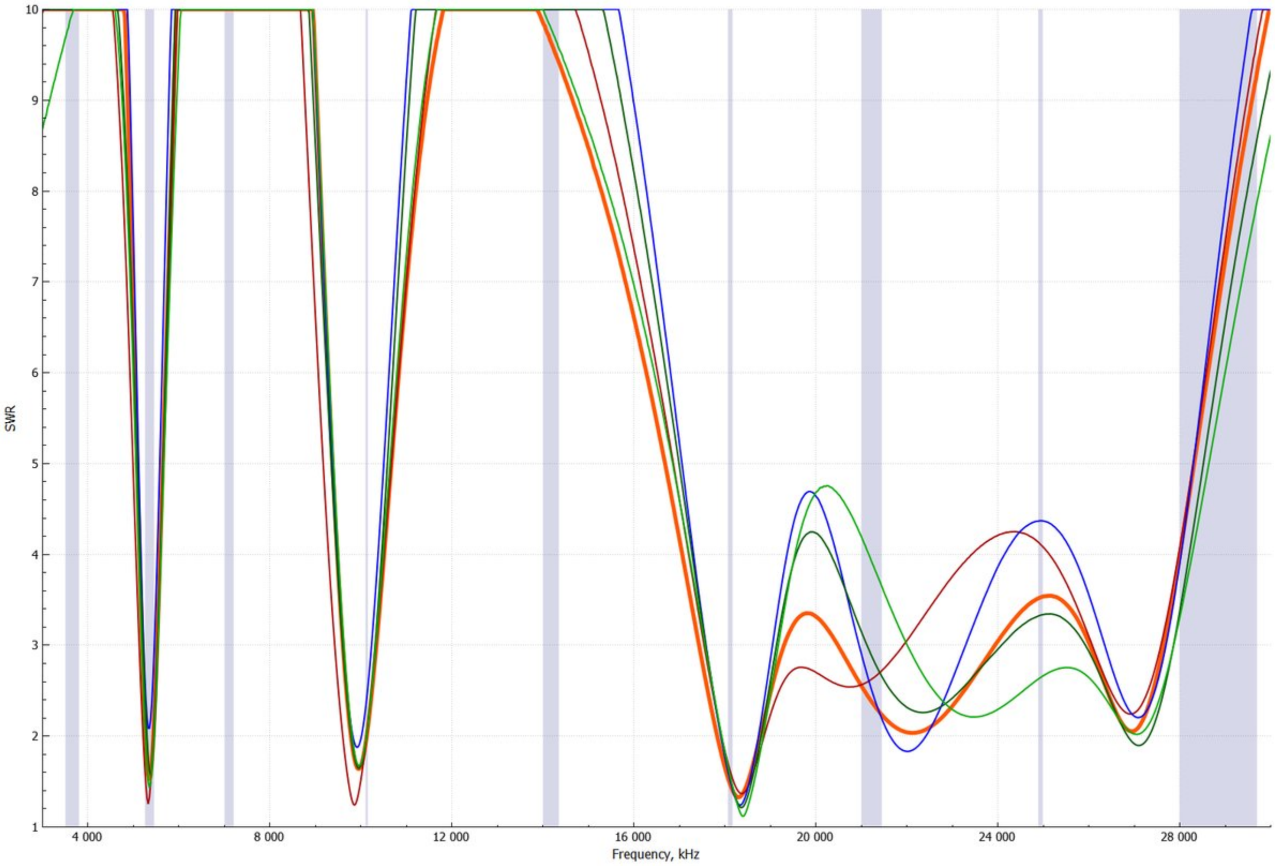

Figure 31: Typical VSWR measurements with enabled loading coil

When using the loading coil, this antenna is also resonant on the 11-meter CB band. Since this antenna is mainly intended for the ham community, I do not explicitly note the fact that, in sum, this antenna is actually resonant on 8 bands.

12.3.1 Adding the 80-Meter Band

Apart from doubling the length of the 20m-long radiator wire, there are basically two possibilities to add the 80-meter band to the antenna:

Solution A) Enabling the 60-meter-band loading coil and adding a 6.35m-long extension wire to the end of the existing radiator wire.

Solution B) Bypassing the 60-meter-band loading coil and adding a 110µH loading coil with a 2.1m-long extension wire to the end of the existing radiator wire.

Figure 32: Finished 80-meter-band loading coil with 2mm gold plated plug

The advantage of solution A) is its simplicity and greater bandwidth, but it needs 4.25m more space than solution B).

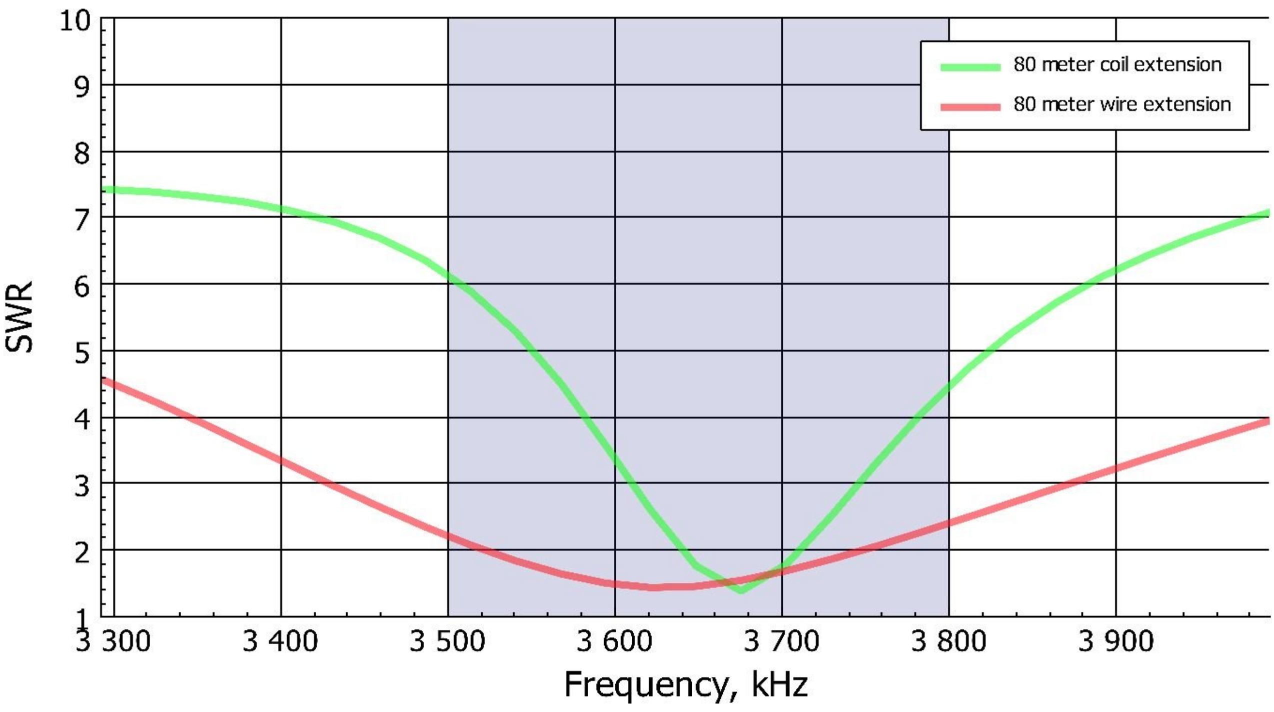

Figure 33: Comparison of the bandwidth of both solutions

Another advantage of solution B) is that one can use the 80-, 40-, 20-, 15-, or 10-meter bands simultaneously without touching the antenna. This is possible since the loading coil acts as a high-impedance choke on the higher bands, and therefore, the resonant frequencies of the higher bands change only marginally.

To get the 110µH inductivity, I wound 136 0.4mm CuL windings on a 20mm-diameter PVC tube. Thanks to this relatively thin wire, the needed 9m of this CuL wire weighs only about 10g, and the resulting coil is about 6cm long.

Figure 34: Building the 80-meter-band loading coil

The exact inductance is not that critical. If it is a bit lower, one has to add a bit more radiator wire after the coil.

Note however that, due to the low height of the antenna in relation to the wavelength, the radiation will mainly be useful for NVIS contacts.

12.3.2 Adding the 160-Meter Band

To add the 160-meter band, I propose starting with solution B) of Adding the 80-Meter Band and attaching a further 8.5m of radiation wire. Then, after the 80-meter loading coil, there will be a total of 10.6m of wire.

To use this low band successfully, one should try to keep the radiator wire as high as possible, without too much sagging. Further, the 1:64 coupler with its 3 primary windings has a low primary inductance at this frequency, and therefore, one should strive for a coupler with at least 4 or 5 primary windings. Since then also more secondary windings would be needed, the selected toroid core will be too small, so a larger one would have to be evaluated and chosen.

Even with all these shortcomings, I could make an NVIS contact on the top band with the described configuration but had some difficulties to get the VSWR well below 2.

12.4 Building the Compact EFHW Antenna

As a backup antenna and for smaller summits, I created a compact, about 12m long, EFHW antenna, applying a similar setup. It has, moreover, a better radiation pattern on the 20-meter band and upwards.

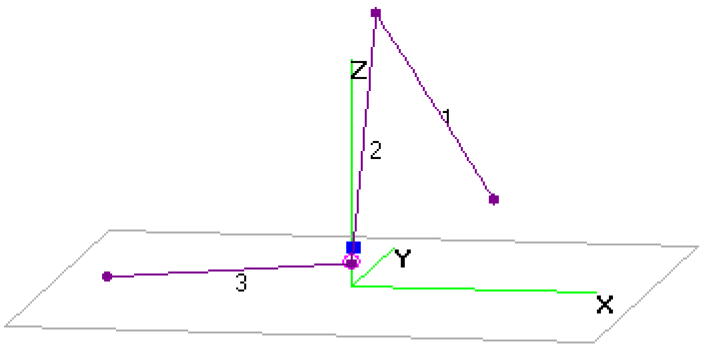

Figure 35: The geometry of the 12m-long inverted-L EFHW antenna setup

It is basically a copy of the widely used *Par EndFedz® EFT-10/20/40 Trail Friendly* EFHW antenna, briefly described in Initial Antenna Evaluations and Experiments, with an improved coupler (better toroid core geometry) and an added link for the 17-meter band.

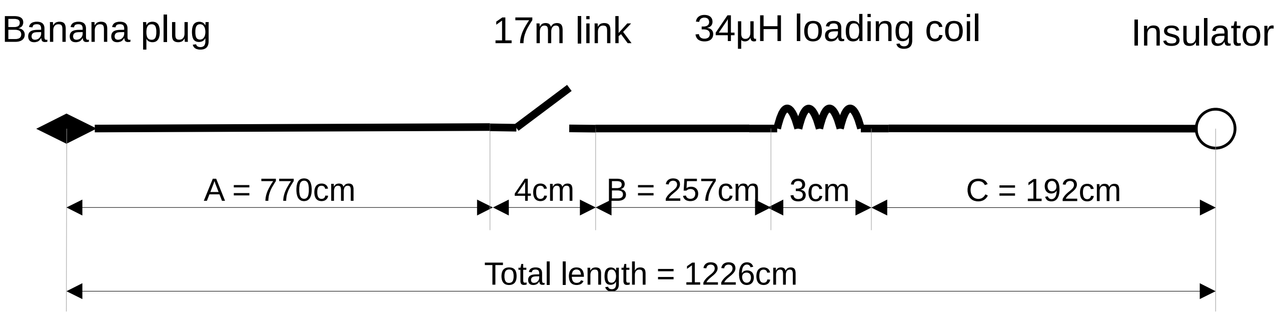

Figure 36: The compact antenna dimensions

Apart from the 17-meter band, when opening the corresponding antenna link, this antenna is resonant on the 40-, 20- and 10-meter bands.

Compared to the standard EFHW antenna, due to the shorter length, the efficiency of this antenna on the 40-meter band is reduced, but still very usable.

Following are some typical VSWR measurements that were taken at different locations with different environments using a 1:64 coupler.

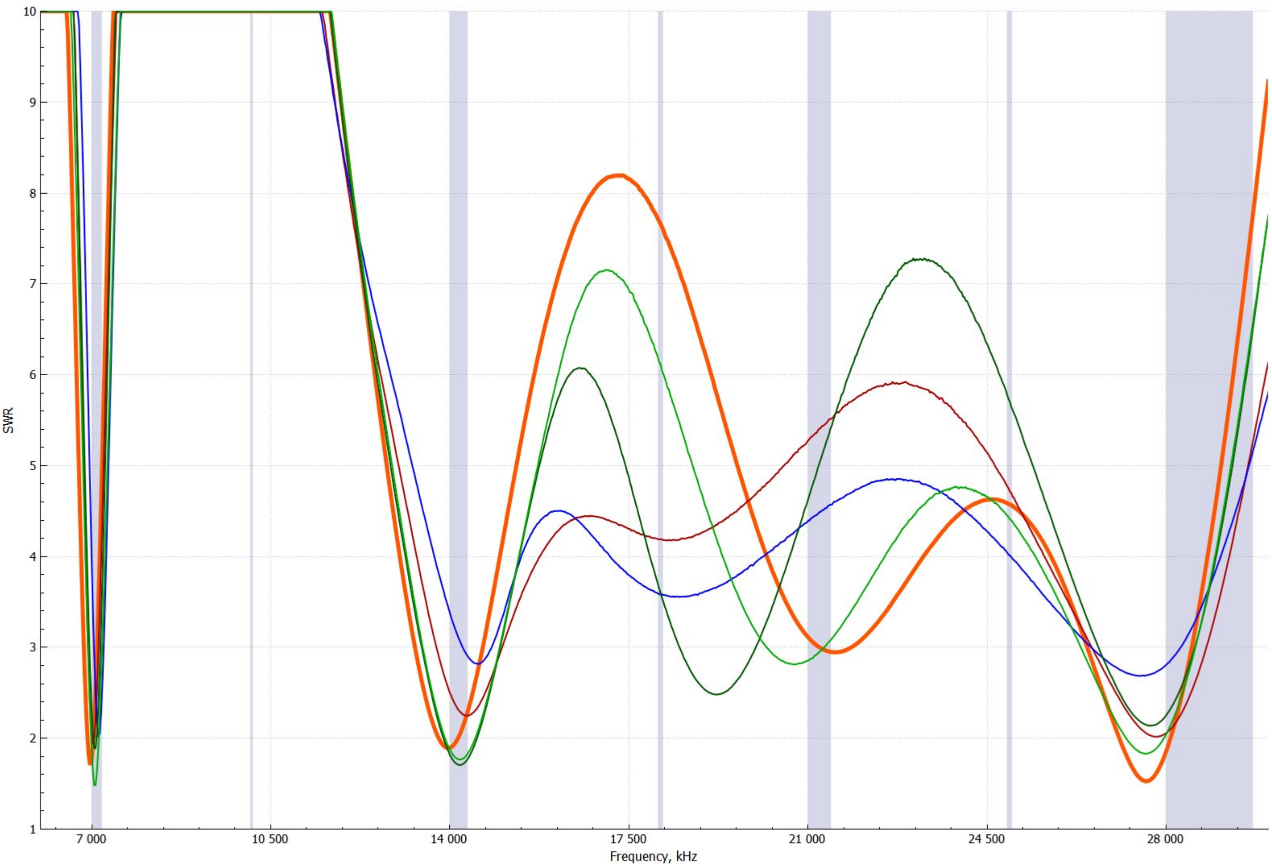

Figure 37: Typical VSWR measurements with closed 17-meter-band link

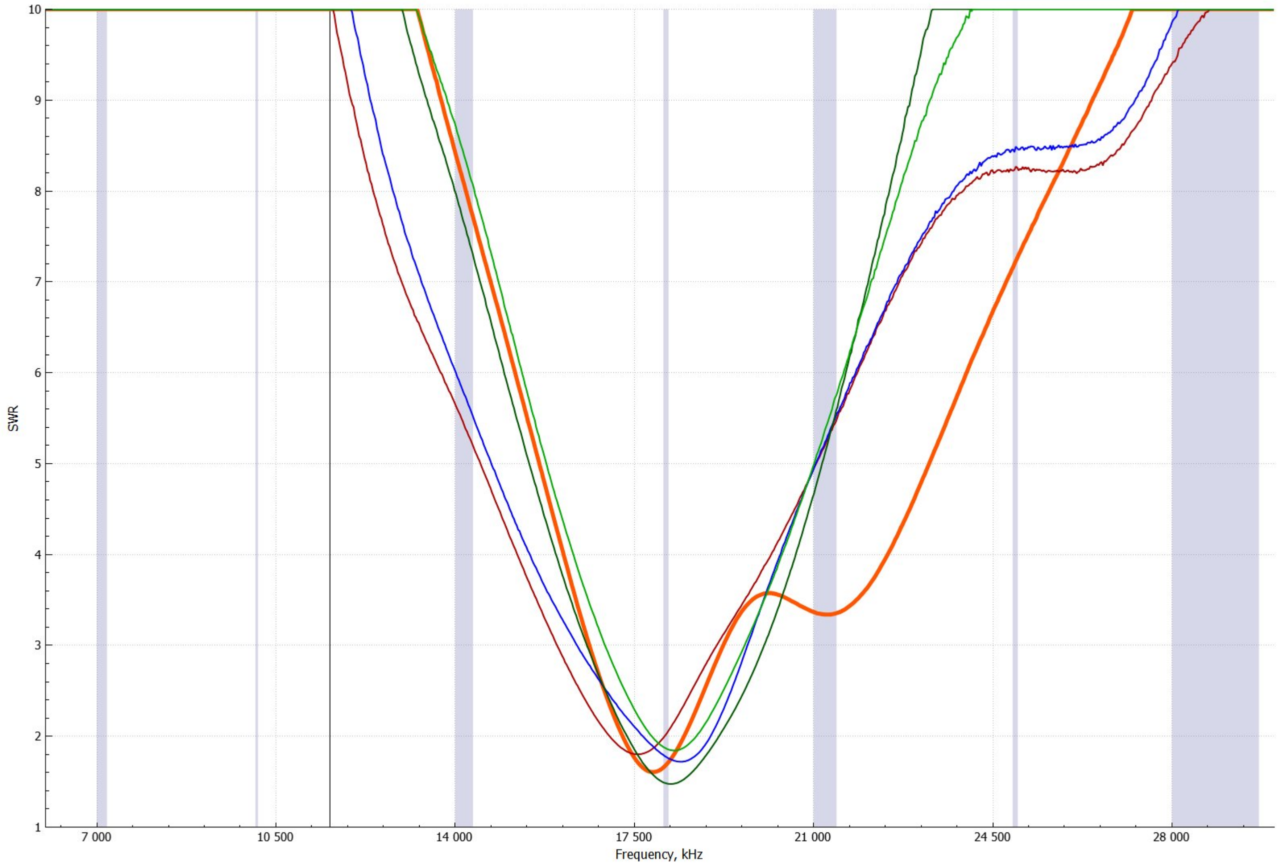

Figure 38: Typical VSWR measurements with open 17-meter-band link

As one can see in the above VSWR charts, the variation of the compact EFHW antenna values are more pronounced than those of the standard EFHW. Moreover, in Figure 37, one can see other reasonably low VSWR values between the 20- and 10-meter bands, depending on the corresponding environment and probably on the coaxial cable layout. A similar effect can be seen in Figure 31 between the 15- and the 10-meter bands, when the 60-meter-band loading coil is in use.

The following charts compare the standard EFHW with a 1:64 coupler and the compact EFHW with a 1:49 coupler, at the same location. Each graph applies a corresponding configuration to compare the minimum VSWR values.

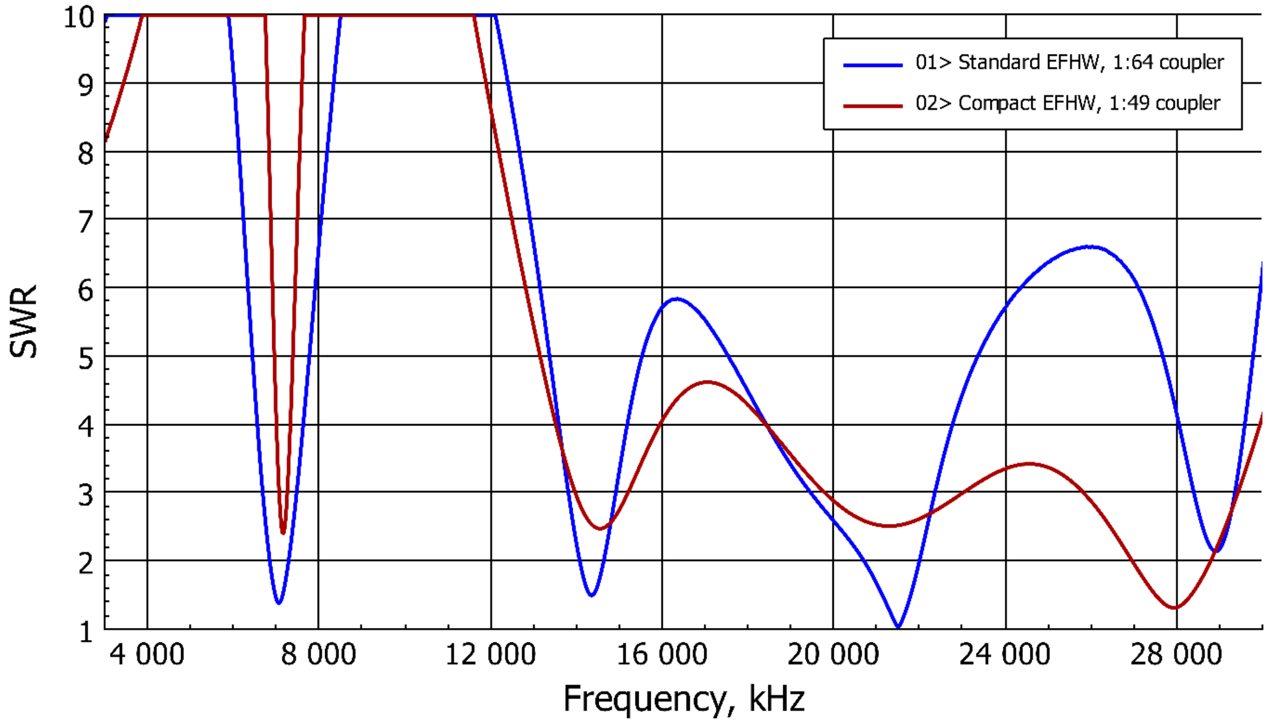

Figure 39: VSWR comparison with standard configuration

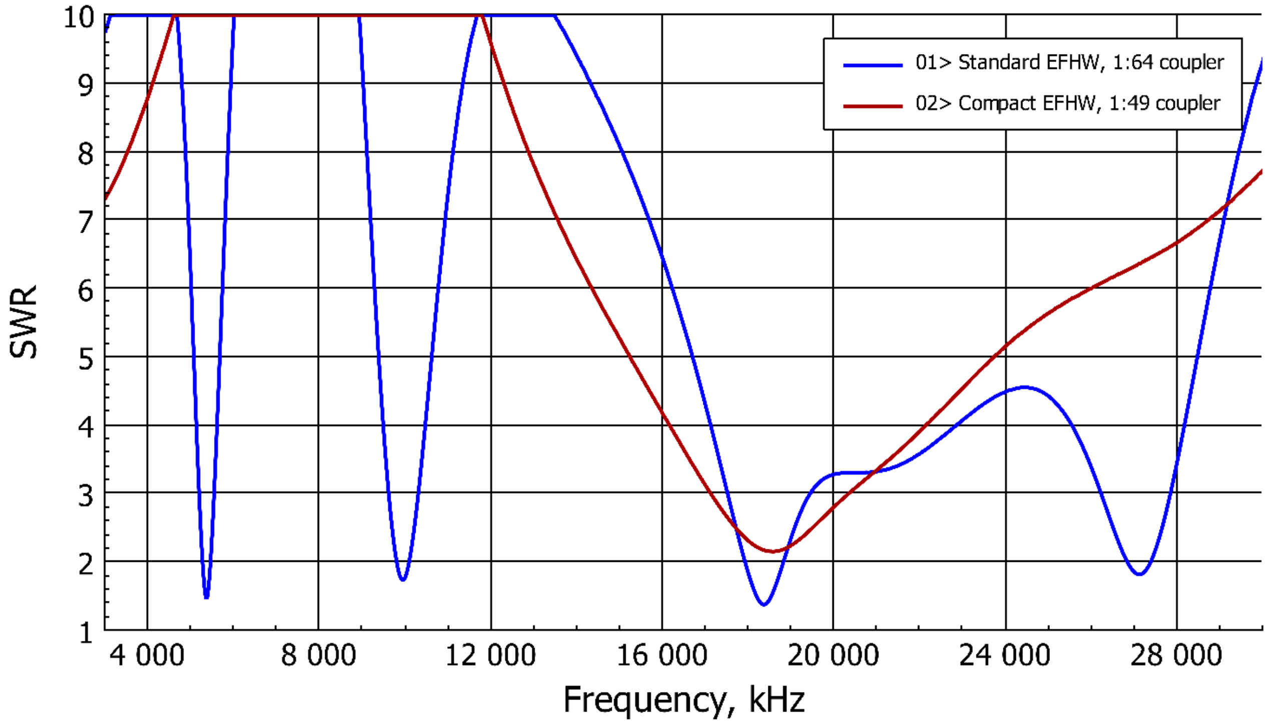

Figure 40: VSWR comparison with enabled 17-meter-band configuration

Using the 1:49 coupler for the compact EFHW, this antenna only shows a good VSWR at the beginning of the 10-meter band. This basically corresponds with the findings from Test Coupler VSWR Measurements in the Field. Because of coaxial cable losses, the VSWR value measured at the transceiver on the lower bands will look better and should not be a problem for most transceivers and therefore not trigger the VSWR fold-back protection circuit that would reduce the output power.

I still own the commercial *Par EndFedz® EFT-10/20/40 Trail Friendly* antenna that basically corresponds to my compact EFHW antenna. But I prefer to carry my home-brewed one because it is lighter and more versatile, especially because some parts can be swapped between my two self-made antennas.

The following VSWR chart compares the two antennas that were measured at the same location, with the same inverted-L configuration.

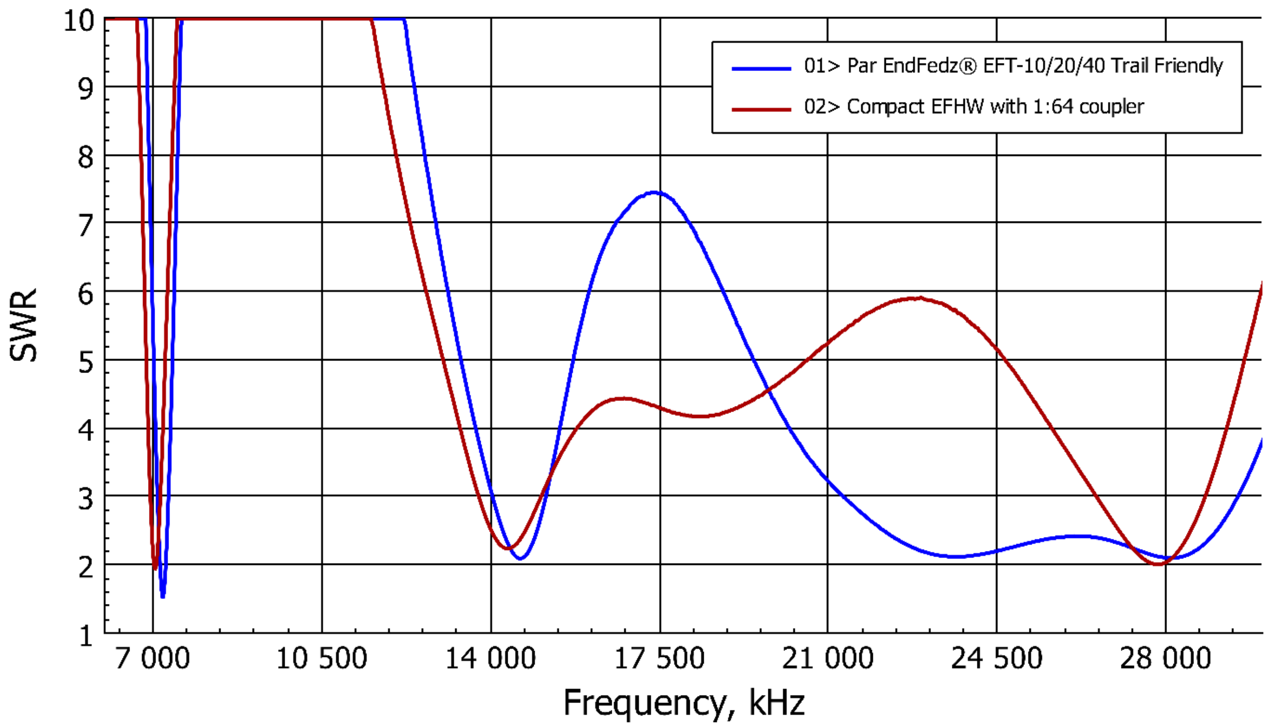

Figure 41: Comparison of a commercial vs. a compact EFHW

As one can see in the above VSWR chart, the antennas are not tuned to exactly the same fundamental frequency. When taking this discrepancy into account, these two antennas are pretty comparable with each other on the targeted 40-, 20- and 10-meter bands.

12.4.1 Adding the 60-Meter Band

To add the 60-meter band to the compact EFHW antenna, simply add a radiator wire of about 2.73m length to the end of the existing radiator wire. Apart from the 60-meter band, it will then also be resonant on the 20- and 10-meter bands.

Note however that the efficiency on this band will not be as good as when using the standard EFHW antenna with the 60-meter-band loading coil enabled.

13 Total Weight of the EFHW Antenna System

The following tables contains all the necessary items to set up and transport the described standard and compact backup antenna. The gray highlighted rows show the difference between the two alternative setups.

Table 1: Total weight with a backup coupler in an enclosure

Item	Description	Weight [g]
1:64 coupler with coaxial cable	Described 1:64 coupler with banana socket, protected with shrink tubing, attached 5m RG-174 A/U coaxial cable with BNC plug, dust cap and top mast wire holder with PVC wire slider.	123
Backup coupler	Previously described 1:64 or 1:49 backup coupler in an ABS enclosure with a BNC and a banana socket, plus a male-male BNC adapter.	53
Standard EFHW	Banana plug attached to a 20m-long radiator wire with switchable coil, attached insulator, 12m-long cord and wire winder.	152
Compact EFHW	Banana plug attached to a 12m-long radiator wire with 40-meter-band coil and 17-meter-band link, attached insulator, 8m-long cord and wire winder.	127
Glass fiber mast	SOTABEAMS compact ultra-portable 6m glass-fiber mast, with push-on top cap.	690
Mast guying kit	Fishing rod holder with cork, mast guying ring with 3 attached 2.4m-long ropes wound on a thick cardboard, 3 aluminum pegs with marker ribbons.	239
Utilities	2 Velcro straps, 2 reusable cable ties, 2 storage bags.	112
Total weight		**1496**

Table 2: Total weight with a backup coupler attached to a coaxial cable

Item	Description	Weight [g]
1:64 coupler with coaxial cable	Described 1:64 coupler with banana socket, protected with shrink tubing, attached 5m RG-174 A/U coaxial cable with BNC plug, dust cap and top mast wire holder with PVC wire slider.	123
1:49 backup coupler with coaxial cable	1:49 backup coupler with banana socket, protected with shrink tubing, attached 5m RG-174 A/U coaxial cable with BNC plug, dust cap and top mast wire holder with PVC wire slider.	123
Standard EFHW	Banana plug attached to a 20m-long radiator wire with switchable coil, attached insulator, 12m-long cord and wire winder.	152
Compact EFHW	Banana plug attached to a 12m-long radiator wire with 40-meter-band coil and 17-meter-band link, attached insulator, 8m-long cord and wire winder.	127
Glass fiber mast	SOTABEAMS compact ultra-portable 6m glass-fiber mast, with push-on top cap.	690
Mast guying kit	Fishing rod holder with cork, mast guying ring with 3 attached 2.4m-long ropes wound on a thick cardboard, 3 aluminum pegs with marker ribbons.	239
Utilities	2 Velcro straps, 2 reusable cable ties, 2 storage bags.	112
Total weight		**1566**

For long alpine hikes, I prefer to carry a lighter and slightly shorter carbon mast[31].

To make this carbon mast more robust, I removed the two top sections. Then I protected the mast base with heat shrink tubing to which I attached the top push-on cap with a cord. With all these modifications, the mast weighs only 327g. Therefore, when using this mast, one can deduct 363g from the above total weights.

Figure 42: Adapted carbon mast in action

31 https://www.sotabeams.co.uk/carbon-6-ultra-light-6-m-19-6-ft-mast/

14 Observations, Tips and Some Final Thoughts

Below are a loose collection of some miscellaneous points that do not fit into previous sections but give food for thought.

- When using links on a radiator wire, take into account that if the wires are close together on an open link, the resonance frequency will drop. I measured about 200kHz difference between the two following link configurations, measured at 18MHz using the compact EFHW antenna.

Figure 43: Open link comparison: 200kHz resonance difference at 18MHz

- I also experimented with a 4.45m-long vertical 10-meter band EFHW antenna using the test coupler. This is a perfect length for the 6m-long glass-fiber mast. After adding an extension wire of about 65cm at the feed point, it was also resonant on the 12-meter band. The VSWR was the lowest when using the 1:36 coupler setting with a 120pF primary shunt capacitor. The counterpoise length and shape had a lot of influence on the resonance frequency and the resulting antenna impedance. When optimizing the coupler or choosing a different matching technique for this antenna setup, this could be a viable alternative for reduced space summits, but unfortunately does not work reliably during low sunspot activity.
- Using thicker antenna wire means less ohmic losses, a marginally wider bandwidth and a slightly lower antenna feed point impedance. In reality, these effects have a small influence on the resulting antenna performance. For me, a lower weight is more important than a little more radiated power.

- The wire winder that is attached to the end of the antenna rope is very handy for attaching the antenna, be it to a tree trunk, a branch, a hiking pole, or even in the snow.

Figure 44: Quickly attaching the antenna cord with the wire winder

- To hold the coupler in place, I use a loop cord that is attached to the coupler. It is held below the fishing rod holder, wrapped around the spike that enters the ground (see Figure 45).
- After many activations using the standard EFHW antenna, I suddenly measured a high VSWR on my transceiver, except on the 17-meter band. I even heard a chirpy noise when touching the screen of the smartphone that I use for logging. The antenna fault was easy to detect: the radiator wire that is connected to the coil end was broken.

Figure 45: Holding the coupler in place with a cord

- The most important factor for a successful contact is the current band conditions. However, setting up the antenna as high and far away from obstacles it also helps to have a shallow radiation pattern. Further, optimizing the efficiency of the antenna system by one dB will be hardly noticeable by the other station, except when the signal is just at the noise level. But, I believe it never hurts to have the optimally efficient antenna system that fulfills your requirements.
- Is this the perfect portable SOTA QRP antenna? No, but while not perfect, for me and for now, it ticks most of the boxes. You will most likely have different goals and requirements (see Definition of the Described EFHW Antenna).
- Is there something that could be improved? Absolutely, there is always something to refine, for example:

  Improve robustness: Optimize the coil-wire connection-strain relief and use a waterproof bypass switch.

  Optimize coil loss and weight: Instead of using a gray PVC pipe as the coil form as it may contain some carbon fill material for UV protection, it would be better to use a form made of polypropylene (PP) or polyethylene (PE) that employs a lower dielectric constant, and as an added benefit, a lower density, resulting in less sag of the radiator wire. Also, the heat shrink tubing material of the coil, and also of the cable-attached coupler, could be RF-optimized.

  Minimize coupler enclosure size: Create a small, round enclosure for the coupler with a BNC socket, e.g., made with a 3D printer.

  Build other test coupler variants: The current test coupler already allows the transformation ratio of the coupler, as well as the shunt capacitor, to be switched. Building similar ones, but with a different number of primary windings, would allow all possible combinations in the field to be measured.

  Make it fancier: Control the loading coil bypass switch remotely, e.g., with a latching relay that is triggered by a miniature Bluetooth receiver. The remote control transmitter could be a simple toggle switch app on the smartphone that you already carry with you.

15 Links to Other EFHW Antenna Articles

AA5TB: The End Fed Half Wave Antenna
https://www.aa5tb.com/efha.html

VK2OMD: Owen Duffy about EFHW antennas
https://owenduffy.net/blog/?s=efhw

KX4O: Articles about feeding an antenna at its high impedance point
https://www.hamradio.me/interests/end-fed

AI6XG: End Fed Half Wave Antennas: More About the Primary Capacitor
https://www.ai6xg.com/post/end-fed-half-wave-antennas-more-about-the-primary-capacitor

K1RF: The End-Fed Half-Wave Antenna
http://gnarc.org/wp-content/uploads/The-End-Fed-Half-Wave-Antenna.pdf

WA7ARK: End Fed Half Wave Multi-Band Antennas
https://hamfest.w7yrc.org/wp-content/uploads/2019/06/EFHWslides.pdf

PA3HHO: Half Wave End Fed
https://pa3hho.wordpress.com/category/antenna-hwef/

DC4KU: KW-Drahtantennen (HF wire antennas, in German)
https://dc4ku.darc.de/KW-Drahtantennen.pdf

K6ARK: Ultimate UL Portable Resonant Antenna Build – DIY Micro End-Fed Half-Wave Matching Unit
https://www.youtube.com/watch?v=s-_LyhdGapM

Coil Inductance Calculator
https://coil32.net/online-calculators/one-layer-coil-calculator.html
Note that there is a negligible variation in the calculated results when comparing the online calculator with the corresponding Windows application or Android app.