A shortened multi-band End-Fed Half Wave (EFHW) antenna for 80-10m

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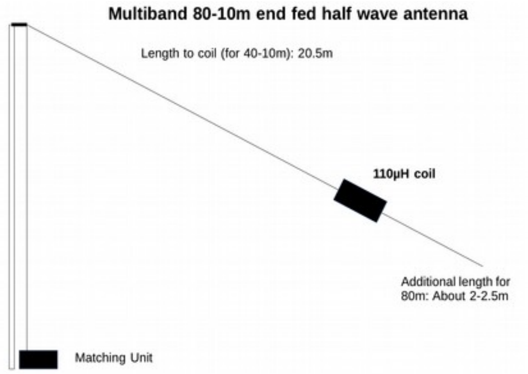


A shortened multiband antenna, about 23m long, for 80m-10m that offers low SWR (1.3:1) on 80m and 40m, and below 3:1 on 20, 15 and 10m. The antenna has a full 300kHz bandwidth on 80m between 3:1 SWR points. But performance is down about 8-12db on a dipole on 80m.

Introduction

This antenna design came from attempts to find an efficient 80m antenna that could fit into a small space. This was because Norfolk Amateur Radio Club likes to take part in the 80m Club Championship (we won in 2016), but many members don't have enough space for a full size (132ft) dipole or the 100-102 feet needed for a G5RV or W5GI antenna.

This antenna lets you get onto 80m in a horizontal distance of about 12m (40ft) when used as an inverted slope with the apex at 8m.

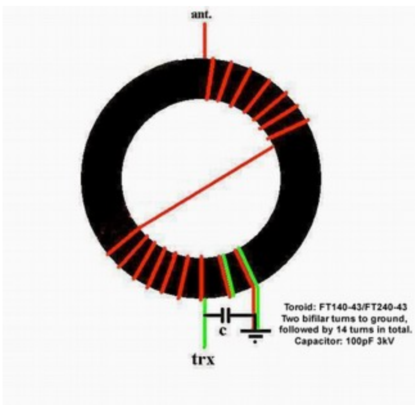
I take little credit for this as it was outlined in PD7MAA's and IK0IXI's blogs after extensive work on the antenna in the Netherlands. However, there was little on their blogs in terms of its performance or SWR characteristics. Hence this write-up.

The antenna

The antenna can be used horizontally or as an inverted L (or inverted L sloper) that uses a cheap fibreglass fishing pole to go up vertically 8m before a further 15m goes out or at an angle to a suitable fixing point.

It uses an FT140-43 or FT240-43 toroid in a 49:1 impedance matching unit at the base and a 110 micro Henry (µH) coil to act as a loading coil for 80m and a choke to stop higher frequencies using the last 2m of wire.

The matching unit



The impedance at the end of a half wave antenna is somewhere between 2000-5000 Ohms. In other designs, mine included, we make a resonant circuit using a toroid coil and capacitor to resonate at the frequency required.

In the PD7MAA design (which is based on a lot of work done by Dutch amateurs) it uses an FT240-43 as an autotransformer with two bifilar turns followed by 14 turns of the "secondary" to give an impedance step-down of 7 squared or 49:1.

Therefore, 2500 Ohms at the end of the EFHW is transformed down to around

50 Ohms and provides a better match to your coax.

However, tests show that the FT240-43 doesn't work as a 49:1 transformer across the whole of 80-10m, but is better at the bottom end. But you don't have to put up with the mismatch towards 10m as a capacitor across the input helps reduce that.

Right: Twisting the wire for the bifilar turns on the toroid

When winding the toroid it is as well to wrap white PTFE tape around the core to stop arcing. This is plumbers' tape and is very cheap on Ebay.

If using an FT240-43, start by measuring out two pieces of 20SWG enamelled copper wire – one is about 1m, long and the other about 22cm. Twist the two together for the first 130mm, ensuring that you do this neatly. The twisted section then makes up the two bifilar turns on the primary.

Then add a further seven turns on the core before passing the wire across and under to the other side of the core and winding seven more, back in the opposite direction (see image). The wire should exit roughly opposite where you started.

Adding a 100pF high voltage capacitor across the centre pin and the earth on the input should improve the match at the top end. Some reports recommend a 150pF capacitor, but I found that this gave slightly higher SWR readings. A 100pF 3kV high voltage one is better and they are very cheap on Ebay.

An alternative is to use an FT140-43 toroid, which is smaller (the "140" refers to the diameter, so 1.4 inches), which is good for at least 50W.

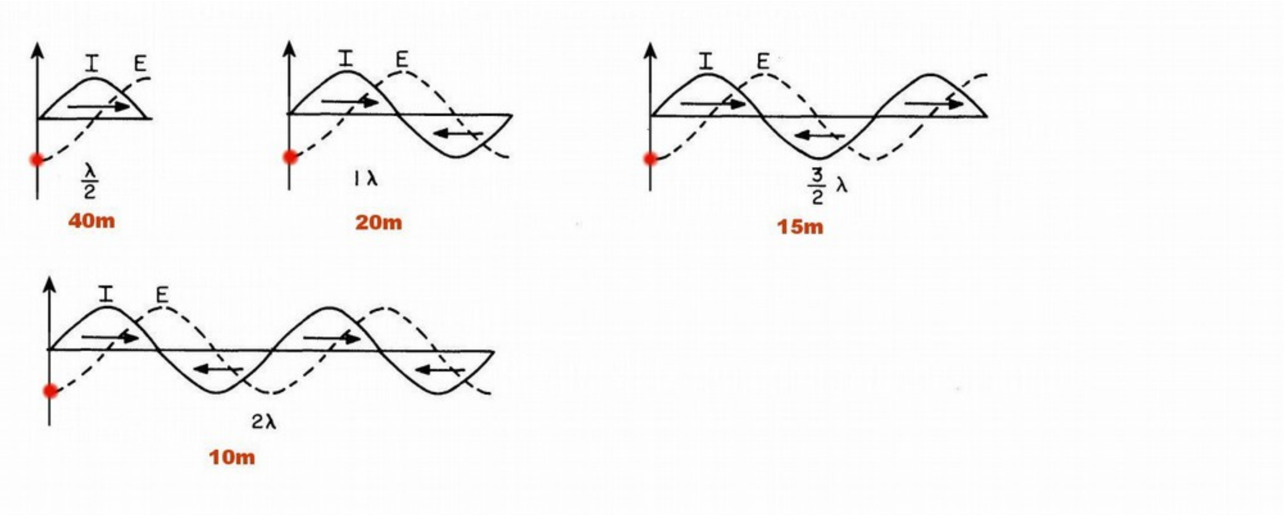
However, some reports say the smaller FT140-43 doesn't really give sufficient inductance on 80m and there are reports of it heating up on 80m. I found that the FT140-43 DID work on 80m and seems to be able to take 100W for short periods, with no fluctuation in SWR

But if you want to make an antenna that can run up to 200W I suggest you use the larger FT240-43.

Save the FT140-43 for 50-100W maximum versions of the antenna.

If you want to make a 500W version use two FT240-43s stacked together.

How the antenna works as a multiple of half wave lengths on the higher bands:



Loading Coil

The 110μH loading coil is used on the version for 80m. The coil effectively stops the RF current flowing in the final 2m or so of wire at 7MHz and above.

It also acts as a loading coil on 80m. I used standard 40mm PVC pipe from B&Q and 20SWG enamelled copper wire, which is 0.914mm in diameter. To get to 110μF I used 76 turns.

This is very tricky to do so I recommend fastening one end of the wire to the former (I used a solder tag and bolted it to the former) and then tape the wire down as you add turns. If you don't do this you can end up with a mess! Adding a final solder tag and bolting it to the former means you can then waterproof the whole coil with insulation tape.

If you don't have 40mm pipe use an online inductance calculator to work out how many turns you need to get to 110μH. This gives a reactance of 4.8 K Ohms at 7MHz.

To earth or not

Conventional wisdom has it that you must have an a earth on a vertical antenna. This is true with a quarter wave antenna, which needs an extensive ground plane. With the EFHW the earth (or a counterpoise) is still important, but not quite as crucial.

Without an earth the antenna will try and use the coax as the return path. The best way to resolve this is to fit a choke, such as 10 turns of RG213 on a four inch former or eight turns of RG58 through an FT240-43 ferrite toroid about a metre or so from the matching unit.

When I connected the earth to an earth stake I found that the 3:1 SWR bandwidth on 80m halved.

With a choke fitted there is no sign or RF on the feed line at the operating position, with or without an earth stake.

WSPR tests shows no difference in performance if it was earthed or just relied on the choke. Given the restricted bandwidth on 80m if it is earthed I suggest you try it with a choke on its own and see how you go.

Tuning the antenna

This can be quite tricky. I found the best way was to build the antenna, complete with the end piece of 2.5m for 80m. Then tune the antenna up on 7.1MHz. To do this you will have to shorten the section between the loading coil and the matching unit. Do a little bit at a time as it can make a big difference. Remember if the lowest SWR point is below 7.1MHz it is too long, above 7.1MHz it is too short.

One you have 40m tuned turn your attention to the piece after the loading coil. Hopefully it will be too long and you can start to shorten it. You have two choices. Either aim to resonate the antenna at 3.650MHz to try and cover the whole band with an SWR below 3:1, or put the low point in the section you prefer ie CW, SSB or data.

On mine I was just able to tune it for 3.650MHz and get it to almost 3:1 at each end of the band.

Performance

The performance is pretty much dipole-like on 40m and 20m. The higher bands were closed at the time. Extensive tests with WSPR on 80m showed it was about 8.5-12dB (perhaps 2 S points) down on a W5GI dipole at the same height.

While this is not a big performer on 80m it will get you on a band that you might otherwise not have access to. And if the other station is 59+20db you will still be loud!

The lowest SWR on 80m was 1.2:1, rising to 3:1 at the band edges. On 40m it was 1:1 rising to 1.2:1 in other parts of the band.

With a 100pF capacitor the antenna was about 2:1 on 14MHz and below 3:1 on 15 and 10m.

You will need to use an external ATU on 30, 17 and 12m where the antenna is not resonant – don't expect brilliant performance on these bands.

It should also work with a full half wavelength of wire on 80m (about 130-136ft) if you have the space. This would no doubt improve the performance on 80m

Update: 7MHz trap

Some “what if” scenarios to consider. The performance and bandwidth of the antenna on 80m is limited by its short length and large 110μH loading coil. But what if you replaced the coil with a 7MHz trap instead? MMANA-GAL shows you could make a 40m (7MHz) trap using a 100pF high voltage capacitor and a 5.690μH coil in parallel. This could be made using the same 40m pipe, 9.44 turns of 1mm wire and the same capacitor you use in the matching unit. It would have to be set up using a GDO or analyser to make sure it really does resonate on 7MHz. Modelling with MMANA-GAL shows you would then need around 14.95m of bare wire (about 14.2m of insulated wire) after the trap to resonate on 3.65MHz. This would no doubt give better bandwidth on 80m, but the vertical (90 degree) gain only looks to be about 1dB better. Worth trying though. The only issue is it might screw the matching up the higher HF bands, such as 20m according to the model. Let me know if you try it.

Update: Inverted V

What if you arrange the antenna as an inverted V with the apex at 8m and the feed point and end point lower? The model shows that the vertical NVIS gain (at 90 degrees as this was designed primarily for intra-UK contacts) on 80m GOES DOWN about 2dB. Might be worth trying through, especially if it suits your garden better.

Update: Full size 132ft EFHW

For one month I replaced the 66ft wire and loading coil and replaced it with a full 132ft of wire, connected to the FT240-43 balun.

This was a little bit of a compromise as the last 20ft of the antenna had to run down a fence to fit it into the garden.

The SWR figures were as follows:

FT240-43 132ft/100pF capacitor

NO earth stake/no choke

Frequency	SWR (:1)
7	1.9
7.01	1.8
7.025	1.8
7.05	1.6
7.075	1.5
7.1	1.4
7.125	1.3
7.15	1.3
7.175	1.3
7.2	1.2
10.1	4.1
10.125	4
10.175	3.9
10.2	3.8
14	2.5
14.05	2.3

Frequency	SWR (:1)
3.5	1.3
3.55	1.6
3.6	1.9
3.65	2.1
3.7	2.3
3.75	2.6
3.8	3

14.1	2.2
14.15	2.1
14.2	2
14.25	1.9
14.3	1.9
14.35	1.8

18.068	2.3
18.1	3.9
18.15	2.3
18.168	2.3

21	3.3
21.05	3.3
21.1	3.2
21.15	3.2
21.2	3.1
21.25	3.1
21.3	2.9
21.35	2.9
21.4	2.9
21.45	2.9

24.89	2.8
24.9	2.8
24.95	2.8
24.99	2.8

28	3.7
28.1	3.7
28.2	3.7
28.3	3.7
28.4	3.6

28.5	3.5
28.6	3.4
28.7	3.4
28.8	3.3
28.9	3.2
29	3.1
29.1	3
29.2	2.9
29.3	2.9
29.4	2.9
29.5	2.9
29.6	2.9
29.7	2.9

Performance on 80m was equal to or down 1-2 S pts on the W5GI. Performance on 40m was down quite a bit, perhaps 2-3 S pts. It appeared to be more directional compared with the W5GI (which was at right angles). Equal performance on 20m to Tunisia.

So the performance on 80m was marginally better than the shortened version, but the 40m performance was worse. This was confirmed with WPSR tests. The performance on 20m was roughly similar. The bands higher than 20m were mostly closed during the test.

I think the compromise position of the 132ft wire didn't help the antenna's performance and I think that overall, the 66ft and loading coil version was better on 40m an higher. If you could get the whole wire in the clear you might better results.

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Sources:

http://pa-11019.blogspot.co.uk/2012/04/149-transformer-for-endfed-antennas-35.html

http://nuke.ik0ixi.it/Antenne/LOlandesina/tabid/606/Default.aspx

Appendix: SWR results using FT140-43 toroid:

FT140-43/100pF capacitor with 110μH coil

No earth stake/choke 1m down coax

Frequency	SWR (:1)
7	1.1
7.01	1
7.025	1
7.05	1
7.075	1
7.1	1
7.125	1.1
7.15	1.1
7.175	1.1
7.2	1.2
10.1	2.5
10.125	2.5
10.15	2.5
10.175	2.5
10.2	2.6
14	1.7
14.05	1.7
14.1	1.7
14.15	1.8
14.2	1.8
14.25	1.8
14.3	1.9
14.35	1.9
18.068	3.5
18.1	3.5
18.15	3.5
18.168	3.6
21	2
21.05	2
21.1	1.9
21.15	1.9
21.2	2
21.25	2
21.3	2
21.35	2
21.4	2
21.45	2.1

Frequency	SWR (:1)
3.5	3.5
3.55	2.4
3.6	1.3
3.65	1.7
3.7	2.2
3.75	2.6
3.8	3

Resonant at 3.610MHz (1.2:1) and 7.090MHz (1:0:1)

2:1 Bandwidth	3.565 – 3.684
	119kHz
3:1 bandwidth	3.526-3.804
	278kHz

Frequency	SWR (:1)
24.89	2.6
24.9	2.7
24.95	2.7
24.99	2.7
28	1.7
28.1	1.8
28.2	1.8
28.3	1.8
28.4	1.8
28.5	1.9
28.6	1.9
28.7	2
28.8	2.1
28.9	2.1
29	2.1
29.1	2.3
29.2	2.3
29.3	2.4
29.4	2.6
29.5	2.5
29.6	2.5
29.7	2.6