

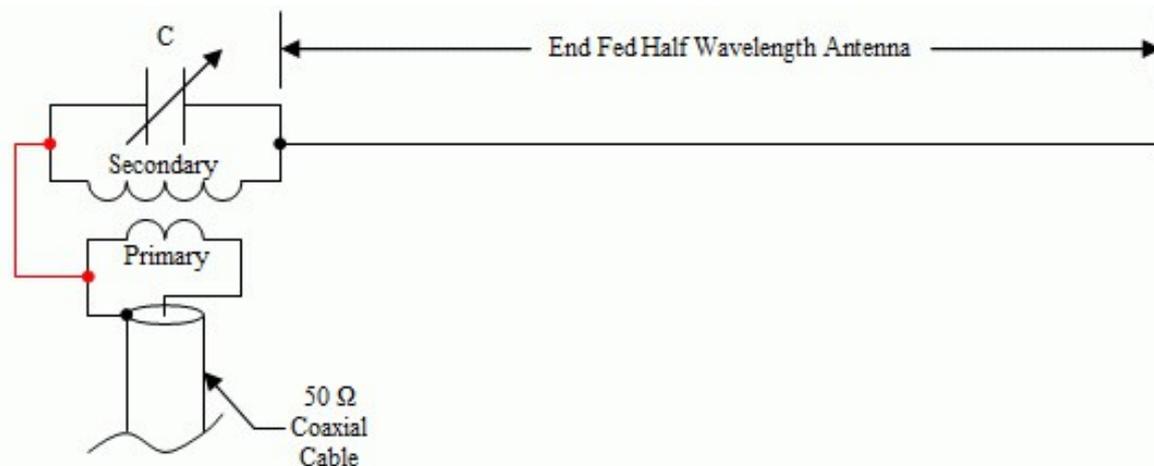
The GOKYA EFHW – an end-fed half wave monoband HF antenna, plus two multiband versions (New!)

A practical, cheap monoband or multiband (new!) vertical antenna that is great for DX and very cheap to build.

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Contents

1. An overview and where it all started
2. Using the [EFHW for 20m](#) at GB0CMS
3. EFHW featured in "[Stealth Antennas](#)"
3. More about [earthing/ground radials](#)
4. Using the [20m EFHW on 10m](#)
5. Detailed [construction](#) notes
6. Turning the EFHW into a [four-band antenna](#)
7. The [20m-17m-15m three-band trapped EFHW](#)



Where it started in 2009: I like half wave dipoles. They are easy to make and easy to set up. They also perform very well and usually beat a compromise antenna hands down. With 10m about to come alive again as solar cycle 24 gets going what I wanted was a low-angle efficient radiator that could be put up and down in a couple of minutes.

My experience with ground plane verticals has been OK, but they are only as good as the earth beneath them. That is, they really need an extensive array of ground radials to work properly – not easy to put down when you are in a hurry.

I also like to use fibreglass fishing poles as antenna supports. These are available cheaply (I have a 7m version and a 10m version that I bought from Sandpiper at the

Leicester rally). The only problem is that they don't have lateral strength – they are good for supporting verticals, but not so good for half-wave horizontal dipoles.

What I really wanted to do was have a vertical half wave dipole, but the problem is that while the impedance at the centre of a dipole is about 50-75 Ohms, and very easy to match to coax, an end-fed half-wave has a very high impedance indeed, around 2000-3000 Ohms. If you just connect it to your coax or rig you will be disappointed.

What can you do?

After a lot of searching on the web I found the answer. Steve AA5TB of Fort Worth Texas has a great site with lots of information at www.aa5tb.com.

It was his site that helped me build my end-fed half wave for 10m, although the design can be modified for any of the HF bands.

First you need a half-wave length of wire. Using the formula $468/\text{frequency}$ I cut a piece 16 feet 5 inches. This comes out at precisely 5m.

Next you need a T200 (red) toroid. These cost £4 from JAB Electrical Components (www.jabdog.com) and can be picked up at many rallies.

I wound 17 turns of enamelled copper wire on the toroid as the secondary winding – each time the wire passes through the toroid counts as one turn. My wire was some I had lying around and was about 1.25mm (18 SWG) in diameter. JAB can supply this too.

Leave a little at the end for connections and then wind two turns over this for the primary, again leaving a little spare.

Across the 17-turn winding you need to connect capacitor. I tried a small variable but as the minimum capacitance was about 22pf I couldn't get the circuit to work.

But never fear, the answer is very simple and very cheap. RG58 coax has a capacitance of about 28.8pF per foot, so cut off about 10 inches and connect that across the ends of the winding. You'll find that an electrical connector (chocolate) block makes life easier.

Now, connect your coax across the two turn primary, connect your antenna to one of the secondary wires **AND CONNECT ANOTHER PIECE OF COPPER WIRE FROM THE OTHER SECONDARY WIRE BACK TO THE BRAID OF THE COAX (shown in red in the diagram)**.

An end fed normally needs an earth or ground plane to work. But with an end-fed half wave there is less current flowing in the ground and it can become almost unnecessary.



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The usual way of feeding an end fed half wave is against a short counterpoise, but I have found that with QRP you can feed this one without an earth stake, counterpoise, or radials. The impedance is so high that little current actually flows down the braid. If the coax is laying on the ground the braid appears to capacitively couple to earth.

If you do get any RF problems or want to run 100W just form a coax choke by coiling about 8-10 loops of coax in a six-inch coil about a foot or two from the antenna and then use a single earth rod and four short radials.

Now the fun starts. If you have an antenna analyser it will make life a lot easier. If not, you can do it with a rig and SWR meter.

If using an analyser connect it to the end of the coax and see where the antenna resonates. It will probably be lower than 10m. Snipping off half-inch lengths of the coax will reduce the capacitance and move the resonant frequency higher. If you get down to about four inches and are still not there try removing a turn off the secondary coil.

I ended up with 15 turns on the secondary and a piece of coax about four inches long – it is better to remove turns than snip too much off the coax.

The end result was an SWR across the entire 10m band of less than 2:1. In fact, at resonance it was about 1.2:1. But did it work?

As always, the 10m band wasn't open as I connected it to my rig to test, but I was able to hear CB stations on 27.6MHz that were at least 20 miles away from my QTH. On switching to my usual 10m half-wave dipole they just vanished, proving that the antenna is working quite well.

The angle of radiation of a vertical half-wave is quite low so it should be quite a DX performer, and it is very easy to install too. It would be very easy to build the matching network into a plastic box to waterproof it.

It was at this point that I had a brainwave – if the antenna could be made to work on 10m, it should be easy to scale for other bands.

I worked out that if I doubled the length of the wire radiator to 10.05m (33 feet) I would have an effective low-angle half-wave radiator for 20m. As one of my fishing poles was 10m long it was able to support the new wire quite easily, even it did look a little unwieldy.

A couple of minutes with a pen and paper and I soon realised that the equation for the resonant frequency of an LC network ($f = 1/2\pi \times (\text{root})LC$) showed that halving the



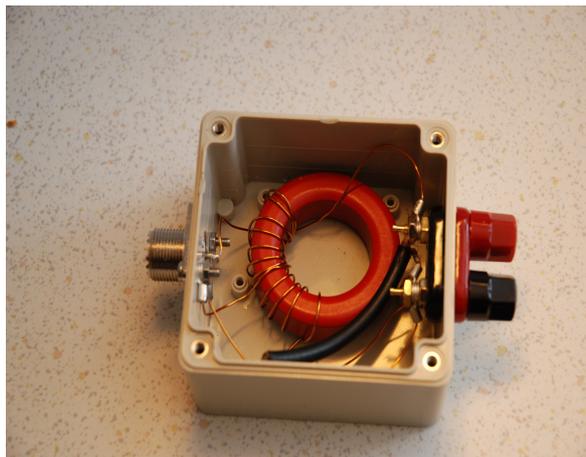
frequency meant that I had to multiply the capacitance value by four to make it resonant.

So I cut another piece of coax at four times the length of the original piece, hooked it all up and plugged it into the MFJ analyser. I couldn't believe it – the instant result was an SWR of 1:1.1 on 14:150MHz rising to only 1:1.5 at the ends of the band.

Tests showed that it was at least as good as a half wave 20m dipole at 30 feet and US stations were romping in during the afternoon on SSB. It outperforms a regular quarter wave vertical with radials laying on the ground by a couple of S points and is a lot easier to put up.

I used it at a "Jamboree On The air" station, GB0CAW in Norfolk, and it outperformed a G5RV at 30 feet by about 1 S point.

The matching unit has now been put in a Maplin's waterproof box (see right) and the 10m pole has been put up through a tree in the garden. While some signals are weaker by 1-2 S points, invariably it works better on DX – notably the USA and the Caribbean.



For a really stealthy antenna I could take the pole down and put a fishing line over the top branch (using the pole) so that I can haul a wire up into the branches. It should be virtually invisible.

These antennas are very easy to make and only need a few components. If you have little space in your back garden for dipoles a vertical half-wave could be the way to go. Why not try one?

Update: April 2010

We used the EFHW for 20m at GB0CMS – the station set up for International Marconi Day at Caister Lifeboat (see right).

I now have a ground spike for mounting the 10m fishing pole, which is available in the UK from [Coopers of Stortford](#). This corkscrews into the ground and is very solid.

The antenna worked very well and we were able to work around the world, including VK4, KP2, and numerous US and EU stations. Two friends have also built 20m and 17m versions and rave about them.

Update: November 2010

The design was featured in the RSGB's *RadCom* magazine and also my own [Stealth Antenna](#) book.

It has generated a lot of interest. I have now built them for 20m, 17m, 15m and 10m. Using lengths of PVC-coated wire of 10.15m, 6.78m and 5.05m respectively.



They all worked well, but you may have to fiddle with the number of turns and the spacing, plus the length of the coax, to get a good SWR.

I tested the 15m version against the Rybakov (7.8m and 4:1 UNUN), which is also described on this blog. The EFHW was better by about 1 S point, sometimes a little more.

This was a good test as it shows that the Rybakov, which handles five bands (20m, 17m, 15m 12m and 10m), is a damn good antenna for the amount of work it takes to build one. But, it is ground dependent and needs a good radial system. As a compromise it works well, but if you want something a little better for DXing, contesting or DXpeditioning the EFHW works a little better, albeit as a monoband antenna.

Update April 2012

I've always been a little concerned by people who say "it can't work" and "you need more ground radials". I think I need to address this latter statement a little more.

Yes, you get ground currents with an EFHW, but they are less than with a quarter wave vertical as the current maximum is moved a quarter wavelength up the wire away from the earth.

If a fair length of coax is fitted to the antenna the capacitive coupling of the coax outer to earth seems to suffice, especially if running QRP. Even with 100W I haven't had a problem when running on my own.

However, if the antenna is being used in a multi-station set-up you need to take more care with grounding. During the 2011 International Marconi Day (IMD) event we found that the 20m EFHW antenna caused interference to our other station on 40m. Even keying the microphone and saying nothing resulted in noise on 40m.



This was cured completely in the 2012 IMD event. All I did was a) ground the matching unit to the screw-in steel spike used to support the fibreglass antenna pole, b) add four eight-foot radials at the base, again connected to the earth terminal on the matching unit, and c) I put a choke balun (about eight turns of RG58 through two ferrite rings superglued together and then boxed) on the coax about 20 ft from the antenna.

This worked well, the antenna helped us make about 250 contacts including Australia and Barbados on 20m and there was zero interference to the 40m station (which was running a horizontal W5GI "Mystery Antenna").

The choice of vertical for 20m and horizontal for 40m wasn't an accident – I thought that having different polarisation might help with interference issues. We also situated the antennas as far apart as possible.

You can see all this in action in a video at www.youtube.com

Update July 2012

My local club took part in our annual "Radio by the Seaside" event and I took my EFHW for 20m along – there is actually a [YouTube video you can watch](#).

I had a bit of brainwave while there. Surely the impedance at the end of a half wave for 20m must be similar to the impedance of a full wave wire for 10m?

In other words, can you attach the 10m matching unit to a length of wire that is a half wave for 20m (a piece 10.05m long) and get a good match?

So I tried it and found that I actually got quite a good match at around 28.7MHz. Although the band was dead it could be a quick way to QSY from 20m – 10m, just by switching the matching box over.

The radiation pattern isn't so good with a one wavelength wire (you get some high angle radiation) but it saves having two antennas up or taking one down and changing the wire.

Try it and let me know what you find.

So now, you want to build one – read on!

Detailed construction notes

Introduction

The EFHW monoband matching unit (inspired by AA5TB) allows for a half wavelength of wire to be connected, giving a 50 Ohm impedance match to the transmitter (without a ground plane or ATU) at the frequency of operation. The SWR is likely to be below 1:1.5 and when used as an omnidirectional vertical the low angle of radiation (typically with a maximum at about 20 degrees) will give good results on DX, outperforming a G5RV, doublet or similar by up to 2 Spts.

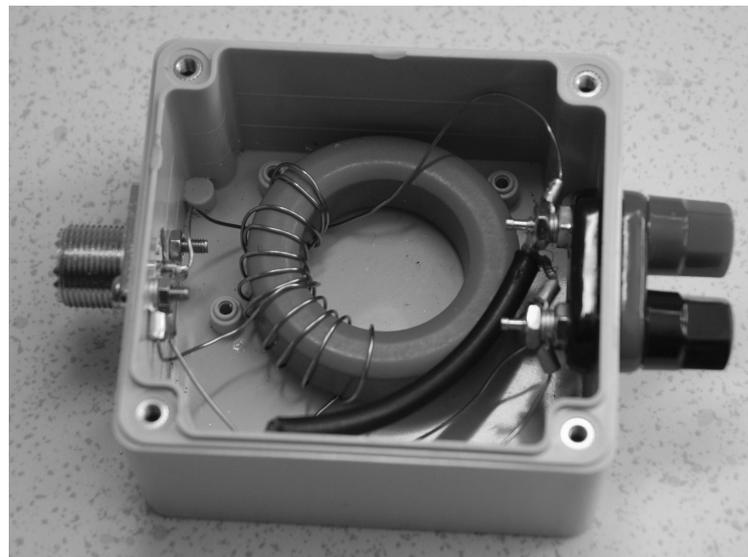
The mounting box

Start by putting two pieces of masking tape on opposite sides of the mounting box. Carefully mark the centre of one side and drill a 15mm hole for the SO239 socket.

Note: If you haven't got a big enough drill use a Dremel tool or file to make the hole large enough.

Holding the SO239 in place, use it as a guide to drill two 3mm holes diagonally opposite each other for its mounting bolts.

On the opposite side of the box drill two 8mm holes for the antenna connection post and optional earth. Fit the two posts.



Winding the matching toroid

Using the enameled copper wire wind 13 turns on the toroid. Each time the wire passes through the toroid counts as one turn. This is the secondary winding. Don't overlap the turns, but keep them quite close together – we may need to space the windings out later when we get to the tuning phase.

Now wind two turns over the existing winding. This is the primary winding. Scrape or burn some of the enamel off the ends of the primary winding and also cut another short piece of enamelled copper wire (about 5in/130mm long) and scrape the enamel off the ends. This is the secondary to primary earth shorting wire which allows the antenna to work without radials or a counterpoise (see diagram). Using a solder tag connect one side of the primary winding and the earth shorting wire to one of the SO239 earth mounting bolts. Connect the other end of the primary winding to the centre of the SO239.

The coax capacitor

Now cut the coax capacitor to the length shown in the table below, depending on the band you are designing the matching unit for. Once tuned, the overall length of the coax capacitor will probably be about 1-2 inches shorter than this.

Bare the wires at one end of the coax and leave the other end as it is – you will be snipping this with cutters to tune the antenna later.

Band	Starting coax capacitor length (you will cut approx. 1-2in shorter than this to tune)	Length of half wave antenna (assuming insulated wire)
20m (14.175MHz)	35.5cm (14in)	10.05m (32ft 11.6in)
17m (18.1MHz)	24.5cm (9.5in)	7.87m (25ft 9.8in)
15m (21.225MHz)	19cm (7.5in)	6.72m (22ft 0.2in)
12m (24.9MHz)	15.25cm (6in)	5.72m (18ft 9in)
10m (28.5MHz)	13cm (5 ins)	5m (16ft 5in)

Wiring up the secondary/coax capacitor/earth shorting wire

Connect one end of the secondary and the inner of the capacitor coax to the red antenna terminal using a solder tag. Connect the other end of the secondary, the braid of the coax and the earth shorting wire to the green terminal using another tag.

Tuning

Caution: This is best done with an antenna analyser. Arrange for the half wave antenna wire to be supported vertically outdoors, well away from any metallic object (a fibreglass fishing pole is ideal). Connect the antenna to the red EFHW connection and connect the analyser to the SO239. Earth the other terminal and add two 5m radials on the ground. Sweep and you will find a resonant point, probably BELOW where you expect it to be in terms of frequency.

If this is the case space out the secondary windings until the antenna is resonant at the bottom of the band you require. At this point you can snip away the coax (quarter of an inch at a time) to shift the resonant point upwards slightly. Do not remove more than one inch.

Shortening the coax will move the resonant point up in frequency, as will spacing out the turns. Compressing the turns will move the resonant point downwards.

This is a very sensitive procedure and may require many iterations. Once you have the resonant point where you want it in the middle of the band use a hot melt glue

gun to hold the windings in place and the toroid firmly in the box. Make sure that the end of the coax capacitor cannot short out (Check for stray copper wires and cover the end with PVC tape).

Problem solving

The antenna is designed to work on QRP (5W) without a ground plane or counterpoise – it uses the outer of the coax as the return path for the minimal antenna currents. If you use higher power or do have RF problems you can connect an earth or short (2 or 4 x 5m) counterpoises to the earth (green) terminal.

This may be required if using the antenna as a horizontal end fed dipole with a short length of coax. If you cannot get the antenna to tune, check the wiring first. Do not cut the capacitor any shorter than 2in less than the starting length. If the antenna resonates lower in frequency than you require remove a secondary winding and try again. If higher add a winding.

By the way, regarding adjusting the tuned circuit Ken G8BEQ told me that more C [the coax] and less L will give a narrower bandwidth. There might be room for some experimentation here.

Turning the EFHW into a four-band antenna

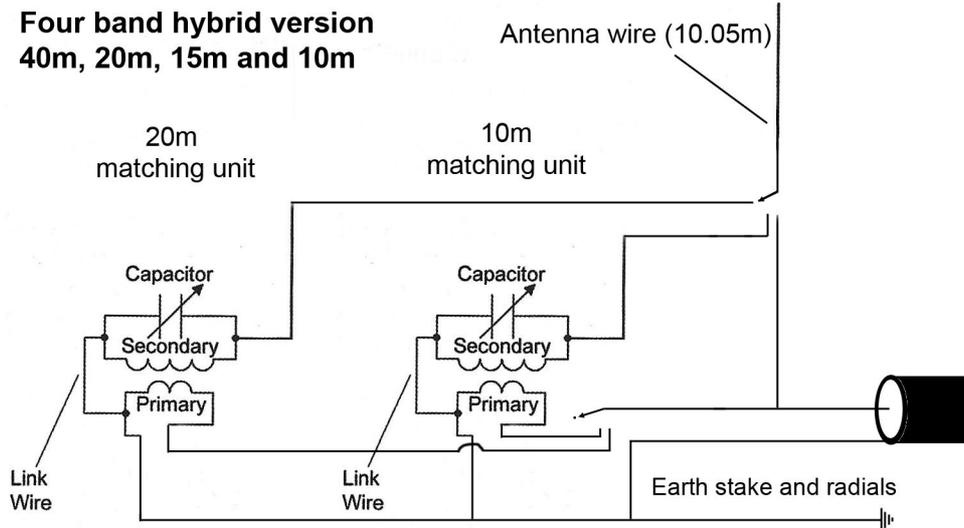
The one good thing about the 20m version of the EFHW is that you can turn it into a four-band hybrid antenna. The 10.05m radiator is a half-wave long on 20m, a full wave on 10m, a quarter wave on 40m and three quarter waves on 15m.

This means that you can feed the wire directly and use it as a quarter wave on 40m – as long as you have a good earth (I suggest at least 8/16 radials about 10m long).

This will also work (reasonably) on 15m (21MHz) as a three quarter wave. The radiation pattern is not as good for DX in this configuration, but it should work with a slightly higher SWR.

Obviously, it can also work as an end fed half wave on 20m with the appropriate matching unit and as a full wave on 10m with the 28MHz matching unit. Again the radiation pattern isn't as good for low angle, but it works – the lowest SWR point climbs to about 28.7MHz. OK, it is a compromise, but do experiment with it.

If you are really canny you can switch these so that you can go position 1 (direct for 40m/15m) – position 2 (20m) – position 3 (10m). You need to switch both the input and output as shown in the diagram. If you build one let me know how you get on.



April 2013 (NEW!): Using traps to build a three-band EFHW,

Ever since I first published the details of the original monoband EFHW people have been asking me can you design a multi-band version? My stock answer has always been "no" – I couldn't see how I could.

Anyway, this had been bugging me for some time and I tried modelling a version that could use parallel-fed half-wave radiators, but it didn't work.

I had always dismissed traps as these are used on quarter-wave radiators so they wouldn't work on a half-wave design – or would they? Turns out they do. I started modelling an antenna in MMANA-GAL and found that you could make a 20-15-10m version using traps for 10m and 15m. But you would need a variable capacitor to bring the EFHW tuning unit to resonance (more on that later).



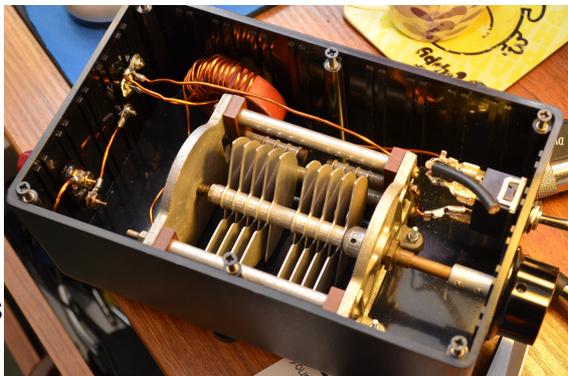
This actually makes sense as the end of an EFHW is at the same impedance as the end of a quarter-wave vertical, so a trap does the same thing. All you have to control is the resultant high feedpoint impedance. Doh! – why didn't I think of that earlier?

A search on Ebay for a wide-spaced high voltage butterfly variable capacitor turned up an old Eddystone model with a maximum capacitance of about 50pF. Unfortunately, I subsequently found that its minimum capacitance was too high to work 10 and 12m, so I decided to build a 20, 17 and 15m EFHW version instead.

I built the 17m and 15m traps out of UR76 coax using Tony VE6YP's Coax Trap calculator (Google it). The 15m one worked out quite well, but the 17m one needed to have about 3/4 of a turn less than than calculated. I set the 15m one resonant at about 21.450 MHz using my MFJ-269 analyser, I set the 17m one at about 18.150 MHz.

The reason I set the 15m trap high in frequency was that I didn't want to end up with a possible "negative" value for the section between the 15m and 17m traps. This seems to work. The consensus is also that coax traps are lossiest at their resonant frequency, so don't put set it in the middle of the band.

I built the EFHW tuner using the Eddystone capacitor and a T-200 toroid (with 13 turns output/2-turns input) as per the other EFHW designs mentioned earlier. Putting a 2200 Ohm (you could use 3000 Ohm) resistor across the terminals of the tuner and measuring the SWR with the MFJ analyser showed that it should tune 20m, 17m and 15m quite easily. You'll see in the photograph that I tried switching in series some additional capacitance using a coax capacitor. This was in an attempt to reduce the overall value, but it didn't really get me to where I wanted to be (12m and 10m).



The MMANA-GAL model for a 15m, 17m and 20m EFHW suggested that I needed a vertical wire of 6.36m (allowing for the reduced velocity ratio of PVC-coated wire), then the 15m trap, then 0.76m wire, the 17m trap and a further 1.33m length of wire to resonate on 20m.

In reality, and after a morning of tuning, I ended up with the 15m vertical length of 5.76m, then the 15m trap, a further 42cm to the 17m trap and then 97cm of wire to the tip. This would all fit on an 8m fishing pole, although I used a 10m version and took the final two sections out as it would be stronger at the top.

I earthed the tuner (to the [Clas Ohlson galvanised ground screw](#), which I now prefer to the original Coopers of Stortford one) and also connected two 5m earth radials and laid them on the ground. The result (after two hours tuning) was an SWR minimum of less than 1.5:1 on all three bands. If you do make one of these I suggest you start with each piece of wire too long and then tune it, starting with the 15m section first. Once you have that right move on to the short 17m section and finally the 20m final piece of wire.

You can also add a coax choke about 5m back down the feedline.

I then connected the antenna to the radio and found that it performed well, either equal to or better than my [M0CVO 20m OCFD \(Windom\)](#) at 30ft.

The antenna will be used portable so I needn't waterproof the traps to stop water getting in their coax.

An added bonus was that if I set the tuner to minimum capacitance I found that the antenna showed a low SWR on all three bands without further adjustment. I measured this as a resonant frequency of 21.650 MHz using a 2200 Ohm resistor across the ATU terminals.



This suggested that a simple fixed tuning box (using a coax capacitor and set for around 21.650 MHz minimum SWR into 2000 Ohms) could give you a simple three-band vertical for 20, 17 and 15m.

I built such a matching box, tuned it for around 21 MHz and yes it works. You get an SWR below 1.5:1 on 15m and 20m, and below 1.8:1 on 17m. This was at the feedpoint. At the end of 20m of coax it was even better due to coax losses.

I hope this gives you some encouragement to try a trapped EFHW. The traps are not too hard to build as long as you have a GDO or MFJ analyser with a suitable attachment for measuring the SWR dip of the trap at resonance.

Overall, the multiband antenna is harder to build than the monoband version, but seems to work well.

The goal has been a multiband trapped EFHW with a single matching box that doesn't need adjusting. This is a fit and forget multiband HF antenna for small gardens and portable use.

And in use ...

I set up the three-band EFHW for the 2014 International Marconi Day event at GB0CMS in Caister, Norfolk.

Conditions on 20m were lousy in the morning with a K index of 3. The 17m and 15m bands weren't really even open properly.

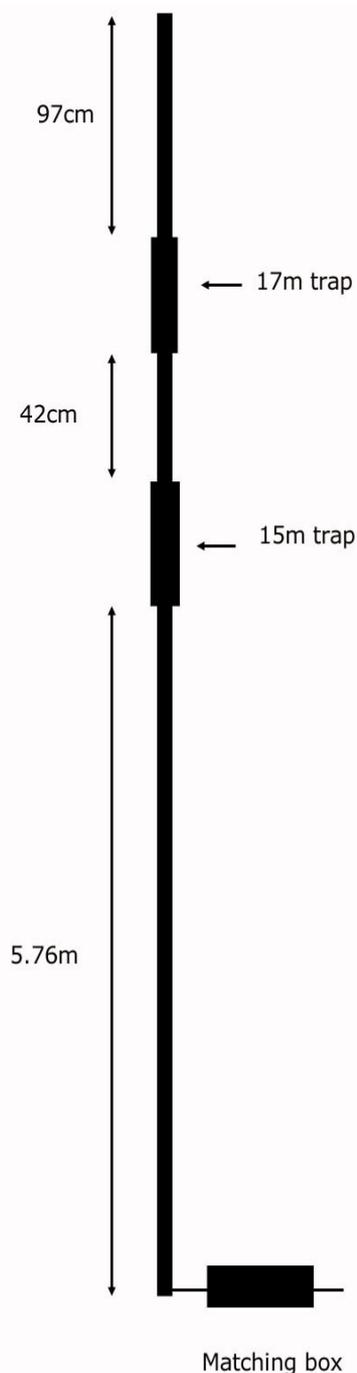
After getting very few QSOs I checked the antenna against the W5GI dipole we were using on 40m and this showed that it was working OK on 20m.

Nevertheless, I wondered if we would be better off with the 20m monoband EFHW and duly swapped it over.

The result was that it seemed to work better, although conditions had improved slightly anyway, with the K index down to 2. We worked around 130 stations on 20m, so it was working well.

After the event I checked the traps on the multiband EFHW (they were OK) and did some back to back tests (some with the Reverse Beacon Network) between the 20/17/15m multiband and 20m monoband EFHWs. The net result was that the multiband version was either equal to or down no more than 1-2 S points on the monoband version on 20m.

That didn't surprise me as the loading effects of the traps make it shorter (by nearly 2.75m) than the 20m monoband version and you get some loss in the traps.



20-17-15m multiband EFHW

So the moral is, if you want the utmost performance go for a monoband EFHW. If you can live with losing an S point or two, but want to be able to swap bands automatically the multiband EFHW isn't a bad antenna, but you do make compromises.

Update on 20-15-10m version

I made a 15m and a 10m trap and built a 10-15-20m metre EFHW. Using the 10m matching box it gave a low SWR on each of the target bands. Performance on 10 and 15m was good, but 20m was 2-3 S points down on a reference dipole. Not sure why this should be (I saw a similar, but less dramatic, effect with the 20m/17/15m version).

One possibility is that the 10m trap is right where the point of maximum radiation would be for 20m, which would affect it adversely. As such, I can't recommend the 10-15-20m version – you are better off with monobanders.

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April 2014

