Fibre Mast Vertical Antenna & π-Network ATU

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Jonathan Hare G1EXG describes a fibre mast vertical antenna and π-network ATU for the 20, 18, 15, 12 and 10m bands (and 40 & 80m band helical antennas).

Last year I got a great birthday present of a 15m (40ft) fibreglass mast. It's a lovely thing with good quality compression fixings between each telescopic section and it is also about 3m longer than my previous 'work horse' aluminium mast. Living in a city I only have a small backyard so large horizontal antennas are not on, but I can go up vertically. The lack of horizontal space also means that guy wires are a problem so my masts are secured using a set of TV-type brackets to the bottom 3 or 4 foot of the mast on the yard wall.

The bottom 2m or so of the aluminium mast is also used to support the fibre mast (using two Tufnol sheets, see photos, **Fig. 1a and b**). This means the forces are applied over a larger length of the bottom of the fibre mast than they would if the fibre mast was clamped directly to the TV brackets. Also, with this set-up I do not need to tighten the U-bolts on the fibre mast too much; reducing the risk of cracking etc.

Electrochemistry is always a problem with metal masts, especially when you have aluminium tubes with stainless steel brackets and bolts holding them together – moisture and dissimilar metals cause corrosion. The nice thing, of course, about the fibre mast is that it won't rust or corrode even in the sea air at my location. In principle you can do everything with the fibre mast that you can do with the metal mast, but with the added advantage that being insulating you can also run a wire up its length to quickly and simply create a vertical antenna.

1/2 vs. 5/8 Wave Vertical Antennas

The half-wave end-fed antenna has a lot going for it. The maximum current distribution is half way up the radiator so the radiation is often above much of the nearby surrounding objects. Although the half wave should (in an ideal world) be a resistive feed at resonance, it is quite a high value (depends on the diameter of the wire/tubes etc.), so some impedance transformer is required to match it to 50Ω.

The feed impedance of the 5/8 wave is much lower than the end-fed half wave but it will have some reactance that will need to be accounted for/balanced out. The 5/8 wave vertical also provides slightly better gain than the 1/2 wave, with (hopefully) more power being radiated at lower angles toward the horizon where you want it.

The 5/8 is longer, of course, but with a 15m mast I have length to spare even on 20m. I decided then to build 5/8 wave verticals for 20, 15 and 10m and 'load up' the 20m vertical as a 'compromise' antenna on 40m (more on that below when I discuss the helical antennas).

When putting up the antenna, the wire was taped to the top section of the fibre mast first and as the sections were erected I put more tape at various places to stop the wind blowing it away from the mast. The other end was soldered to a 4mm plug (or solder tag) to go on to the ATU.

The insulating property of the fibre mast also means that I can wind a long coil up the length to form a helical antenna, like a giant version of the 'rubber duck' antennas used on handhelds. A quarter wave vertical helical antenna for 80m band can be made by cutting 20m of wire and starting by taping one end to the top section. As you raise each section, you also turn as you go. The result is a long spiral almost the whole length of the mast.

The Simplicity of a Vertical Antenna

The 5/8 wave radiator could not be much easier or more economical – it's simply a copper wire running up the length of the fibre mast. See **Table 1** for ideal lengths. I measured out 13.2m of decent quality copper stranded speaker cable, split the two keeping one strand for the 20m 5/8 wave vertical and cutting down the other length for other bands. Using the ATU (see below) the 10m band 5/8 vertical will also work on the 12m band and the 15m 5/8 will work on 18m band. I therefore made up just three wires: 20m band (13.2m length), 15m band (10.4m) and 10m band (6.6m).

Earths and Radials

It's possible to use both end-fed 1/2 and 5/8 wave vertical antennas with no earth radials but a better performance and lower angle of radiation should result if you do use them. A search on the internet for information about vertical antenna radials (in particular 5/8 verticals) will bring up a lot of interesting articles on the type, size and number of earth radials that might be best.

For longer wavelengths (e.g. 80, 40m say) where the total amount of wire becomes quite long (and so expensive and expansive!), eight x 1/8 radials often seem a better choice than say four x 1/4 radials (even though total amount of copper wire used is the same).

Some authors suggest that quarter-wave radials on the 5/8-wave vertical are not ideal and that 1/8-wave radials provide better low angle radiation and less reactance to match to. As I was trying for a multiband approach, I decided to use four on my test setup: two x 3m and two x 5 m radials so that there was a range that might help cover from 80m to 10m. I understand it's not the best set-up for the longer wavelengths but it will get me on the air.

The radials were simply laid out rather randomly from the base of the mast on the concrete/brick yard so it's not likely that they will actually be 'resonant' at any designed frequency based on their particular lengths. The ATU will tune things up. Again Table 1 shows the ideal lengths of the 5/8 wave wire along with the 1/8 wave radial lengths.

Matching

The antenna needs an antenna tuning circuit to match it to 50Ω coax feeder. I used a home-made π-network (see photo and diagram, **Figs. 2** and **3**). The basic circuit is very simple: two capacitors (C_1 and C_2) and an inductor (L). The variable capacitors are connected to ground and either end of the inductor. It looks a bit like the Greek figure π, hence its name. By carefully varying the values of the three components you can match a wide range

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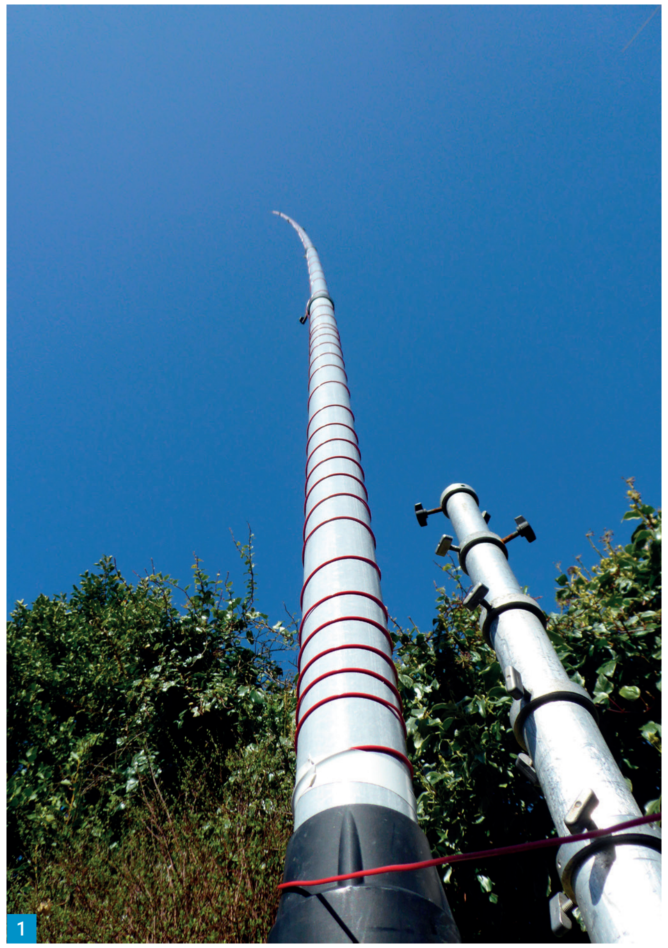

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Fig. 1: On the right you can see my retracted 12m aluminium mast (r) next to my 15m fibre mast (l). Both masts can be used independently when the other is down. The lower 2m of the aluminium mast supports the fibre mast using two (35 x 35cm) Tufnol panels and 8 U-bolts. The 15m fibre glass mast is shown here with 20m of wire wound around it forming a helix antenna for 80m (see text).

of non-balanced setups. Transmitter output stages often have a π-network to match the relatively low impedance of the output transistor to the ubiquitous 50Ω standard.

Note: there is an inevitable interaction between the capacitors and the inductor, so in practice you select an inductor, adjust C_1, then adjust C_2, and then re-adjust C_1, etc. doing this a few times to work your way to a good match.

An L-type circuit (e.g. just L and C_1 or C_2) is often all that is needed to match a 5/8-wave antenna, so if need be one capacitor can in principle be omitted (or turned to minimum capacitance). However, the extra complexity of the π-network means that it can in principle cope with a wider range of reactances that might be present on experimental antennas (especially on my short 40m antenna). A π-network also acts as a bandpass filter, which is useful to reduce unwanted signal transmission and always useful, of course, on receive.

Junk Box Circuit

I had a few large spaced variable capacitors that I have collected over the years so I decided to use the widest spaced caps I had that were clean and of the correct physical size to go in the box I happened to have. I wanted to use wide-spaced variable capacitors to cope with high voltages that might be present when using 100W from my IC-706 transceiver.

I built the ATU into a standard metal diecast box (ca. 190 x 120 x 76mm). I fitted an SO239 socket on one side for the 50Ω input and used two 4mm sockets and two 4M bolts (with two washers and butterfly nuts) to secure the radials. The antenna was connected via a 4mm plug-socket and also a screw binding post (yellow in photo, **Fig. 4**).

Range of Coils

Because of the relatively small capacitance range of my particular capacitors, I chose to make a range of coils to slot into the ATU to provide a good coverage, **Fig. 5**. They are much cheaper than the capacitors and easier to make than tuning capacitors. I simply plug in one I think might work for the band I am using and try a smaller, or larger coil, if that does not manage to tune up correctly.

Band (m)	5/8 wave (m)	1/8 wave (m)
40	26 m	5.2 m
20	13.2	2.6
18	10.4	2.1
15	8.9	1.8
10	6.6	1.3

Table 1: The ideal lengths of the 5/8 wave wire along with the 1/8 wave radial lengths.

My first attempts were frustrated with the coils getting in the way of the tuning capacitor vanes so I needed to make sure the coils were held securely and stayed where they were put. I cut a short piece of fibreglass printed circuit board (copper removed) to take four sockets in a line. These were connected in pairs so that a range of coil sizes (lengths) can be accommodated when pushing the coils in from above. Two bolts with support collars supported the socket board.

Each coil had a pair of plugs soldered to them. I had a number of good quality silver plated plugs and sockets in my 'junk box'

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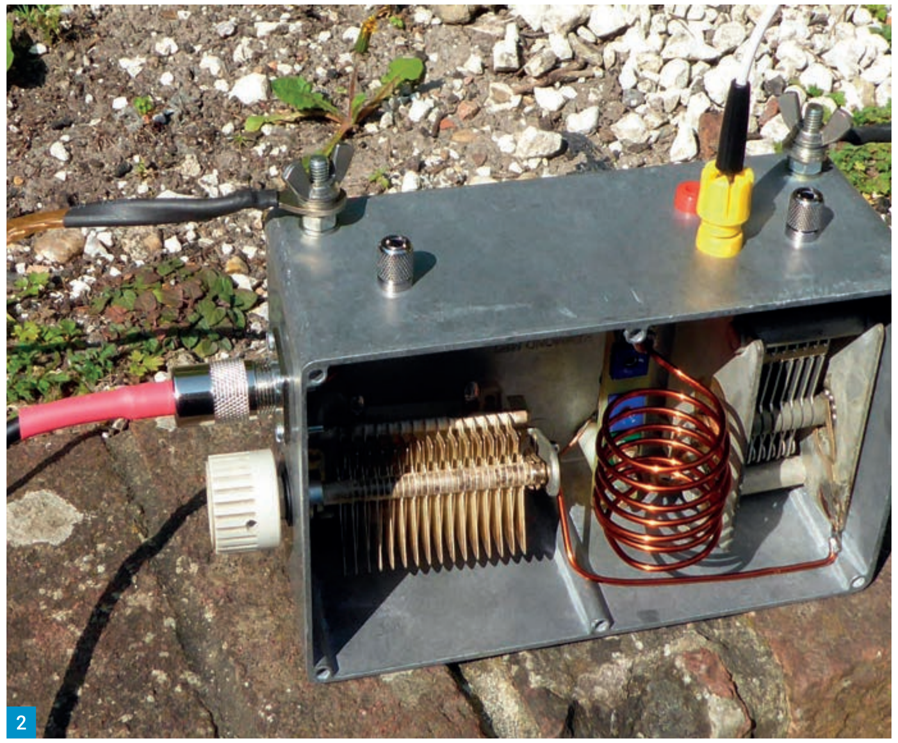

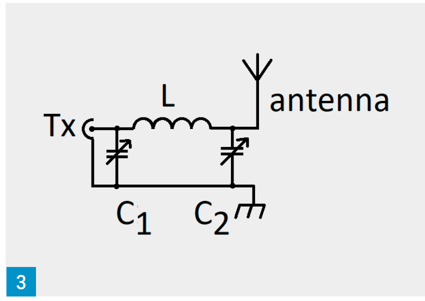

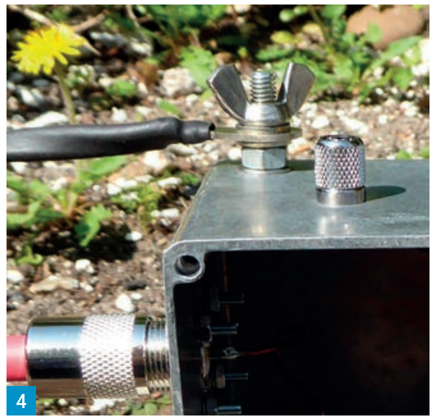

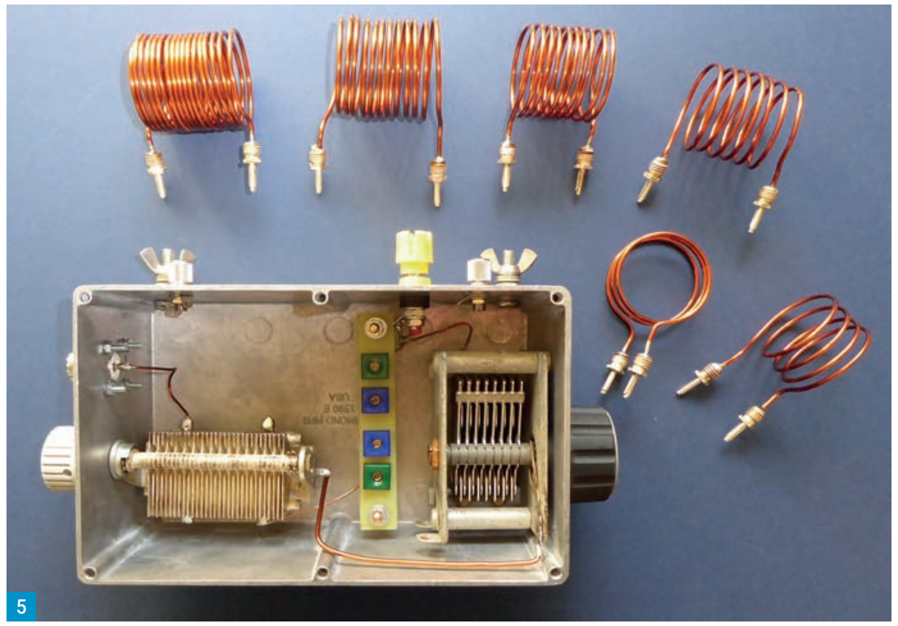

Fig. 2: The π-network ATU: the coax lead on the left goes to transceiver, there are four earth radials in pairs attached to the butterfly nuts, the antenna can be connected to the red 4mm socket or (as shown) pushed (or trapped) in the 4mm yellow screw connector socket. On the left you can see one of the variable capacitor tuning knobs (other cap knob is on the right and out of shot in this view).
Fig. 3: π-network matching
Fig. 4: Close up of the butterfly nut arrangement to connect the earth radials to the ATU, there is also a 4mm socket-thumb screw type connecting post. Both are connected directly to the common earth of the metal box.
Fig. 5: The π-network ATU surrounded by a selection of plug in coils that should allow 80m to 10m band operation. The coil sockets are wired in pairs (top two joined together, bottom two joined together) allowing a range of coil sizes to be accommodated.

and found they worked very well. I made up six coils: 3, 4, 6, 11, 14 and 17 turns to cover 10m – 80m bands. They were all about 4cm in diameter, 14SWG copper enamelled wire (wound on a piece of water outlet pipe as a former).

A Note on Variable Capacitors

I haven't suggested you use any particular type of capacitor in this design, partly because they are expensive to buy new and not always easy to get. The idea is to use the simplicity and versatility of the plug-in coils to provide a wide matching and frequency range as they are far easier and cheaper to make. As a consequence, use almost any good quality large spaced variable capacitors you can get (e.g. on eBay, junk sales, etc.).

Waterproofing

Keeping matching circuits and antenna connections water free is a real challenge for all home made outside installations. I only erect my antennas when I want to use them (they are not permanently 'up') so I only need a portable-type installation that can keep out the weather for a relatively short time (i.e. the issue will be rain rather than long-term damp).

The ATU metal box I used could be made water resistant using an o-ring seal (the lid happened to have provision for this) but the capacitor spindles don't have this facility. I didn't want to use the lid because I wanted easy access to change the coil, so I decided to house the diecast ATU unit in a small Tupperware (or Really Useful storage) crate and simply snake the antenna wire out through the lip of the box. I shrink-wrapped the ends of antenna wires and earth radials and shrink-wrapped the solder tags after soldering. Water proofing sealant 'paint' is also very good (eBay).

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Tuning-up

It's handy to use an antenna analyser close to the ATU to set everything up and get the best match possible. Once tuned up I connect my main coax lead back to my radio room. If you use your main transceiver to set the SWR, then do these adjustments on low power. Note: once the ATU is set this way, changing the length of the coax run should not affect the SWR greatly – it's a good test to check everything is working properly. If you do get very different SWR readings when you add in a line of coax, check the earth radial connections.

On Air Tests

Initial tests with the 5/8 wave on 20m antenna from the UK to Spain and Finland have been really very encouraging.

I found that the ATU settings were not too sharp and could usually go a few tens of kilohertz either side of lowest SWR (to dodge noise and stations that might pop up on frequency) without having to go outside and re-tune the ATU.

The 40m and 80m band helical antenna seems to load up very well and so far results have been very promising (despite the relatively poor earth system on these bands).

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