The Evolution of a Multi-Band, Fan Dipole for Portable Operation

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During our portable Amateur Radio adventures to summits, national parks, islands, museums and lighthouses, Julie and I have tried many different antenna combinations with varying degrees of success. But these days we prefer to use a single resonant, multi-band antenna of our own design that really suits our style of portable operations.

It is a single-feed antenna with no-compromise half-wave dipole performance on 80, 40 and 20 metres. It is easy to deploy, it won't come down in a storm and it provides a good broadband match on all bands without the need for an antenna tuner.

But first a warning: This is not a light-weight portable antenna for serious SOTA work, where every extra gram in your back-pack can slow you down. And it is not a simple "set up in five minutes", "take-anywhere with a squid-pole" or "throw over a bush" type antenna either.

So why describe it as a portable antenna at all? Well, when Julie and I go portable with Amateur Radio we typically set up for a week, a weekend or at least for a 24-hour contest. We want the best performance we can get and are willing to sacrifice a bit more weight, size, cost and set up time to get what we want. Our operation is always on display to the general public, so our portable antenna needs to be safe, sturdy and look really professional.

So what sort of antenna do we use? We certainly don't have enough room in our little 4WD, for a multi-band Yagi, delta beam, hex beam or a full-wave loop. But with the large area available at our camp sites we can certainly do better than a noisy vertical.

So that leaves the good old-fashioned long-wire antennas. They could be resonant or some random length. They could be linked, trapped or fanned for multi-band operation. They could be deployed in a flat-top, inverted V, inverted L or sloper configuration. They could be centre fed, offset-centre fed or end-fed. And they could be fed with open-wire line, window-line or coaxial cable and a balun.

There were originally so many choices, but we worked through them all as we journeyed around and gained more experience. So now seems like a good time to try to explain some of the decisions we made and how they relate to our portable operation.

The feed line

Open-wire feeder or window-line is very efficient for non-resonant antennas like doublets and G5RVs, and those antennas are better for all-round, multi-band operation, with the help of an antenna tuner of course. So the feed line decision sounds like a no-brainer at this point.

But the attenuation of coaxial cable is quite acceptable at low frequencies especially for well-matched resonant antennas. And resonant antennas are always more efficient than random-length wires. So if we know exactly which frequencies we want to use then we should be able to design a resonant antenna using a coaxial cable feed, without the need for an antenna tuner. All we have to do is to match the antenna impedance to the feed line on each band. Simple.

Strangely weight is not much of a factor as coaxial cable, open-wire feeder and window-line are about the same weight per metre.

But there were other more important issues, which we learned through experience in portable operation. Coax is much less bulky when coiled up than either open-wire or window-line. It isn't affected by rain or wind. It doesn't snag on bushes. It is very flexible and doesn't break easily. It can be safely fed into a metal vehicle under the door seals. Finally coax does not tangle up and twist like open-wire or window-line does in a bag or in the bush.

Horror tangles are, by the way, the bane of portable operation. We have wasted literally hours and hours of our setup time trying to untangle light antenna wires. We avoid it now by using thick wire which won't tangle in the first place and careful hand-over-hand, not elbow, roll-up and roll-out techniques.

But using coax means having a heavy balun at the feed point, which is bad news for centre and offset fed antennas. There were still some problems to be solved, but at this point it seemed like coax had won the portable feed line stakes. We could always use open-wire feeder or window-line at home.

The antenna configuration

I evaluated different antenna configurations using an antenna modelling tool. I compared a flat-top dipole, an inverted V dipole and an end-fed sloper, all at the same maximum height. You can do this easily yourself with any antenna modelling program.

Now, personally, I don't believe the absolute performance results of antenna modelling software. I always have to fiddle with the ground characteristics to get the same answer as the real thing. However, these programs can be used very effectively for performance comparisons and sensitivity analysis – which is almost impossible to do accurately in the field due to too many variables and changing conditions.

I found from my antenna modelling that the flat-top configuration had consistently about 3dB more gain than all the others and putting all of the antenna up above the vegetation was an intuitive step. The down side was that flat-top antennas needed two supports instead of one. But that was a small price to pay for effectively doubling our transmit power and receive sensitivity. It may make all the difference in contests and for DX work. So it looked like the flat-top configuration was the go.

The antenna support

You may think the antenna support is just a passive part of our portable setup, but it is actually one of the most important. When we arrive on site the first thing we do is figure out the best location for our antenna. Where are the big trees or where can we put our masts and guys instead?

The antenna supports need to be at least 6m high and must be about 40m apart with a clearing in between for our vehicle-based radio station (which is solar powered by the way). Trees unfortunately don't always cooperate with these Amateur Radio requirements and so masts must be brought along as a backup solution.

Originally we used light hook-up wire antennas which could be suspended from 9m squid poles. However as our antenna designs evolved the squid poles could no longer cope with the increasing load. We still take squid poles along with us, but these days we use them only occasionally to route antenna wires around high branches and other obstacles.

Now a rugged portable antenna will be made of heavy-duty wire, a heavy balun and a coax cable feed line. It will have the equivalent horizontal force of 2kg in weight on the supports. So we will be using pretty big tree branches, where available, or our home brew, 8.5m, guyed, telescopic, aluminium masts.

To string a heavy wire antenna between two big gum trees is actually quite easy. We use another little invention of ours that we call RoboStick☺. It is a safe and perfectly legal antenna launcher modelled after the Australian Aboriginal throwing stick, or Woomera.

With the help of a strong arm, it accurately fires a round lead sinker as high as 15-20m up and over a tree branch. The sinker is attached to some fishing braid, which freely spools out from a hand-line fishing reel.

RoboStick☺ is really just a 1m length of 20mm PVC conduit fitted with a slotted socket on one end and a hand grip on the other. It is very important for safety that the, virtually-unbreakable, fishing braid is never tied directly to the sinker. Instead, a toothpick is pushed into the hole and broken off to provide a strain relief valve in case the braid gets caught around your finger, or the sinker gets caught up a tree.

The fishing braid is just a leader used to pull through some heavy-duty, soft, nylon cord. The latter is tied off against the tree using cam-buckle straps, which don't harm the tree in any way. Julie says: "Trees are people too".

The antenna type

So by now we have pretty much decided on resonant wire antennas. The only multi-band resonant dipole antennas I know of are linked dipoles, Offset-Centre Fed (OCF) dipoles, trapped dipoles and fan dipoles.

Linked dipoles, which have removable shorting links for each band, mean that the antenna has to be brought down just to change bands. That wouldn't be fun at all in a storm and we seem to encounter storms all the time.

OCF dipoles are fed at around 33% from one end of the wire. They can work on all three bands, but I could never seem to get the centre frequencies in just the right spot. For some reason, they don't exactly tune up on the second and fourth harmonics as expected. They have fairly narrow bandwidth and their feed impedance is quite different on each band, so they are a bit of a compromise, really.

Trapped dipoles have wire coils with capacitors or coaxial traps located at strategic points along the dipole. At their resonant frequency the traps go high impedance and effectively disconnect the rest of the antenna. They can be made spot on frequency, but they have extremely narrow bandwidths due to the high Q of the traps. Again, their feed impedance varies considerably and they are actually a non-optimal or "loaded" antenna.

Fan dipoles are really just separate dipoles all connected in parallel to a single feed point. The dipoles can be individually tuned to the required frequencies. They have the same gain and bandwidth on each band as a standard half-wave dipole by itself. They work OK provided that there is not much interaction between each dipole.

To minimize the dipole interaction you have to provide at least some separation between them. Usually each leg is just strung, rather unattractively, in and arc from the feed point back to the longer dipole at the top using some nylon cord. Hence the name "fan" dipole.

But of course, like all the others, the feed impedance of each dipole in a fan dipole is different on each band. A single balun at the feed point could not hope to match them all the to the 50 ohm coaxial cable. I realised that I would have to use an antenna tuner and there would be standing waves on the feed line, so the coax would be inefficient too.

The feed system

But then it occurred to me that you could actually have three different baluns instead of just one, each matching a dipole to the feed point impedance. I Googled it extensively, hoping to find the design of such a multi-tap balun for fan dipoles. But unfortunately, I couldn't find anything even resembling this approach. All the fan dipoles I found were just joined together in parallel. It looked like I would have to design something myself.

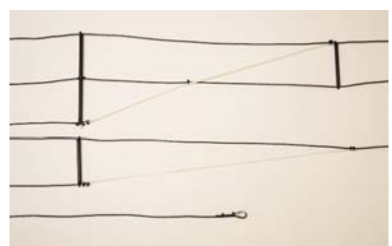
I began by modelling the fan dipole in my favourite antenna modelling tool. I modelled the 80, 40 and 20m dipoles separately and then together at 8.5m high, separated by only 10cm vertically. The design frequencies were 3600, 7100 and 14150 kHz.

To my surprise, I found that there was little interaction between the dipoles on these frequencies. The feed impedances, with the virtual matching transformers in place, were 26, 46 and 56 ohms, the gains were 7.9, 5.6 and 5.9 dBi and the bandwidths were 69, 120 and 400 kHz respectively. It appeared that the combined dipoles would work much the same as the individual dipoles.

The build

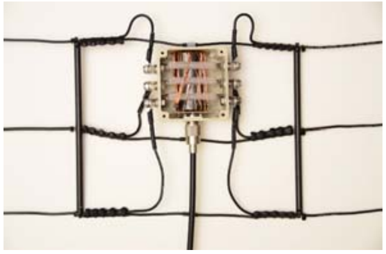
Julie and I then set about building the three dipoles exactly as I modelled them out of heavy duty 5mm^2, multi-strand, insulated, copper wire as used in household electrical wiring. The full dipole lengths were 38.52, 19.50 and 9.52 metres respectively.

The dipoles were separated 10cm with short lengths of fibreglass tent-pole material and rigged parallel, with nylon cord and cable ties. Each dipole was connected to a set of stainless steel, feed-through bolts into a weather-proof enclosure at the feed point.

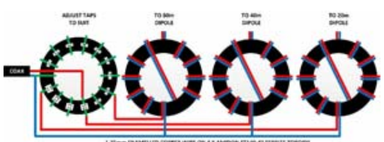


Inside the enclosure, we put three 1:1 baluns and an autotransformer to match the different dipole impedances. The balanced side of each balun connects directly to one of the dipoles. The unbalanced side connects to ground and to one of three different impedance taps on the autotransformer. The coax cable connects to ground and to a 50 ohm tap on the autotransformer.

The feed-point enclosure is suspended from the top dipole wire. Strain relief for each dipole is provided by a short peace of unconnected insulated wire, 5 cable ties and some heat shrink.



The 1:1 parallel transmission-line current baluns and the autotransformer were all made by winding 1.25mm enamelled copper wire on Amidon FT140-43 toroidal, ferrite cores, which can each handle 100W or more. An insulating sheet is also placed between the cores to discourage any arcing. The autotransformer has 13 turns with taps at 8 (80m), 10 (40m/Feed) and 13 (20m).



The results

When we had finished building our new antenna, Julie and I couldn't wait to try it out at our "Antenna Test Range" (a nearby vacant lot) and after some tweaking of the taps we obtained the following results on our antenna analyser: For 80, 40 and 20m we had centre frequencies of 3590, 7110 and 14110 kHz; SWRs of 1.1, 1.0 and 1.1 and bandwidths of 100, 190 and 480 kHz respectively. All results agreed well with the antenna modelling.

Since then, we have used this antenna successfully on many occasions. We recently back-packed our rigs, antenna and masts across to French Island for the IOTA contest and following that we camped out at Queenscliff for the International Lighthouse and Lightship Weekend. It works without an antenna tuner or switch. It works perfectly with our HF triplexer, enabling us to work all three bands simultaneously. The combination just couldn't be more convenient for our portable operations.

One final word about safety: We never set up our portable station without connecting an in-line lightning arrestor and a 1.5m ground rod to the coax feed. And we always put caution tape and "NO ENTRY" signs around our guy wires. It is always better to be safe than sorry.