A few thoughts on Multi Band VHF Aerials by Peter Ward VK3ZAV

Some of the options

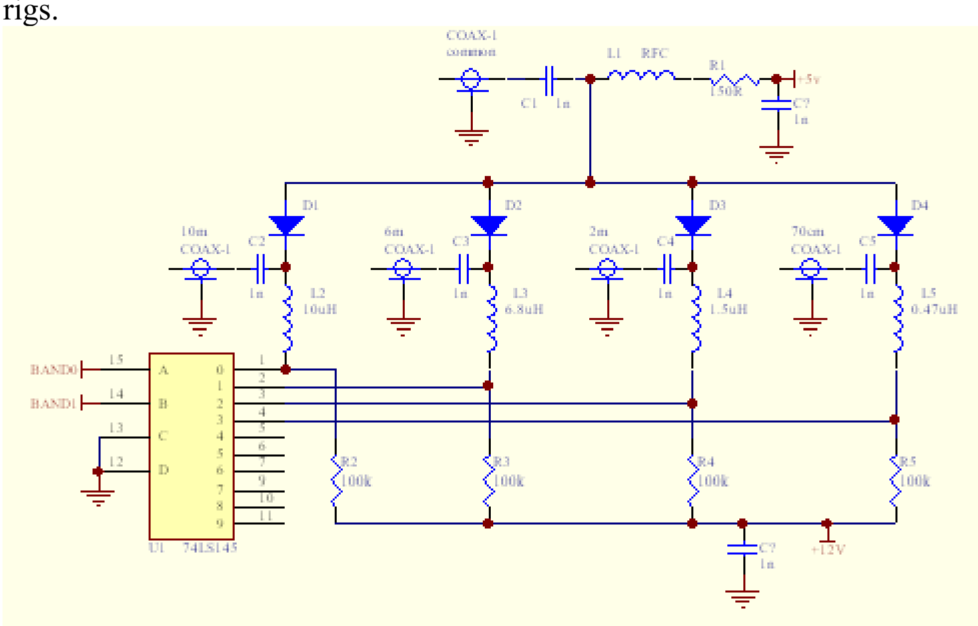
There are several different ways to approach the making of a multiband VHF aerial. One way is to connect two different feedlines through frequency selecting networks, so that two completely different radios can simultaneously use the same vertically polarized aerial. See "My first attempt".

Another way is to use a remotely tuned network, so that the one aerial can be tuned to any frequency, this is commonly used for HF bands.

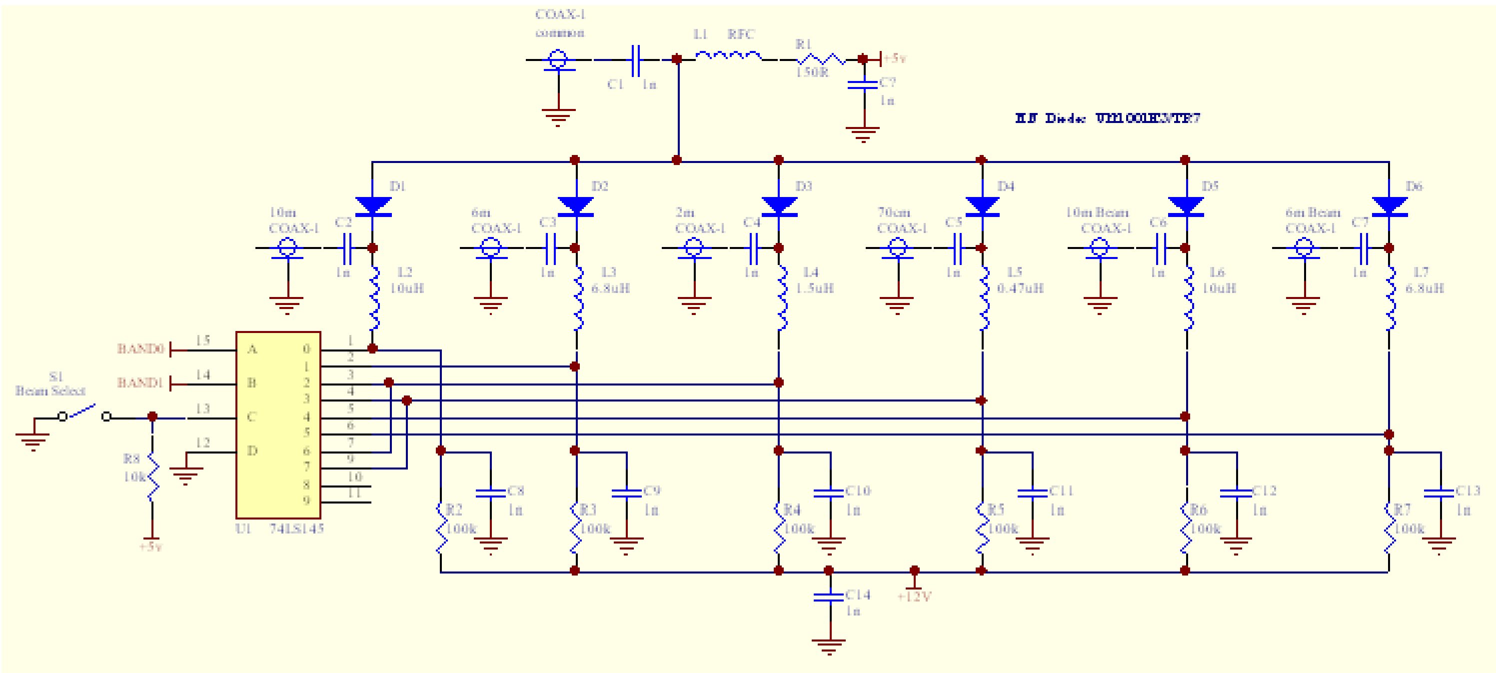
A further approach is to remotely switch between, say, four different matching networks, with either separate feedlines, or one common feedline. This allows the saving of cost for only one feedline, and maybe the purchase of super low loss cable.

It depends largely what you want to connect to at the equipment end of the cables, mobile or home station. The separate feedlines arrangement is ideal for separate receivers, so you can simultaneously monitor all bands, to pick up DX activity when its there. For instance you may monitor vertically polarized FM repeaters to find band openings, then change to horizontal polarization and SSB to fill up the log book.

However, many have multiband and multimode rigs, with only one aerial connector, where changing connectors to change bands is quite inconvenient. Of course, you can build a switching box, that will allow either manual switching or the rig to switch the aerial cable, using relays or PIN diodes. Such a switch box can be used in the opposite direction too, to switch one cable to different rigs.



Mix into this the fact that you might have beams for each band also, with either vertical or horizontal polarization, so when, say working 2m SSB DX, you want at maintain your monitoring of 6 & 10m for openings there. Or if you want to switch to beams for 10 & 6 metres. The use of the 74LS145 for control of pin diodes or relays gives you a decoder with outputs that can switch 15v at 80mA. Suggested PIN diodes are UPP1001E3/TR7, available from Digikey. Other suggestions are being investigated.



Try to plan your growth path so as to not get locked into a limited range of operation, then also be free to build your own additions to make your shack and mobile a flexible as possible.

My first attempt

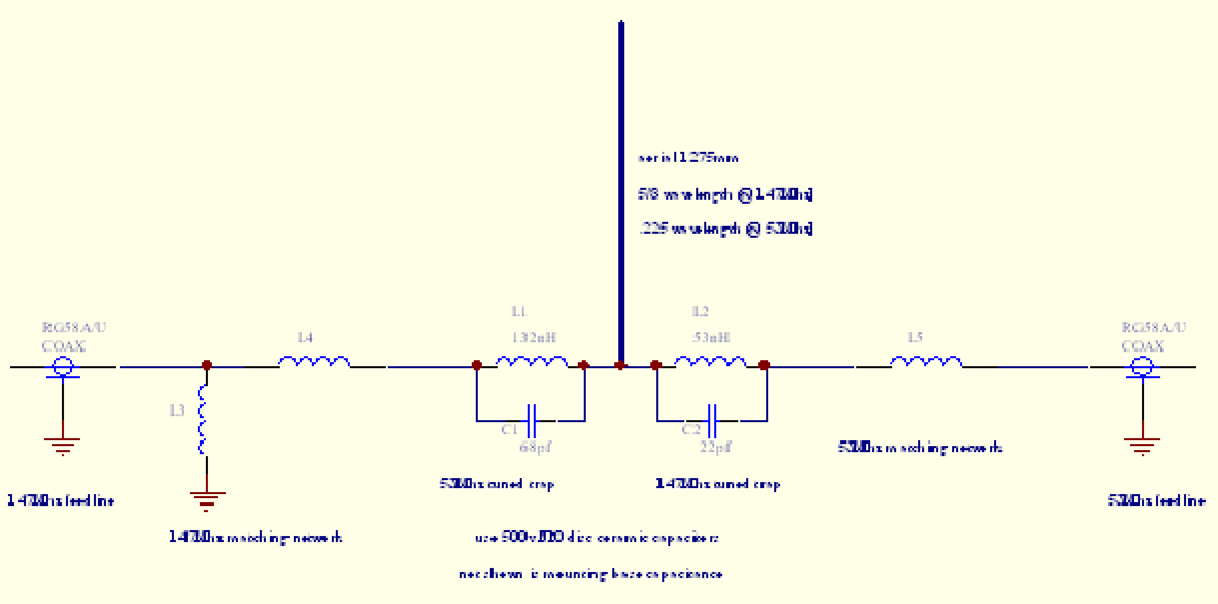
Back in the 1960's I had been using a 2 metre FM mobile in my VW Kombi, when I obtained a cast off low band commercial FM mobile which I put on 6m, so the question arose, could I make one aerial do both jobs.
I didn't like the idea of two separate aerials, because of the interference to the radiation pattern known to occur when a lower frequency aerial was mounted relatively near to higher frequency one. There are critical distances that can be found to minimize this effect, but wanted several other bands, and fox hunt rotary aerials too, so the one aerial with two feedlines approach was looked at closely.

I was aware that two local AM broadcasting stations shared the one aerial tower, and had a copy of the paper written describing how it was done, so that was my starting point, although my power level wasn't quite 10kw. The highest gain available from a single vertical aerial above a ground plane, before the vertical pattern breaks up, is from a 5/8 wavelength, very commonly used for AM broadcasting, and also common for 2m mobiles.

The idea then was for 6m and 2m, to use a 5/8 wavelength for the highest frequency, just as the AM broadcasters did on 774 and 621Khz. This meant a length of 1275mm for 147Mhz, and that worked out at .225 wavelength at 53Mhz. This was close enough to A quarter wavelength to be able to match it efficiency.

The circuit shows how the matching networks are separated for the two frequencies, by inserting a trap, ie. a resonant circuit in series between the aerial and the matching network. In this case, L1 C1 resonates at 53Mhz, and so is a very high impedance (nearly an open circuit) in series with the 147Mhz matching network. Similarly L2 C2 resonates at 147Mhz, so as to effectively disconnect the 53Mhz matching network.

This aerial has a resistive component of about 50 ohms in series with about 4.5pf (at 146Mhz), which is a capacitive reactance of 230 ohms (impedance 50 -j230 ohms), so needs a series inductance to tune it to resonance. Without the tuning inductor the SWR would be up to 20:1 (making it an ornament, not an aerial). Calculations show that the series circuit of L1 C1 becomes



60pf at this frequency, so increases the reactance by another 18 ohms, not causing a significant alteration to the efficiency.

Now the same aerial at 53Mhz is a little short of a ¼ wavelength, so its impedance is 29 -j35 ohms, that is 29 ohms of resistance in series with 85pf, giving 35 ohms of reactance.
and the 147Mhz circuit L2 C2 becomes an inductance of 62nH at this frequency, so decreases the reactance by 20 ohms to 15 ohms.

When I originally built this aerial, I installed it into my Kombi, and then measured the actual impedance (admittance) using a GR Admittance Meter, then plotted the networks on a smiths chart. Unfortunately I didn't keep the Smith Chart or the measured figures, so these figures were obtained from MMANA-GAL (see LINKS, Design Software 3), by simulation.

I have however found the original network, but its not in good enough condition for a picture. The type of base I used is no longer available, but a possible alternative is a normal 27Mhz CB aerial base, however the capacity will somewhat less.

Now this is not the normally accepted way to match VHF aerials, and may give poor efficiency if L and C values are not chosen correctly. Soon after I made the ham version, I had a need to build a commercial aerial for 162 and 75 Mhz, and my collegues doubted that it would work well, so we tested it carefully. The result was the 75 Mhz performance was the same as the stub matched ¼ wavelength that it replaced, and the 162 Mhz performance measured 3db gain.

The adjustment procedure is really not too difficult. You need a signal generator to enable adjustment of the two tuned trap circuits. Connect a 6m receiver to the 2m cable, and the signal generator to the 6m cable, and adjust L1 by spreading or squeezing the turns to minimise the signal received. A null of more than 40db should be achieved.

Start with coils of 1.6mm enamelled copper wire, not tinned copper, for L1 about 6 turns on 8mm diameter and 100mm long, and for L2 4 turns. Keep the lead lengths down to 5mm or less, this is VHF. For C1 & C2 use NP0 500v ceramic, and a 50w mobile should be fine.

Then swap around, and use the 2m receiver, re-tune the sig gen, and adjust L2. Connecting the receivers to the opposite aerial cable, the possibility of “off air” signals preventing adjustment is reduced. The matching is adjusted with a normal SWR meter, and the 2m transmitter adjusting coils. The matching coils are going to be about half the turns of the traps, try it and see.

A New model for 10m & 6m.

It becomes impractical to make the above type of matching system for more than two bands, as you would end up with two or three tuned traps in series. I am now looking at 10m & 6m together, and there are several possibilities that are worth looking at.

Band	Frequency	¼ wave	5/8 wave
2m	147Mhz	510mm	1275mm
6m	53Mhz	1415mm	3538mm
10m	29Mhz	2588mm	6465mm

The 5/8 wavelength vertical above a ground plane on 6m would be nice for a home station, giving about 4db of gain, and maybe 1db gain at 10m, but it's 3.5m long, so some complexity is required to support it and make it strong enough. The VK3DJ, “Squid Pole” approach might work well.

Another possibility is the ¼ wave at 10m, 2,5m long, still requiring some sort of guy support, and 0.457 wavelengths at 6m. As this is close to a half wavelength long, its capable of about 2.5db gain, but the impedance would be in the order of 800 +j400 ohms, too high to match readily, and prone to high voltages on transmit.

How about the 6m ¼ wave at only 1415mm long?, thats ok at 6m, and at 10m presents 7 -j235 which could be used, but might be improved. By increasing the length till the resistance at 6m reaches 50 ohms, we get 51 + j47 ohms for a length of 1480mm, then at 10m we get 8.45 -j207, a small improvement. This would make a good mobile, as its not too high, and a simple home station, that's easy to build. One way to make this suggests itself by starting with a 1800mm CB helical whip, and cutting it to 1480mm, then maybe unwind it, depending on the impedance.

If the winding wire is run straight, and covered with black heat shrink tube, you have a simple mobile two band aerial. The matching network is readily calculated from the MMANA-GAL figures, but may be somewhat different from the built model. The use of an accurate impedance bridge would give figures that are accurate enough to build the matching networks.

Depending on how the helical whip is made, it may prove unnecessary to unwind the whip, once its cut to the shorter length. The main thing is to look and see how it will match to a 50ohm cable (or 75 if you wish). The best way to do this is with a Smith Chart, see
http://www.antennex.com/preview/Folder03/Oct4/smith.htm,
and/or http://www.maxim-ic.com/appnotes.cfm/appnote_number/742
These explain how it works, but a really cool program to actually do it was released years ago by Motorola Semiconductor, and is still available here http://pcb-pool.com/download/shareware/mmp.exe

Run MIMP.exe and follow the prompts on the screen:
1 select the number of frequencies, start with only 1.
2 set that frequency in Mhz, say 53
3 set the aerial (load) impedance, MMANA-GAL simulation or measured, say 130 +j209
note you enter series impedance, (numerals and sign only, not the “j”)
but the equivalent parallel value, 466.01 -j289.86 is also displayed.
4 set the cable (source) impedance, say 50 +j0 ohms (you can use 75 if you prefer)
5 Then hit escape key, or right mouse button takes you to select circuit element

6 select 7 for the 10 metre tuned trap, enter inductance of 301.2nH
7 and capacitance of 100pf (in both cases 54.8811 ohms reactance at 29Mhz)
8 Then hit escape key, or right mouse button takes you to the Smiths Chart
9 **DON'T PANIC**, its not as bad as it seems at first.
you do all your adjustments with the mouse, along the top edge of the display.
10 Go to Zo, (the output impedance), and click on the character you wish to change, the 10's digit, until the red underline moves to there.
11 Then click on the blue (cyan) up arrow to step the impedance up to 50 ohms. The yellow marker circle then moves to the middle, to show where the 50 ohm finishing point should be.
12 use the right mouse button to travel to the circuit, and add:
series cap 40 PF (39)
shunt L of 390nH
series cap 45pf (47)
or:
Shunt cap 32pf
series L
This is not as good. It has a higher Q, is more lossy, more critical to adjust, and has a narrower bandwidth.
A more detailed description of how to use the Smith Chart will come in due course. First draft 31/12/2007