Extending a Cushcraft A3S Triband Yagi to add 18 and 24MHz (17m and 12m)

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It is not a direct modification of any elements as such but rather re-using the boom of the Cushcraft A3S (http://www.cushcraftamateur.com/Product.php?productid=a-3s) by adding two more elements to provide the coverage of these bands, while still maintaining the “tribander operation”. The same modification could undoubtedly be done to other tribanders provided the boom was long enough to minimise interaction with its existing frequency coverage (the A3S boom is slightly over 4200mm long). I also found an article by K7HG (/ W6EFB) that actually modified the A3S away from the original 20/15/10 metre configuratio (http://www.qsl.net/w6efb/antenna.html)n but that was not what I wanted to achieve - I wanted the new bands in addition.. (PDF of the web page (/~vk4adc/web/images/UserFiles/Image/a3s_mod/Converting%20the%20Cushcraft%20A3%20to%20a%2012%20_%2017%20Meter%20Yagi.pdf))

I had not previously paid much attention to the bands of 17 metres and 12 metres (17m / 12m, 18 and 24 MHz) but my holiday activation as VK9NU (http://vk9nu.net/) earlier in 2016 highlighted that 18MHz was open while 14 and 21 were not and my existing antenna arrays at the VK4ADC home QTH did not really cover those bands. It was also apparent that the antennas needed to be directional and rotatable even though there wasn’t going to be space on the HF tower to add another yagi. Adding a couple more elements to the A3S would solve the space problem and give me that coverage – if it worked….

After a lot of Google-ing for articles on 12m/17m - 18/24MHz - yagis and dual band dipoles, it confirmed in my mind that the trapped element approach should work for me. There are two thought lines on this approach though – whether the traps are tuned at the centre of the band or midway between the two bands. So option1 gives the trap tuned to 24.9MHz while the second suggests the arithmetic mean of about 21.5MHz. The two techniques provide different element lengths for the inner dipole segment because the trap at resonance should provide a high impedance and not contribute significant values of inductive or capacitive reactance. Alternatively the trap tuned at 21.5 provides a highly capacitive effect at 24 thus lengthening the dipole element versus the standard free-space dipole yet is inductive at 18MHz thus providing the overall shortening effect needed there.

My first experimentation phase involved using an LC trap of about 50uH and 50pF (resonating at 24.9) on a dipole and then adjusting the element lengths to provide the resonance dip at 24.9 and 18.1MHz respectively with the dipole fed via a 1:1 balun and low loss coax. What I found was that the frequency change was not consistent with the element length changes. If I shortened the 24MHz dipole arms, the resonant frequency did not always make the corresponding linear change even though the test frequencies were the same and the trap tuning was not altered. I subsequently squeezed the coil turns closer together and moved each trap frequency down to about 22MHz. The frequency versus length changes were still inconsistent though different to the previous lengths (i.e. different capacitive and inductive effects were present).

I drew conclusions that centred around the style of the first traps and then considered that I had successfully used the VE6YP trap calculator (http://www.qsl.net/ve6yp/CoaxTrap.html) to create coaxial traps for my wire dipoles previously – and those antennas worked well and tuned linearly. I created new traps using RG316 teflon coax and re-created the dual band dipole using them and with both traps set to about 23MHz. I was now starting to see closer to a consistent frequency shift versus 24.9MHz dipole length changes.

The single trap dipole was extended by a similar (but longer) element to create a two element yagi with 2.4 metres of driven element to reflector spacing. The dipole and reflector lengths were adjusted to provide the resonance dip at both 24.9 and 18.1 while maximising the front to back (F/B) ratio while using a low power oscillator into a small antenna about 60 metres away as a signal source. The F/B at 24MHz was only about 9dB but rose to about 15dB at 18.1MHz. The nulls off the sides were down about 30dB to 40dB so there was certainly some directivity involved.

After I could not improve the two element yagi any more through adjustment, it was time to add the elements to the Cushcraft A3S. The tower was tilted with the yagi reflector downward and a ¼” hole drilled 1500mm from the driven element u-bolt (and still 830mm from the original reflector). The new 18/24 reflector was then bolted on using a 60mm long bolt through the plastic element insulator and then though the boom. The tower was raised to about 45 degrees and the antennas rotated through 180 degrees so the front of the tribander was down and then lowered back towards the ground. Another hole was drilled at 900mm from the driven element u-bolt (and still 950mm from the original director) to provide the 2.4 metre overall DE to reflector spacing and the new 18/24 dipole attached. The 1:1 balun was then re-fixed in place at the dipole centre and a new low-loss foam 10mm 50 ohm coax feeder added to the existing LDF4-50 and RG213 feeder bundle down the tower with nylon ties.

The tower was raised back to vertical so that I could evaluate the tuning on the 5 bands now involved. The basic A3S SWR was essentially the same on 14MHz, shifted up a little in frequency on 21MHz and around the same on 28MHz although the SWR dip was not as deep – this latter effect undoubtedly due to the fact that the new lower frequency elements were interacting with it. The SWR dip on 18.1 was essentially as it was when used as the stand-alone 2 element yagi but the 24MHz dip had shifted up slightly. Given that the overall dip at 24.9 was quite wide, this latter shift did not concern me. I could have dropped the tower again and moved the 21MHz response back to where it was previously and done the same for 24.9 but there was no real need.

By virtue of adding the two extra elements, I now had a 5 band 5 element HF yagi – selectable via a coax antenna switch - but how well did it work? It is unfortunate that propagation is so poor on the higher HF bands at the moment however 14MHz and 18MHz were working well when I tried listening to the NCDXA beacons on those bands. With the yagi pointed at 60 degrees (to the USA for me), I was able to hear the 4U1, W6, KH6, ZL6, JA2 beacon signals on 18.1096 though only the ZL beacon was really strong enough to get a useable S-meter reading. Turning the yagi to 120 degrees made the ZL beacon rise to S8 while the JA beacon disappeared. Turning the yagi to 300 degrees dropped the ZL beacon to about S1 and the JA signal rose to about S6. The yagi at 18MHz certainly had front-to-back (and therefore gain) but no definitive measurements have yet been achieved. The band at 24.9 was clear of signals though my band noise certainly varied as I rotated the yagi.

The whole array will eventually need to be evaluated for front-to-back on each band using a signal source at a reasonable distance (rather than just 60 metres away) and the values compared to the 25dB published specification for the A3S F/B. In the meantime, I now have antenna gain and directivity on the highest five HF bands…..

Final dimensions for the extra elements are as follows:

Driven element, measured from inside edge of the trap to the centre of the boom : 2903mm

Driven element, measured from outside edge of the trap to the end of the 18MHz element tip : 405mm

Reflector element, measured from inside edge of the trap to the centre of the boom : 3050mm

Reflector element, measured from outside edge of the trap to the end of the 18MHz element tip : 465mm

Note that trap body is 150mm long and that the aluminium element length inside is 50mm thus the 24MHz dipole length is effectively (2903 + 50) * 2 = 5906mm. That calculates out as an end-effect factor of 0.9804 for this method of construction.

The following images and brief descriptions should give you the background to how the project advanced:

(mouse-over the images for a larger view)

The major parts used to build the traps for each side of the dipole and reflector are shown at right. The only items missing are some selft-tapping screws and the RG316 teflon- coax cable. The 13mm aluminium tubing slides inside the 20mm OD orange conduit (15mm ID) and then into the DN25 (/PE100) high pressure PVC pipe (25mm OD / 21mm ID) to get the correct overall diameter for the trap construction.	
Each 125mm length of 13mm aluminium tube goes into the 150mm length of orange conduit for 50mm each side thus leaving a 50mm gap between the two tubes and 75mm protruding from each side of the trap assembly. The 150mm length of high pressure pipe ends up flush with the end of the conduit.	
The traps were calculated using the VE6YP trap calculator (http://www.qsl.net/ve6yp/CoaxTrap.html) and are tuned to around 23MHz, with both trap frequencies within about 100KHz. The screw holes are 60mm apart so are about 5mm from the end of each internal aluminium tube, the screws have a compression washer between the head and the solder lug. A second screw was eventually added about 10mm from each end of the 150mm long outer tube but that was for mechanical stability. The traps were subsequently covered in 40mm black heatshrink, then a second layer when construction was completed and just prior to final attachment to the A3S yagi.	
This was the test configuration as a single dipole to see how the tuning to frequency progressed at 18.1 and 24.9MHz. The dipole was set on top of an old TV rotator so I could simplify my tests when using a signal source about 60 metres away. The split dipole was fed via an old RAIK 1:1 balun and low loss coax.	
The single dipole morphed into a two element dual band yagi by the addition of the trapped reflector element. The actual taper back to front seems larger in this image than it was in practice. The SWR curves for both 18 and 24 moved when the reflector was attached so the dimensions of both elements were reset to place them at the desired portions of the two bands. The dimension changes were also checked against the virtual front-to-back ratio noted by using the signal source and the rotator to accurately gauge direction. The two cables making their way toward the camera are the rotator control cable and the low loss coax feeder.	

This is how the Cushcraft A3S looked before the extra elements were added, note that there are 2 traps on each side of these. The 6 element 50 MHz yagi above it is described elsewhere on this web site. The full size HF dipole set that connect to the 1:1 balun hanging off the outrigger arm at left cover 160, 80, 40 and 30 metres. The side mount dipole for 2 metres FM is visible to the RHS. An Icom AH7000 discone is set on the very top of the tower as a general coverage antenna for 25 to 1300MHz.	
With the tower tilted over, the reflector element was added 1500mm from the original driven element. A 1/4" hole was drilled through the A3S boom at this point and a 60mm bolt used to fit the reflector. The 8-turn choke balun is used on the split dipole feed of the original A3S.	
The tower was raised to 45 degrees and the antennas rotated 180 degrees so that the front of the yagi was pointing downwards when it was lowered again. This photo is prior to the driven element being fitted. The front section of the 6m yagi is the limiting factor as to how close to the ground the array could be tilted, but even so the work was accomplished using a high A-frame stepladder.	
Another 1/4" hole was drilled 900mm to the front of the original driven element to provide a 2400mm spacing between the elements for 18 and 24 MHz. The new driven element was fitted using another 60mm long bolt. The RAIK balun was re-mounted at the centres of the new driven element and a one-turn coax loop provided so that future maintenance would be easy.	
The ***new*** view of the antenna array, shown directed away from the camera. The two new elements can be distinguished as there is only one trap on each side of the element where the original element series has two per side. The whole array now covers 14, 18, 21, 24 and 28MHz ..... even if via two coax feeders and a coaxial antenna switch..