8ele (70cm) x 4ele (2m) Crossed Satellite Yagi
By Rob Greaves - VK2GOM

Firstly, I make no claims for originality for this antenna! The basic design was arrived at using the DL6WU DOS-based Yagi designer program, which is freely available on the internet. The finished antenna provides around 10.5dBd gain on 70cm, and 6.5dBd gain on 2m, which is more than adequate to work the FM satellites with a handheld dual band radio (or two mono-band radios) and a couple of Watts.

The antenna design parameters can be tweaked in software, based on the materials you have available. I used aluminium from Bunnings (popular Australian store) tube and section, which was all sized in metric.

All elements are 10mm diameter, and the boom is 19.05mm square x 1.2mm wall, which is actually 3/4" tube that has been 'metrified'!

The Bunnings aluminium is available in 3m lengths, or 1m lengths. For the boom, you will need a single 3m length, cut down of course, and the elements can be cut from the 3m lengths. Careful planning will ensure minimum wastage. One and a bit 3m pieces will do all the 2m elements, and the remaining 70cm elements can be cut from another 3m length of tube, and perhaps another 1m length, if required.

I built my antenna such that the 70cm elements are permanently fixed to the boom, but all 2m elements (including the driven element) are removable to make for easier transport.

All elements are electrically bonded to the boom, which again the DL6WU software can take account of for the necessary boom correction factor.

The driven elements in each case are fed by a simple Gamma match, which is easy to tune using nothing more than an rf source – your hand held radio – and an SWR meter.

OK. Let's build the antenna!

Depending on whether you wish to hand-hold the boom, or mount it on some sort of support or field tripod determines the boom length you will need. My advice is start long – you can always trim it later. My particular antenna is handheld for /P use, which makes for easier operation, since it's not usually a case of simply pointing the antenna at the satellite; quite often you need to compensate for changes in polarisation by twisting the antenna about its boom axis.

First start by cutting the elements. D6, D5, D4 etc. = Directors. DE = Driven Element. Ref = Reflector.

Where necessary, I will refer to each band as 145MHz and 436MHz where confusion could occur with measurements.

For the 145MHz elements, you will need:

D2	=	900.0mm
D1	=	911.5mm
DE	=	972.0mm
Ref	=	1013.0mm

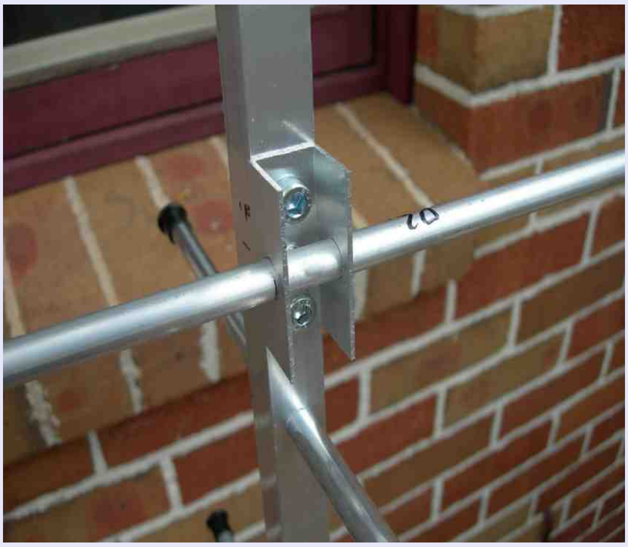
And for the 436MHz elements, you will need:

D6	=	278.4mm
D5	=	280.8mm
D4	=	283.2mm
D3	=	288.0mm
D2	=	294.1mm
D1	=	299.0mm
DE	=	324.6mm
Ref	=	345.9mm

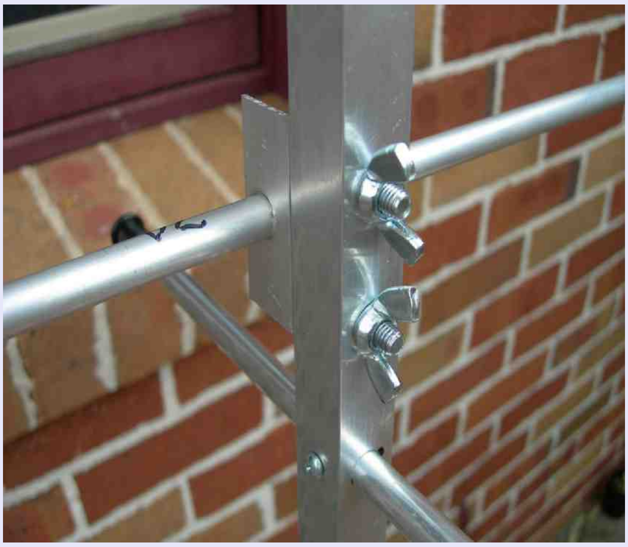
The calculated figures from the DL6WU software come out to two decimal places, which is impractical for home based metalwork, so I have rounded them to one decimal place. Just cut them as accurately as you can. I suggest using a rotating tube cutter to ensure the cuts are absolutely square and neat.
The boom can now be drilled.
It may be prudent to mark with a marker pen which edge of the boom will be drilled for the 436MHz elements, and the other edge for the 145MHz to avoid getting mixed up.
Both sets of elements live on the same boom of course, but 90deg apart. It is normal for the 145MHz elements to be horizontal when the boom is held, and the 436MHz elements vertical.
Choose a side of the boom, and mark it '436MHz'. Now, from one end, measure back 10mm and mark a line. This is your datum point from which the measurements will be made. This is also the point that 436MHz D6 fits through the boom.
For the remaining elements, measure back from the datum point:
From D6 (Datum point), 207.0mm for D5
From D5, 192.8mm for D4
From D4, 172.9mm for D3
From D3, 148.2mm for D2
From D2, 123.5mm for D1
From D1, 54.2mm for DE
From DE, 127.0mm for Ref
Now, centre punch the boom gently at each of these points, mid-width of the boom. Using a sharp 10mm drill bit, drill each hole through both sides of the boom. Here, it is critical to use a bench mounted pillar drill. Do not hope to achieve perpendicular holes with a hand held drill. Bench mount pillar drills are a cheap investment – mine was about $50 from Super Cheap Auto, and ensures perpendicular holes and a straight antenna.
Each 436MHz element can then be slid into the boom, such that the same amount protrudes each side. Eventually, the will be fixed by drilling a small hole through the boom and into one side of the element, and securing with a self-tapping screw, but do not do that yet – we have to deal with the 145MHz elements first.
Your antenna should so far look like this. You will note I have fitted white plastic boom plugs (Bunnings) and plastic end caps to each element (again from Bunnings) except for the driven element. I would suggest only fitting the bung plugs after you have shaken all the swarf out!

436MHz elements installed

On my antenna, I made all the 145MHz elements removable for ease of transport. I achieved this by making a 'sub mount' for each element from a 50mm length of 20mm U channel aluminium from (you guessed it) Bunnings. A picture explains a thousand words, which is shown overleaf:
(see next page)



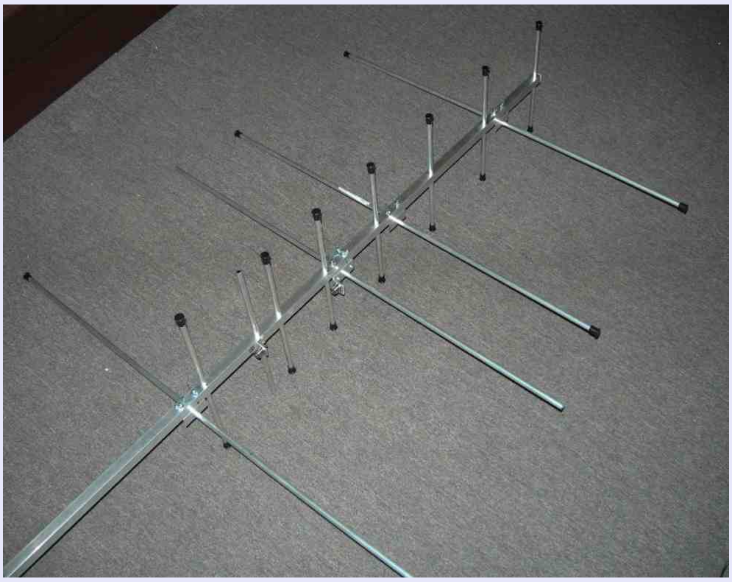
2m element mount from top side



2m element mount from lower side

To drill the U channel, slide each 50mm long section of U channel onto a piece of scrap wood trimmed to size, then centre punch the metal, and drill through both sides with a 10mm drill bit. The U channel is then drilled on the base, as per the pictures, each side of where the element passes through. I used M6 bolts and wing nuts. Each element is secured to the U channel by a small self-tapper from the underside (hence invisible in the pictures) of the U channel, and into one edge of the 10mm element. When it comes to getting the element to sit flush on the boom, you will have to counter-drill a hole slightly larger than the screw head on the boom to accommodate the protruding screw thread. Alternatively, you could use an Aluminium pop rivet and then perhaps just a dimple on the boom surface
All the U channel mounts for the 145MHz elements are drilled with M6 holes 30mm apart, so exactly between those two holes is the centreline on which the element holes lie, and where the element spacings are measured when mounted on the boom.
Again, looking from the 'far' end of the boom, the 145MHz elements mount thus:
From the very end of the boom, 160.0mm for D2
From D2, 373.0mm for D1
From D1, 162.5mm for DE
From DE, 379.5mm for Ref
You should find the 145MHz elements fit neatly between the 436MHz elements, as per the picture overleaf:

145MHz and 436MHz elements fitted



Again, you will see plastic end caps have been fitted to all but the driven elements.

I used N socket connectors for each driven element as shown in the picture above. The 436MHz N socket mounts on a small piece of angle aluminium (from Bunnings!) pop riveted or screwed to the boom just behind the driven element, as shown in the picture above. Try and aim that the brass solderable part on the back of the socket is 20mm out, radially, from the element when measured centre to centre.

The 145MHz N socket is slightly different – it has to be mounted on a small bracket fixed to the side of the U channel element holder, such that when the element is removed, the N socket comes with it. I used a piece of flat strip aluminium, bent 90deg, then drilled 10mm to slide over the element. This bent strip was then pop riveted to the side of the U channel. The photo below shows the 145MHz element with the N socket (and the gamma match) which we will come to shortly.

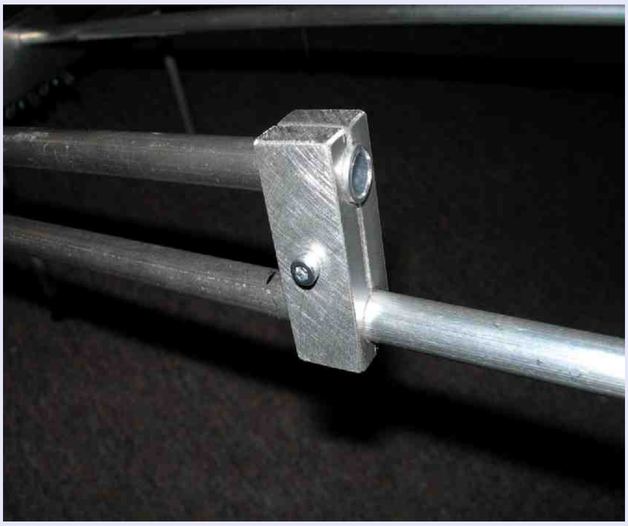
N socket mounting on 145MHz element

Now is the time to build the gamma matches. You will need approx 1m length of RG213, stripped of its inusulation and braid, to leave just the insulated core. This is a nice sliding fit inside the 10mm tube.
For the 145MHz gamma match, cut 230mm of this inner section of the coax, and for 436MHz cut 68mm of coax inner.
You will also need to cut some more sections of 10mm tubing from the scrap left over. For 145MHz, cut 150mm of tube, and for 436MHz, cut 50mm of tube.
Dealing with the 145MHz Gamma match first, as you will see from the photo above, I used a small scrap piece of 3mm thick Perspex, pop riveted to the side of the U channel element holder, drilled to slip over the element, and also drilled to allow the RG213 coax inner to pass through. This RG213 inner needs to be supported 30mm from the aluminium element when measured centre to centre. The short protruding end of the RG213 where it passes through the perspex plate is held in place with a cable zip tie, and the centre conductor is connected to the N socket with a short piece of RG58C coax.

The braid of the RG58C is only connected at the N socket end, and ends just before where the RG58C inner is soldered to the RG213. The whole lot is then wrapped in self-amalgamating tape to protect it. The 150mm length of Gamma tube is then slid over the RG213 inner.

At the other end of the Gamma tube, a moveable shorting bar is used, which during tuning is carefully moved to achieve best SWR before being clamped into position. Rather than a flimsy aluminium strap, I made some solid structural blocks from some scrap 50mm or so lengths of 16mm square section solid aluminium I already had (no luck this time, Bunnings!). I drilled two 10mm holes, 30mm apart (centre to centre) – one for the element, one for the gamma tube. I then drilled a 2.5mm hole through the centre that will take the clamp bolt, then carefully hack-sawed along the length of the shorting block, through the centreline of each 10mm hole. You now you have two halves, which can be clamped together with a bolt. In my case, I tapped one side so the bolt threaded into it, but you could enlarge the hole slightly, and use a small nut and bolt.

The 145MHz Gamma shorting bar looks like this, when mounted on the end of the gamma tube:



145MHz Gamma shorting block

The 436MHz gamma match is made the same way, except the RG213 coax inner is soldered directly to the brass centre pin of the N socket, to lie parallel to the element, this time spaced 20mm from the element, measured centre to centre, as shown below.

Direct connection to N Socket for 436MHz

As far as the positions of the Gamma parts go, my antenna tunes nicely as follows:

145MHz: The gamma tube is slid over the outer 48mm of RG213 coax inner, and the clamp is fitted 321mm out from the centre of the boom to the centre of the clamp.

436MHz: The gamma tube is slid over the outer 29mm of RG213 coax inner, and the clamp fitted 74mm out from the centre of the boom to the centre of the clamp.

Of course, your tuning may be slightly different based on your construction or measurement tolerances. To set up the Gamma matches, you will need an SWR meter, and a handheld radio. Tune the antenna by a combination of moving the shorting bar and the tube over the RG213 inner by small amounts, and finally clamping the shorting bar when you are happy at the lowest SWR at the desired satellite operating frequencies. The process is the same for both bands.

As far as operation with the antenna goes, initially I used a dual band hand held (Icom ICW-32E) with an Andrews duplexer. However, I still suffered de-sensitising on the 70cm Rx frequency when Tx'ing on 2m. I then came by another hand held, this time a Yaesu VX-6R. I have mounted this radio on the boom, for easy adjustment as the Rx radio for 70cm. The 2m radio now simply sits on my belt on a clip, and I use a speaker mic. The 2m radio needs no adjustment during the course of a satellite QSO, but the 70cm radio will need tuning to cater for Doppler shift during the pass. Having the radio in front of you mounted on the boom helps immensely. Also, using a speaker mic allows you to control audio feedback that might otherwise occur when you are hearing your downlink on a separate radio real-time as you are transmitting.

I also mounted a plastic handle that was taken from an old electric drill, and also an arm rest from a metal detector, to ease with holding and aiming the antenna during the satellite pass.

Yaesu VX-6R (70cm Rx) mounted on the boom, with Icom ICW-32E (2m Tx) that I clip onto my belt

I won't go into how to operate the FM satellites, CTCSS access tones (like the ground based repeaters) or the theory of Doppler shift etc. etc. as this is all information that can be easily gleaned from the internet, as well as the AMSAT website.

However, I do encourage you to give the FM satellites a go with this antenna. I have worked VK's 1 to 8 and ZL with this antenna. All with an FM hand-held! It also makes a useful portable antenna for terrestrial use, although it may require a little re-tuning to work well in the SSB portions of each band.

If anyone needs any further information on the antenna, please drop me a line. I can be contacted via vklogger.com.au, or vk2gom@wia.org.au

73 – and hopefully see you on the air!
Rob VK2GOM