RADCOM CONSTRUCTION FEATURE

Adjustable Beam for 14-28MHz

by L J Smith, G3HJF

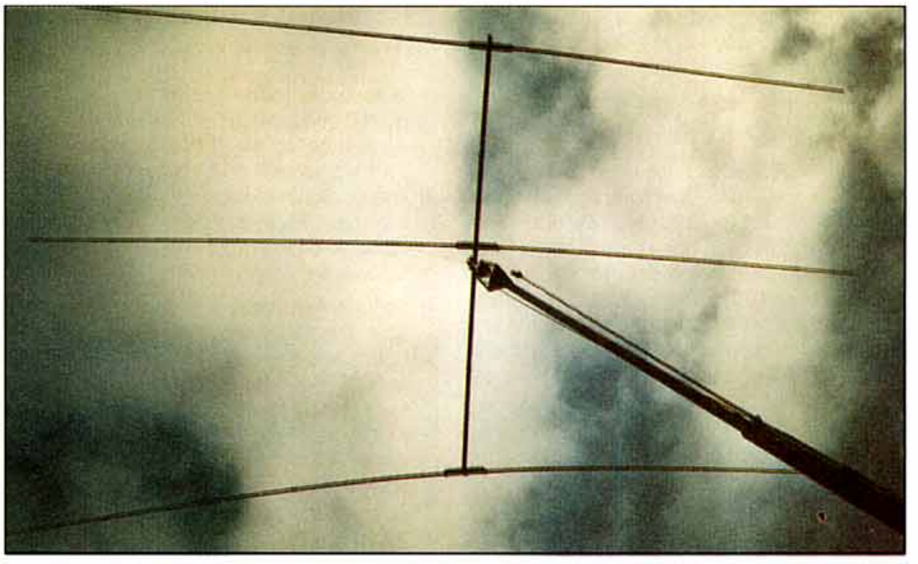
HERE'S A THREE element Yagi which can be constructed as cheaply as possible and reconfigured, reasonably quickly, for operation on the amateur bands from 14 to 29MHz. Before readers get too excited and think that this is some magic piece of ironmongery let me explain in more detail.

Having installed a telescopic, tilt-over mast I resisted the temptation to remount the tribander which had been in use for some years. It worked well enough but even the most enthusiastic users concede that a tribander is a compromise and only a mean substitute for the real thing.

With easy access to the mast head, I could attach almost any sort of beam. At first I toyed with the idea of a separate beam for each band. The manufacturers catalogues were not encouraging! A three element 20m beam was well over £200 and not much less for beams for 10 and 15m. And what about the 17 and 12m bands?

For some years, I have used CB verticals in a variety of HF band antennas. Now two of these, laid horizontally end-to-end at full extension, produce a neat, lightweight tapered element over 36ft long – quite long enough for a 20m reflector and yet easily telescoped down to around 16ft or so for a 10m director.

CB antennas can be obtained cheaply now. I got a good price from a dealer at a rally for six of them, brand new and boxed, enough for



a full sized three element 20m beam. The same dealer also gave me a good price for four 5ft lightweight mast sections which, fitted together would form the boom. Finally, at the same rally, I found a superb heavy-duty mast-to-boom bracket. Yes, there are still real bargains to be found at rallies!

CONSTRUCTION PROCEDURE

I AIMED TO MAKE the conversion from CB antenna to HF beam as simple as possible. The detailed construction of CB antennas tends to differ from one make to another but whether it is drilling out pop rivets or removing screws or bolts, the procedure is essentially the same.

Each antenna is shifted off its lower insulator, from which is removed the matching device, usually a tapped coil. Also removed is the SO239 coaxial socket. Each pair of CB mast mounting brackets are then drilled ready to be bolted together end to end. Plated 'roofing bolts', available in most DIY shops are used, three being sufficient for each pair of brackets. There is now a choice to be made: whether to dispense with the lower insulators altogether and join the ends of the elements with a short length of aluminium tubing, or to remount the insulators, reinforcing them with a short length of rod or tube passing from one to the other **Fig 1**.

In either case the idea is to strengthen the element union to take the additional strain put upon it by the horizontal elements. If the element is to be electrically continuous, joining the elements with a short length of tube is the strongest method. The holes vacated by the SO239 sockets can be reamed out to take the new tube section. A really top notch job can be made if you have access to aluminium welding equipment.

To strengthen the element support further, another hole is drilled in each 'top' insulator, through the element and a stout self-tapping screw or small bolt passed through to lock the element and stop it sliding as the mounting flexes. In my case I remounted the lower insulators using countersunk-head screws

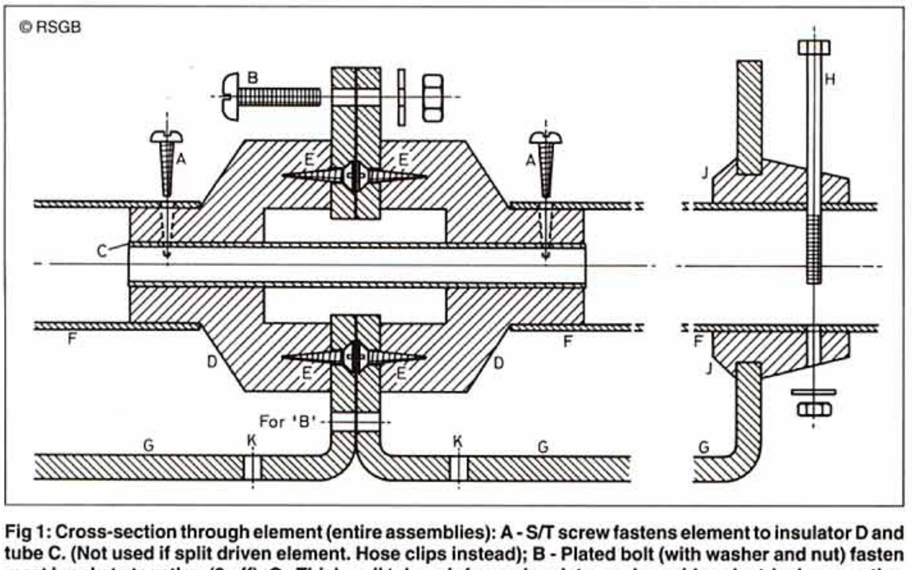
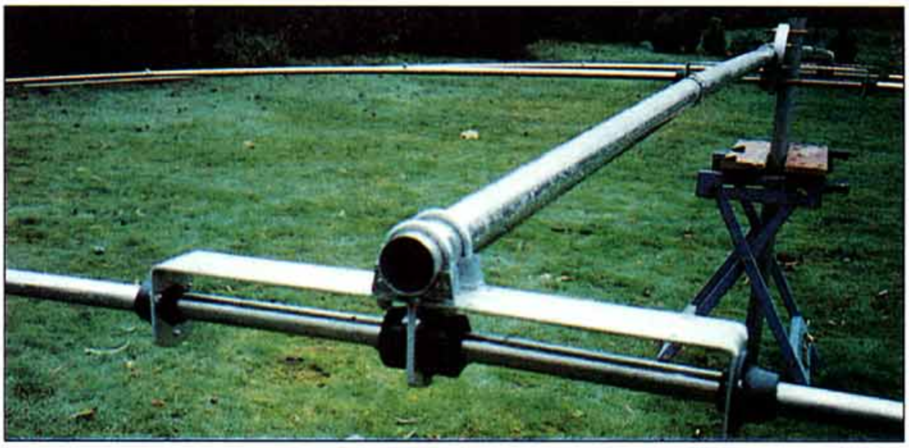


Fig 1: Cross-section through element (entire assemblies): A - S/T screw fastens element to insulator D and tube C. (Not used if split driven element. Hose clips instead); B - Plated bolt (with washer and nut) fasten mast brackets together (3 off); C - Thick wall tube reinforces insulator and provides electrical connection between elements F, via bolts A; D - Lower insulators; E - C/S screws fastening Ds to brackets G; F - CB antenna elements; G - Mast mounting brackets; H - Bolt, locks element to J to prevent element sliding in J; J - Top insulator and K - Holes for boom brackets (2" car exhaust clamps).

so that the ends of each of mast mounting brackets could be butted up flush and bolted together.

I chose to retain the lower insulators for convenience so that I had the option of a split driven element. A piece of thick wall aluminium tube, about ½in. in diameter and 6in long, is pushed through one insulator to the other to act as a strengthener. This also allows an electrical connection to be made by replacing the original self-tapping screws which had connected each element to the matching coil. If a split driven element is required then these screws are omitted and the ends of the elements are slit and clamped to the insulators with hose clips.

The brackets for each element are mounted to the boom by pairs of U bolts (2in exhaust clamps from a car parts shop).



The beam at ground level showing the neat method of joining two CB antennas together.

BOOM AND ELEMENT SIZE

THE 5FT SECTIONS are used to form the boom. To prevent the sections coming apart the ends are slit for a couple of inches and clamped by 2in diam hose clips. The lengths and spacing of the elements for each band can be obtained from the usual handbooks. Lengths for the higher frequency bands can be marked with paint or scribed with a sharp pointed tool. Don't use PVC tape or it will be scraped off or jam the joints when the elements are telescoped.

For those who love to tinker, the book *Yagi Antenna Design* by Jim Lawson, W2PV, provides a wealth of information on element lengths, boom sizes and spacings to optimize gain, bandwidth and Front to Back ratio. Using dimensions 'from the book', a gain of at least 6dB with 20-25dB F/B ratio can be expected. Generally, by altering the lengths and spacings greater gain can be obtained at the expense of reduced F/B ratio, and vice versa.

The complete antenna, assembled and ready to be fitted to the mast head weighs approximately 32lbs (14.5kg).

Finally, to keep the whole antenna looking shiny new it was given an application of silcone car polish from a spray can at the final assembly.

FEEDING AND MATCHING

THERE ARE MANY WAYS of feeding a Yagi beam, the most popular being the Gamma Match and Bill Orr's, W6SAI, 'Inducto-Match' or Hairpin. An entirely separate article would be needed to discuss them all fully. The methods described here are the ones that I've tried.

a) **Delta Match:** Probably the simplest system is the Delta Match **Fig 2(a)**. This involves taking open wire line up to the beam, the ends being splayed out and joined to the (continuous) driven element at points equidistant from the centre. The triangle so formed should have roughly equal sides: I found that sides as short as $^1/_{20}$th wavelength (ie just under 4ft at 20m) worked well. When changing bands one can opt to reduce this but in practice these dimensions are very uncritical. I have used this matching system for many experimental beams and found it excellent. However some form of antenna tuner is required and though this has many benefits it must be admitted that most operators prefer coax and no ATU. In addition open line does not like being wrapped around the mast when the beam is rotated nor dumped on the ground when the antenna is lowered.

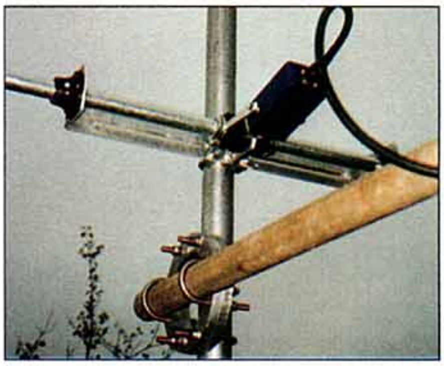
b) **Balun:** Alternatively if coax is preferred then the cable could be run up to a 4:1 balun and thence straight into the Delta section. But this implies that a low SWR is to be sought for each band and this means that there is a lot of experimentation to be done to find the right Delta lengths and spacings. In my trials with this system I could rarely get the SWR below 6:1, 10:1 being the most common. For open wire line and an ATU this is no problem, but for coax it is. Altogether I found this method of coax/balun/delta match more trouble than it was worth.

c) **Quarter Wave Transformer Match:** Bill Orr, W6SAI, once wrote that he had climbed more masts to measure the feed impedance of Yagi arrays than he cared to remember and that in every case this impedance was found to be in the range 18 to 20Ω. If this is so then another very feasible feed system would be to use 50Ω coax terminating in a ¼-wave transformer of 35Ω impedance and a 1:1 balun into the split driven element. The transformer section can be made up from two lengths of 70Ω coax (¼ wavelength long allowing for the velocity factor of the cable) in parallel. Since changing bands with this antenna involves dropping the beam down to alter element lengths, it can be no great trouble to have pre-cut ¼-wave transformers ready and to swap those over at the same time. However I found that obtaining a low SWR with this system is not quite as easy as it may appear as one has to be quite sure what the feed impedance of the beam is and select the transformer accordingly. In the end it seemed easier to settle for an SWR of 1.5-1.8:1 and a 'Coax Line Flattener' (ie an ATU!)

d) **Hairpin Match** ('Inducto-Match'): This method enables a good match to be obtained to coax on each band with the minimum of re-adjustment. The cable is run up to the centre of the (split) driven element and a choke balun consisting of 8 – 10 turns of light coax around a ferrite rod, inserted between it and the element. At the same connecting points some shunt inductance is added, taking the form of a pair of ½in dia aluminium tubes, about 2ft long and spaced a couple of inches apart and running back along but insulated from, the boom.

A shorting strap between the rods enables the value of the inductance to be varied. Adjustment is made by shortening the driven element from its design value by some 4 – 6 inches (at 20m) and checking the SWR whilst adjusting the position of the shorting bar. Once the right position for each band has been found it should be marked so that the shorting bar can be reset to the right position when changing bands.

The snag with this method is that finding the setting for minimum SWR can become very fiddly and it will certainly change to some extent when the beam is lifted to its operating height.



The 'Bit Match' box.

e) **The 'BIT Match':** All of the above methods are frequency sensitive and need re-adjustment every time the beam is set to a new band. Although element lengths for each band must be changed I confess that I didn't want to do more work than is really necessary. If W6SAI is right and the impedance of the driven element is around 20ohms then a transformer will do the job. A linear matching section as mentioned above is one such. But there is no reason why a 'Broadband Isolating Transformer' should not give just as good a match. Hence the 'BIT Match'. Such a transformer is very easily made.

The BIT Match shown in **Fig 2(b)** consists of two windings on a large ferrite ring. I used a stack of three of the 38mm type available from the RSGB for EMC purposes [see BookCase pages 94/95 – *Ed*]. Two 10in lengths of 18SWG PVC covered copper wire are used. One is wound for three turns, evenly spaced, around the ferrite ring. The ends go to a SO239 socket for connection to the feeder. The other wire is now wound for two turns through the ring (making the transformer turns ratio 3:2), evenly spaced, taped and the ends taken to the (split) driven element of the beam. Because there is now some small value of inductance at the centre of the driven element its overall length should be reduced by three or four inches. The transformer is housed in a small plastic utility box and located right at the centre of the driven element.

Initial trials of this method gave an SWR of 1.5:1 or better across all of the bands. This can easily accomodated by the auto-ATU in many rigs these days. There is clearly room for experimentation here. The acid test seems to be to check the SWR and then run the rig at full power for half a minute or so. If the SWR starts to climb suddenly then switch off – the core is overheating!

A side benefit of this method is the reduction of interference from local broadcast stations. The BIT Match acts as very effective high-pass filter.

PERSONAL PREFERENCE

FOR EXPERIMENTATION I have a preference for the Delta match with open line and an ATU. Despite its mechanical drawbacks, electrically it works superbly! Otherwise the BIT Match described above is quite adequate for all normal operation and far less trouble than any other system.

CHANGING BANDS

THIS IS ONLY A few minutes work with practice and a little help from the an assistant! The mast is lowered and tilted over until the director is flat on the ground. At this position both it and the driven element are adjusted to pre-marked lengths. The beam is then hoisted high enough to allow it to be rotated through 180 degree and then lowered again to get at the reflector. I prefer to telescope the inner sections of each element rather than remove sections. This way no section gets lost! Although the position of the elements on the boom should be changed for each band, the Yagi is not particularly critical as to element spacing. Wider spacings will give a greater gain but reduced front-to-back ratio. Experience with this antenna has shown that the spacing is so uncritical that I now no longer bother to change it. As a wide spaced beam on the 10 metre band it has proved to be excellent.

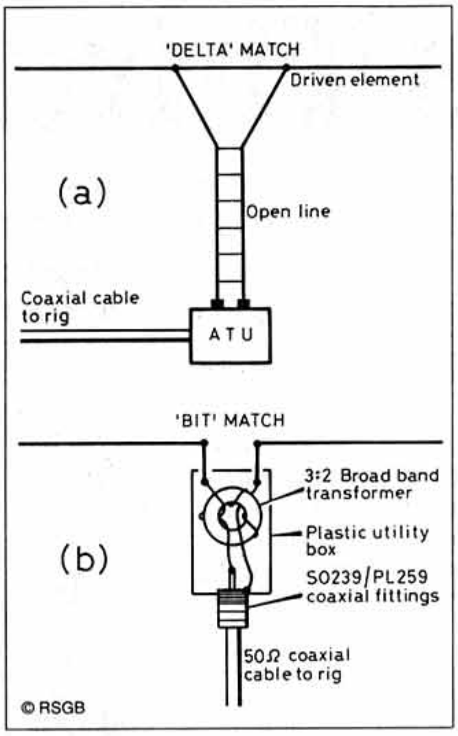


Fig 2: Preferred feed methods.

CONCLUSIONS

THE COST OF THE ANTENNA hardware was well under £100. The performance is excellent on all of the HF bands.

To those used to instant bandswitching the necessity of lowering the antenna and adjusting the elements may seem to be too much trouble. I will leave them to the expense of separate antennas and masts or a tribander. Perhaps because it takes a little time to change the antenna configuration, one is encouraged to stick with a band for a few days or even weeks. This is particularly rewarding on the HF WARC bands. It is remarkable the DX that lurks on these bands, away from the pile-ups and contests!

This use of CB antennas to make a Yagi is surely not unique. Someone, somewhere must have tried it before, but if they have and had it published, then I have not come across it. However, I will gracefully concede precedence.

If you would like to try a full-size, tuned-on-the-nose monobander then this must be about the cheapest way of doing it. But be warned, if you do you will find it hard to go back to anything else!

YAGI DESIGN FORMULAE

DESIGN FORMULAE for Yagi antennas vary only slightly from one reference book to another. I followed the data given in Bill Orr's 'Beam Antenna Handbook' [see BookCase p94 to order this informative book – *Ed*]. His formulae are:

Driven element length (feet)	=	473/F(MHz)
Director length (feet)	=	445/F(MHz)
Reflector length (feet)	=	501/F(MHz)
Element spacing (feet)	=	140/F(MHz)

Like most Yagi dimensions these are not particularly critical. One does not need to measure slavishly the lengths to fractions of an inch. I have found that setting the driven element to the formula above and then making the reflector some 3 – 5% longer and the director the same amount shorter worked just as well!

To allow the mast-to-boom bracket to be fitted at the point of balance the driven element was shifted 12 inches towards the director.

ACKNOWLEDGEMENTS

IT WOULD BE UNFAIR of me to conclude this article without a mention of the root cause of it! I would not have been tempted to design and build this antenna had I not had easy access to the top of my mast, in this case a 40ft Standard Plus (guy-less) model from Tennamast (Scotland). Holding aloft a beam of this size with over 120ft of aluminium tubing is no mean requirement. I can recommend this firm both for its products and the helpful advice of its proprietor, Norrie Brown, GM4VHZ.