Build yourself an exceptional 430MHz u.h.f. Yagi antenna!

Alan Ford's

antenna workshop

Alan Ford VK2DRR presents Part 1 of his 70cm antenna by describing the background to the project and workshop techniques.

An 8-Element 430MHz Yagi Antenna. Part 1.

In this article I'll briefly explore the history and theory of the famous **Yagi-Uda** antenna (to give it the correct title), as well as address some workshop techniques that will be used in the construction of an eight element 435MHz Yagi. The actual construction will be dealt with in an article to follow.

Yuda Who?

Poor old **Shintaro Uda**! With **Hidetsugu Yagi's** assistance, he developed the Yagi-Uda antenna in Japan well over 80 years ago. However, the translation to English was done by Yagi and the antenna quickly became known simply as the 'Yagi' with 'Uda' left off for simplicity. So Uda quickly slipped almost into oblivion!

Yagis antennas are all around us. They are the most common form of terrestrial TV antennas and are also used for Band II frequency modulated (f.m.) radio broadcast reception, some business radio point-to-point applications and of course by Amateur Radio operators.

Experimenting with antennas has always been a popular branch of Amateur Radio – and indeed Foundation Licencees in particular value this outlet for creativity as they're not allowed to use home constructed transmitters or transceivers; nor can they modify them). There's much fun to be had constructing various antennas and experimenting, trying to get the maximum gain in the required direction (more on that later).

Like most antennas, the dimensions of the Yagi are closely related to the band of operation. In general, the higher the frequency the smaller is the antenna (more detail in due course) The 430MHz (70cm) and 144MHz (2 metre) bands are particularly suited to the construction of Yagi antennas that can be rotated, thus making use of their directional properties.

Basic Antenna Theory

Let's now look at some basic antenna theory – and before you groan, I'll promise to keep it brief and simple, provided the old hands will forgive me for cutting a few corners!

The job of an antenna is to transfer the maximum energy from the transmitter to free space (almost always with air in it!) or from free space to the receiver. To do this efficiently the antenna needs to be in resonance as well as having its impedance matched to the feeder.

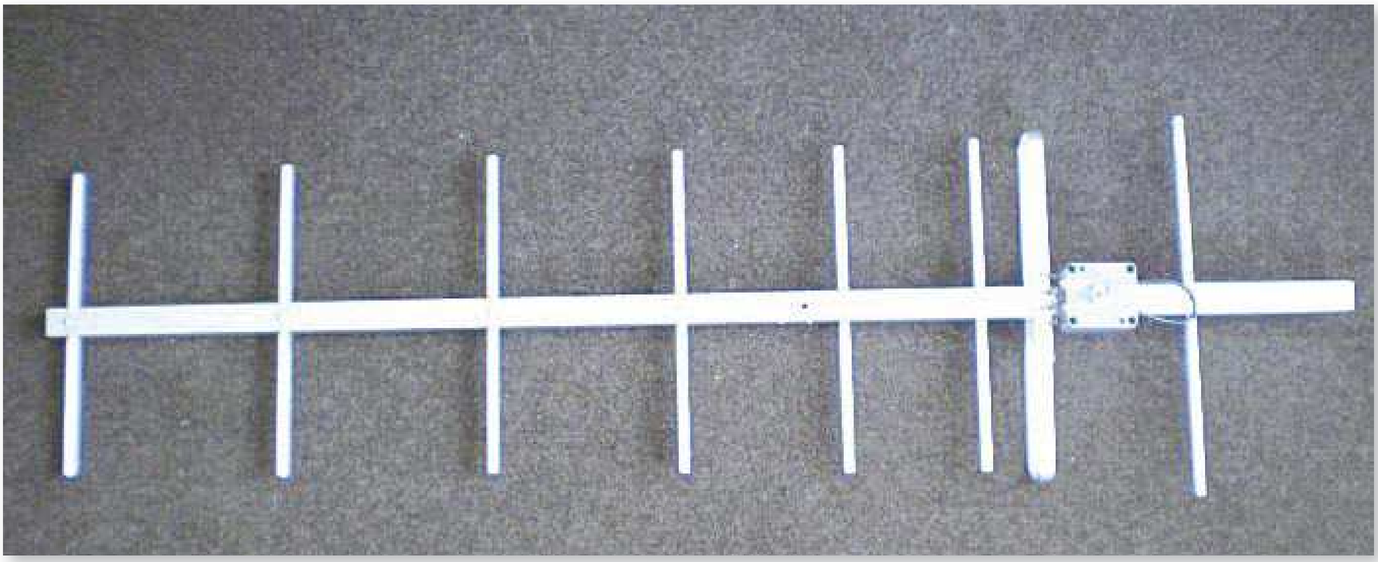
The resonance part is directly related to the length of the radiating element and is not hard to understand. The impedance part is a little harder but follows simple practical rules.

One thing is very convenient – and that's if an antenna is designed to transmit well on a certain frequency then its receive performance will also be optimum at that frequency. This is fine if you are working simplex (i.e. the receiver and transmitter are on the same frequency and take turns to use it) but of course with a repeater the frequencies are nearly always offset!

Fortunately a practical Yagi antenna can work well over quite a range centred around its design frequency. Because of this we say it has 'bandwidth' (again, more on this later).

Basic Isotropic Radiator

Now the most basic antenna of all is the theoretical isotropic radiator (**Fig 1.1**). It's virtually impossible to make one. It would also be grossly inefficient anyway as the whole principle of the isotropic radiator is that radio energy is radiated evenly



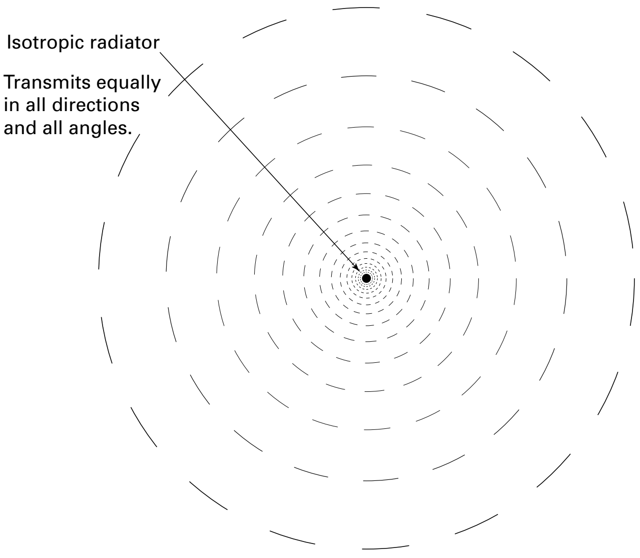


Fig. 1.1: An isotropic theoretical antenna is shown, this radiates in all directions equally but is almost impossible to create in reality.

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all around the antenna, up and down and in all other directions. In practice that means large amounts of energy would be sent up into space or down into the earth.

In contrast, one of the simplest practical antennas is the half wave dipole. Here the energy is concentrated in one of two planes, depending on the attitude of the antenna – horizontally or vertically – but still all round in those planes, though not from the ends. This automatically gives some gain as the available energy from the feeder is concentrated into one of those planes.

It's important at this stage to emphasise that any passive antenna (not including an 'active' type with some form of amplifier) can only produce gain by concentrating the radiation (or reception) in one direction. The basic physics rule applies that you cannot get something for nothing. Gain in the chosen direction must be accompanied by an equal attenuation in others.

Basic Half Wave Dipole?

So what is the basic half wave dipole? Simply speaking, the answer is two pieces of conducting material such as a tube, strip or wire, placed end to end and fed at the middle, as in **Fig 1.2,** so that tip-to-tip the two conductors form a half-wave (electrically).

The **pure** wavelength is found simply by dividing the frequency in MHz into the speed of radio waves (same as the speed of light) being approximately 300,000km/sec, when the answer will be in millimetres. For example, for 435MHz (in the 70cm Amateur band) the calculation to the nearest millimetre would be:

Wavelength(m) = (300,000/435)
=0.690m (or 690mm)

So, a pure half wavelength would be 345mm (again to the nearest millimetre). However, this is not the same as its length **electrically**. In practice we have to make allowances for other factors, such as the different speed of radio waves in metals (found by applying what is called the velocity factor).

Note: I hope you've read this far and not given up in despair, because you'll be glad to know that when it comes to the actual construction (in a later article) you are not required to do any calculating. I will provide all the measurements for you. But it's always interesting to know the underlying thinking.

The Yagi

After the basic theory of the dipole we come to the Yagi antenna itself. So, just what is it that makes this type of antenna so special? The answer is, that the principle is that we arrange the dipole (which we now call the driven element because it's driven by the feeder on transmit and by the radio waves on receive). Then behind it we place another slightly longer element, and in front we place one, or more, slightly shorter elements. Reasonably enough, the longer one is called a reflector and the shorter ones are called directors.

The beauty of both the reflector and the directors is that they're not connected to any feeders. Their operation is purely influenced by currents in the driven element. Because of this they're known as 'parasitic elements'.

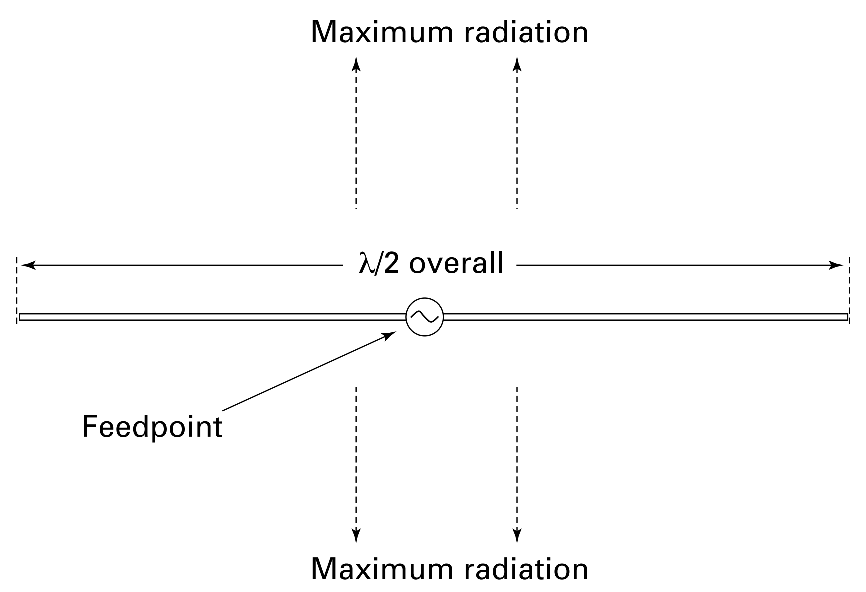

Fig. 1.2: Shown here is the half-wave dipole antenna, which radiates at right-angle to the element's length (including out of the page, towards and away from you).

Uda and Yagi found that by adding parasitic elements they could reduce the beam over which radiation occurs and thus produce signal-gain in the direction of the shorter elements (hence 'directors'). Additionally, they found that by increasing the number of directors they could reduce the beam-width more, further increasing gain (but at the same time making accurate 'pointing' more essential). Incidentally, it was also found by experiment that there was a negligible effect from increasing the number of reflectors (when they were in line).

The practical Yagi design has therefore evolved into a design with one reflector, the driven element and as many directors as is practical to add. The simplest Yagi is a three-element beam. It has one reflector, the driven element and one director, as in **Fig 1.3**.

Remember that we have a trade-off here. The more directors that are added the greater the gain is, but the beam-width becomes less, and with it, the need to point accurately becomes increasingly important.

You can probably see by now that a Yagi antenna is of little use at a base station trying to work mobiles, as they would be forever moving in and out of the optimum diurection. Also it's of limited use when there are various differing base-to-base paths, such as during a competition (where other stations are at different bearings), unless there is a means of steering the array. And now you know where rotators fit in! Before or instead of those, the Yagi mast could be rotated by using a strong arm – the well known 'Armstrong' method!

A Yagi can be made with a supporting boom that is made of metal (as the one to be described is) or it can be made with insulating material (the various dimensions are different). I prefer metal as it's often stronger.

Note: Here's one very convenient thing – if the boom is made of metal, it's perfectly in order for the parasitic elements to be in contact with it! This makes the practical construction of a sturdy Yagi much easier. However, the driven element **does** need to be insulated from the boom for reasons to be described in the second part of this article.

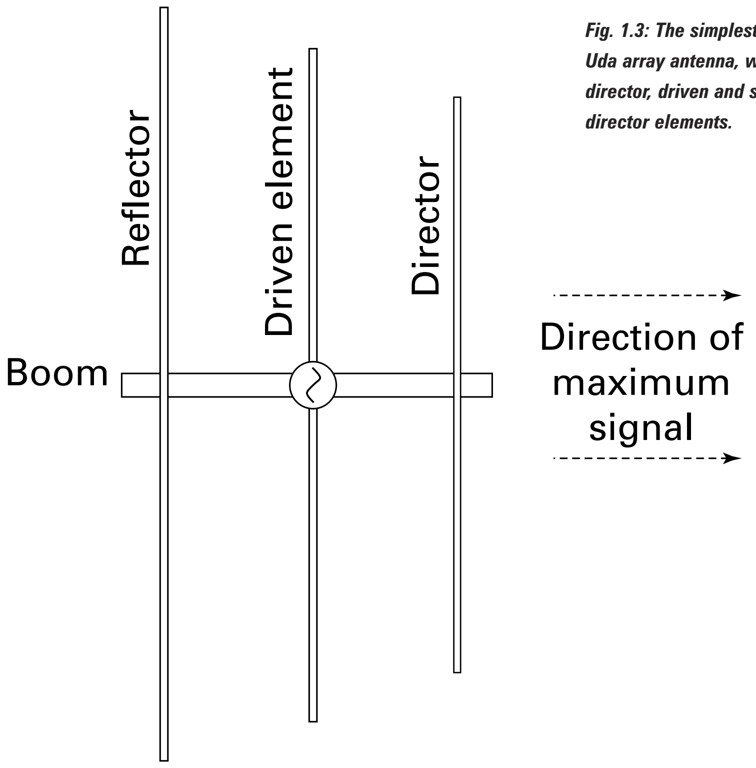

Fig. 1.3: The simplest Yagi-Uda array antenna, with its director, driven and single director elements.

It's common to make use of the popular folded dipole rather than a 'normal' one. This is shown in **Fig 1.4**. One advantage of the folded dipole is that it has a wider bandwidth, that is to say it can cope with a wider band of signals about the centre design frequency. The vital measurement is the overall length and it turns out that for the practical eight element Yagi I shall describe it should be about 324mm.

The Balun

Having taken care of the resonance issue, now we come to impedance and at the same time a most important point with regard to the feeding of the antenna. Nowadays, all modern transceivers are produced with a 50Ω coaxial cable antenna feed arrangement. This is an **unbalanced** feed, because the outer screening of a coaxial cable is obviously neither physically nor electrically the same as the inner core. In contrast, the dipole or folded dipole is a **balanced** arrangement, with both sides of the connection appearing the same electrically.

The impedance of a folded dipole is around 300Ω and on the Yagi to be described the proximity of the parasitic elements brings this down to approximately 200Ω. The combined effect of the impedance mismatch and unbalanced to balanced connection would give rise to losses and such unwanted effects as TVI, caused when the outer screen of the coaxial cable tries to become part of the antenna and radiates.

Fortunately we can fix both these things at the same time by introducing a 4:1 (impedance) balun, which of course stands for 'balanced to unbalanced'. The balun is in effect a radio frequency (r.f.) transformer.

Many bright ideas have been developed for baluns but one of the simplest is made by introducing a loop of coaxial cable, which is electrically a half wavelength long (this time a relatively simple calculation involving only the velocity factor of the coaxial cable used for the balun). With the aid of the 4:1 balun to be described the 200Ω impedance at the centre of our folded dipole is matched to 50Ω, which is conveniently suitable for the transceiver.

Construction Techniques

I hope the old hands will forgive me for detailing some workshop techniques now! I suggest this because the art of 'chassis bashing', where Amateurs drilled and punched metal chassis in preparation for valve-holders and other such parts, is almost defunct. However,

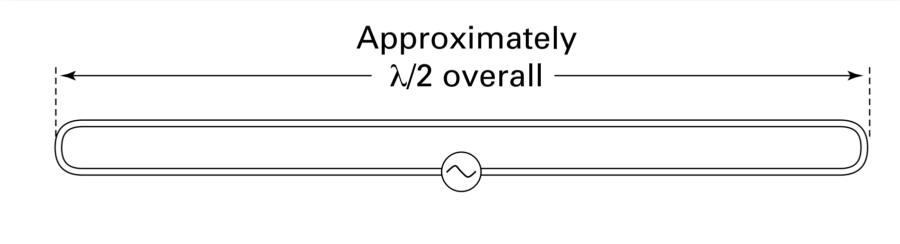

Fig. 1.4: The folded dipole has both an wider bandwidth and a rather higher impedance than a simple half-wave dipole, although they're both similar lengths overall.

metalworking and similar workshop skills can be and are put to use in constructing antennas.

The most common material used is, of course, aluminium, which has become quite cheap and easily obtained at hardware stores. For the Yagi project here, we will be using readily available 1in (25.4mm) square section tube for the boom, 1.5x1/8in (approx. 12mmx3mm) strip for the driven element and 3/8in round tube for the parasitic elements (in metric countries use 10mm tube but note that the slight difference in size means that the holes to be drilled in the boom for these parasitic elements must be either imperial **or** metric to suit the element themselves!)

Aluminium is relatively easy to work, being light, fairly soft and yet strong. However, one specialist tool you will need is a 4mm tap for cutting 4mm threads. Fortunately, they have become quite common and inexpensive.

Tapping threads used to be quite a 'black art' but there's nothing to it nowadays at the hobby level – although I doubt they'd let me loose on a spacecraft! You simply drill a pilot hole smaller than the M4 bolt to accommodate it, and then you turn the tap in the hole by hand a couple of turns at a time, then backing off to clear the swarf, and it will cut a thread.

You may ask – "How much smaller than the finished size should the pilot hole be?" In reply I'd advise that for a 4mm (M4) bolt in aluminium 3.3mm is ideal – but you can get away with 3.5mm, and drills of that size are readily available. For the purists, the tap will be of the 'taper' variety and we won't trouble ourselves with 'bottoming' or 'finishing' taps.

I'm assuming that you'll have the rudimentary workshop facilities of a sturdy workbench and adequate metalworker's vice. Additionally, although you can do without it, a drill press (a drill on a stand) makes the whole job much easier and more attractive as a finished product. For this job you'll also need a hacksaw, set square, centre-punch (this one has a sharp point – **not** a nail punch with a flat head!), steel rule, steel measuring tape, reamer, drill bits of 3/8in (or 10mm) for the parasitic elements, and 4mm for clearance for the 4mm (M4) bolts, 3mm for a BNC socket mounting flange and 3.5mm to provide pilot holes for tapped 4mm holes. The materials required will be listed in the second part of the article.

Basic Workshop Rules

Now for some very basic workshop rules: Eye protection must always be employed. Use a sturdy workbench and keep it clear of clutter! Never make sawcuts without marking out first. Never drill any hole without marking out and centre-punching first.

Larger holes should be started with a small 'pilot' drill. In this regard, note that in such cases if the pilot hole is too big, the larger drill will tend to 'grab' in the hole. The workpiece must also always be held securely when cutting or drilling – remember the good tradesman's motto "Measure twice and cut once!"

When marking out a line on the boom or the strip (driven element) for either a straight cut or hole, always use a try square and don't try to estimate a right angle. The established metalworking method is to scratch the line with a scribe (a sharp point – not a village 'literate person' of old times!) but I use a sharp pencil with a fine lead.

When you're sawing, don't force the saw. Instead, try to concentrate on keeping the saw blade vertical (making sure first that the piece you are cutting is exactly horizontal (no, using a spirit level is not overkill here). Some people like to use both hands on the saw, to make a steadier cut, but this isn't to mean that you should be pressing down with all your might on the saw.

Another tradesman's motto is "Let the saw do the work." And, when cutting along a marked line, you need to cut exactly on the 'waste' (un-measured) side as the saw cut has a width too (albeit small) and cutting exactly in the middle of the line will result in a piece that is slightly too small.

The Tolerance

Having given you my advice, I should also mention that the tolerance for all cut measurements in this 435MHz Yagi is a little over ±2mm. In practice you'll be able to cut reliably to within 1mm of the desired measurement. So generally fractions of a millimetre are irrelevant for our purposes and usually I have not attempted to use them. Neither need you sit in a corner of the workshop feeling upset because you think you've failed to make a cut accurate to a tenth of a mm!

Finally, another important reminder needs to be repeated! A drilled hole must first be marked and centre-punched, or the drill will 'wander' on the material as you apply it. Hopefully you'll be using the drill press (although using a hand drill is possible – though it's tedious). Again, do not force the drill down – just apply a gentle pressure, the smaller the drill the lighter the pressure. And a second reminder: wear protective glasses when doing any form of cutting or drilling.

As far as hole sizes go, theoretically an M4 bolt needs a hole somewhat larger than 4mm in order to give clearance. But in practice you will probably find that purchased 4mm bolts actually have a diameter of 3.9mm, and a 4mm hole will then give clearance.

In the next article to appear I will describe exactly how to make the 70cm Yagi. In the meantime if you've never worked with metal before I suggest you try making some cuts and drilling some holes, always remembering those safety rules!

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Time to get 'stuck into' Alan's 430MHz antenna design.

Alan Ford's

antenna workshop

Alan Ford VK2DRR present part 2 of his 70cm Yagi antenna and describes the construction stages.

Errors & Updates
Unfortunately, Murphy struck during preparation of Alan VK2DRR's Yagi article (Part 1) for printing! On p25 of the September issue, in column 1 line 10, the driven element is described as being made from '1.5 X 1/8in (approx 12mm x 3mm)' strip. Of course that should be '1/2 x 1/8 in', as per the copy. In other words 0.5 not 1.5. (Alan points out that 1.5in is a lot longer than 12mm and at over 38mm would make a very difficult bending job for the folded dipole!). My apologies for the problem working with Imperial and Metric mixtures is fraught with difficulties! **Editor**.

An 8-Element 430MHz Yagi Antenna. Part 2.

Welcome to Part 2 and I hope you found that my earlier article on the background to the Yagi type of antenna plus some workshop tips gave you an appetite to build one!

The tools needed are listed in the previous article. The full list of materials is at **Table 2. 1** and I'm dividing up this fairly ambitious project into five separate sections. The sections are construction of the parasitic elements, the boom, the insulating piece, the driven element and finally the balun.

Table 2.1

Boom	1,204mm length of 25.4 mm square section aluminium
Parasitic elements	Either 3/8" or 10mm round aluminium tube. Seven lengths per Table 2. Total amount of material is 2,450mm, but allow for cutting and for end waste too short for an element.
Driven element	676mm Either 1/2" X 1/8" or 12mm X 3mm aluminium strip
Insulating piece	110mm 15mm X 10mm plastic rectangular stock
Balun	Plastic sealable box BNC bulkhead (flange) mounting socket Short length of 50Ω coaxial cable
Miscellaneous	M4 bots, nuts, shakeproof washers, solder tags, plus suitable nuts, bolts and washers to mount bulkhead socket plus solder tags to suit.

Table 2.2

	Length	**Spacing (to centre-lines)**
Reflector	351	150* from start of boom
Driven element	324	138 from Reflector
Director 1	305	52 from driven element
Director 2	302	124 from Director 1
Director 3	298	148 from Director 2
Director 4	293	172 from Director 3
Director 5	290	193 from Director 4
Director 6	287	207 from Director 5
Boom excess		20* to end from Director 6

4:1 balun. 50Ω coaxial cable 227mm shield to shield, plus tails for connections.

Design frequency 435 MHz boom 25.4mm square section. parasitic elements 10mm or 3/8in tube. Driven element 12mm x 3mm or 1/2in x 1/8in strip all table measurements in millimetres – measurements marked * are not critical

The Easy Job

To build up confidence, let's start with the easy job, marking out and cutting the parasitic elements. From 3/8in (or 10mm) diameter aluminium tube or round stock. One by one, mark and cut the individual lengths according to **Table 2.2**.

Remember, the saw cut itself has a width, depending on the thickness of the saw blade plus the offset of the cutting teeth (typically a total of 1mm), so – don't mark all the elements at once — measure, mark and cut and then start again once the particular piece has been removed. De-burr the ends with a very light touch of the file – or emery paper. If you have large jagged ends after cutting, you are pushing down too hard on the hacksaw!

After you have finished you should have one reflector and six directors. Arrange these in length order in a safe place.

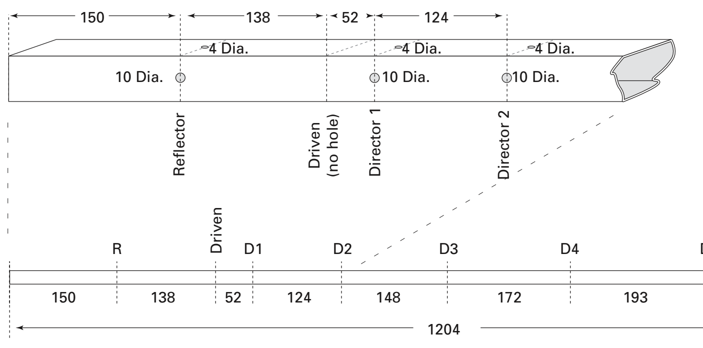

Fig. 2.1: The overall measurements for the antenna and how to apply them. See also Table 2.2.

The Boom

Next, for the antenna boom, cut a piece 1204mm long from square aluminium stock, using a strong vice with wooden or plastic cheeks to avoid marking the aluminium. You'll then have a more manageable length than the two metre stock length you probably bought!

Now referring to the spacings figures in Table 2.2 and using the try square, mark out lines across the boom for the positions of the reflector, driven element and six directors, taking the lines round two adjacent sides of the boom section, and note that, with **the exception** of the driven element, these markings are for 3/8in (or 10mm) holes to accommodate the parasitic elements. To accept the parasitic elements, you'll have to mark a position for each hole exactly at the middle of the marked line on one side of the boom, using a steel rule, and not trying to judge by eye (See **Fig. 2.1**).

You should arrive at a number of crossed lines where the holes will be, and the centre-punch can then be applied to locate the proposed holes exactly. The diagram **Fig. 2.2** makes this clear. **Do not** centre-punch any holes for the driven element as the method

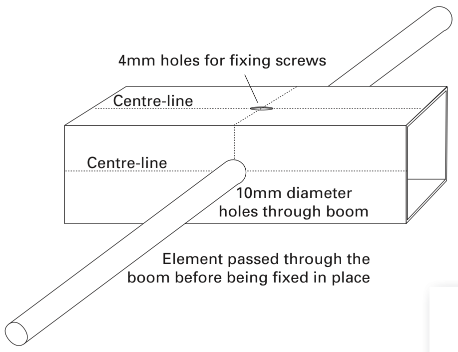

Fig. 2.2: How the parasitic elements are fixed to the boom. Their 'pass-through' holes have their centres on the horizontal centre-lines of the boom. The 4mm fixing screw hole is on the top centre-line of the boom.

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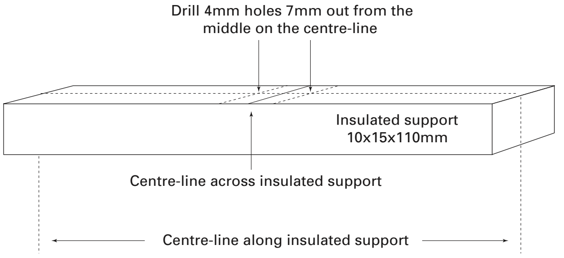

Fig. 2.3: The insulating piece that the folded, driven element is mounted on, is made from 10x15mm plastic material.

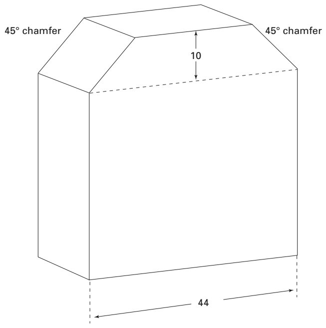

Fig. 2.4: The bending jig for the driven element.

of mounting this element is different. You can either use a traditional centre-punch and panel hammer or one of the new automatic punches that have spring-loaded point.

Having checked all your dimensions at least twice, it's time to drill out the holes for the elements, drilling right through the boom. Assuming you have a drill press, you'll need to place a piece of scrap wood under the boom, and first drill small pilot holes – say 3mm – in each place. These can then be 'opened out' to 3/8in (or 10mm) with a 3/8in (or 10mm) drill.

You'll find that the 3/8in (or 10mm) parasitic elements will just fit into the holes drilled in the boom (we call this an interference fit) and in some cases you may need to very slightly ream out a hole (just a touch of this tool is enough). It helps to lay out the elements on the workbench in order (decreasing or increasing depending on which end you wish to start at). Then take the first element and slide or push it into the hole until it protrudes approximately equally either side of the boom. Check and adjust using a steel rule so that the protrusions are spot on, and then mark the position on the element.

One element at a time, and – with the element still in the boom – you will next drill a 3.5mm (**only**) hole through the boom, at 90° to the 3/8in (or 10mm) element hole. This hole will at the same time penetrate the parasitic element inside the boom, hopefully in just the right place. The interference fit of the element in the boom aided by just a little finger pressure, should be enough to keep the pieces in alignment. Now, having first removed the element, open out the hole in the boom to 4mm for clearance. In the element you should still have the original 3.5mm hole. After carefully withdrawing the element, insert the 4mm tap and cut the thread.

You should now be able to re-insert the element to the previously marked line and put a 4mm bolt through the boom, bolting it into the element (you may have to gently smooth the area around the new tapped hole). It can be helpful to hold the boom under a bright light so that you can glimpse the hole in the element through the hole in the boom. After the first one it becomes easier! When you've finished, you should have a row of neat directors, of gradually reducing length, plus a rather longer reflector at the other end of the boom.

Insulating Piece

We need to insulate the driven element from the boom, where the feeder is connected at the gap in the folded dipole. The unbroken piece has a theoretical zero potential at its centre and so could be bolted to the boom. However, the theoretical results are not always achieved and bolting to the boom would introduce losses, so we simply leave the centre point unattached.

From some 15x10mm rectangular plastic stock, cut just 110mm. Mark the centre line (55mm from each end). Then measure 7mm to each side of this line and centre-punch and drill 4mm holes, as in **Fig. 2.3**. On the boom, the position for the driven element has been marked but a gap left with no drilling yet.

Measure 7.5mm from the driven element (centre) line, and then place the insulating piece right against that line. Arrange the insulating piece centrally and mark through the 4mm holes already drilled in the insulating piece. Remove the piece from the boom and then centre-punch and drill the two holes in the boom to 3.5mm **only**. Finally, cut 4mm threads to those holes in the boom.

Driven Element

Without doubt the driven element is the hardest part of the antenna to build. Here I'd recommend a 'jig'. Beloved of all keen workshop users, a jig is a fabricated piece that is used to temporarily align or hold in alignment the piece we are working on – the 'workpiece'.

The jig consists of a piece of hardwood as shown in **Fig. 2.4**, round which we will be bending aluminium strip to turn it into the final folded shape for the driven element. Although the jig doesn't find its way to the final project, make it carefully as its accuracy will markedly add in the ease of creating the driven element.

The element itself is going to be a folded dipole made from the strip 1/2 x 1/8in (or 12x3mm). The overall length of the dipole when folded will be 324mm as in Table 2.2. To accomplish this, with an allowance for the ends of the fold, the bends and the gap at the feed point we'll need 676mm of aluminium, so cut this from your strip, as shown at **Fig. 2.5**. Then mark and centre-punch two holes at each end, one 10mm from the end and the second a further 20mm.

Drill those holes to 4mm.

You now need to mark the centre line, which will be 338mm from each end. **Note:** the most critical marks are what I've called the 'bending lines'. Clearly mark two bending lines 149.5mm back on each side of the centre line. Yes, I know half a mm is difficult (and we don't normally try for it), but try it this time as it represents the exact half-way point.

Next comes the hard part! Place the jig firmly in a vice with the bending line against the end of one the chamfers and bend to a right angle as shown in **Figs. 2.6a** and **b**.

If necessary, re-arrange the jig and strip in the vice and continue to bend the strip round the adjacent chamfer as in **Fig. 2.6c**. The strip tends to spring back a little after bending, so you will have to remove the jig now and 'persuade' (push gently!) the two ends of the strip so that you achieve a shape like **Fig. 2.6d**.

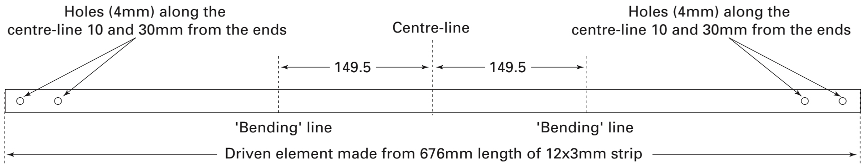

Fig. 2.5: The driven element is created by folding a 676mm length of 12x3mm aluminium strip as described in the article.

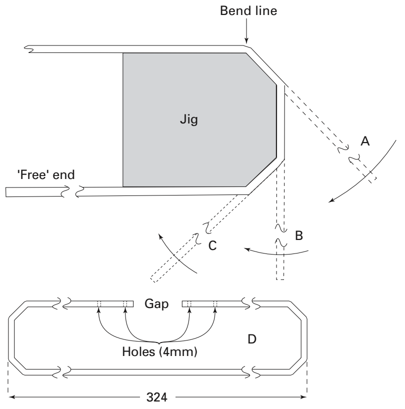

Fig. 2.6: Using the bending jig to carefully bend the strip into the correct shape.

If you've marked out and bent the strip carefully, you should finish up with a gap about 30-35mm wide. This gap is not critical as long as bolts can be passed through the two end-most holes that were previously drilled, and not foul on the 25.4mm boom when assembled. In prototyping this antenna I had four tries at making the driven element, although only two of them made use of a jig. So don't be discouraged if your first effort looks horrible!

The driven element is going to be insulated from the boom, but secured to it via the insulating piece you have prepared. You'll need to place the insulating piece firmly in the vice, and then lay the driven element down on it as shown in **Fig. 2.7**.

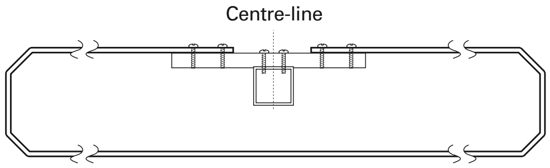

Fig. 2.7: How the driven element attaches to the boom, but is insulated from it.

Arrange the pieces carefully so that they are even and look like the figure (except that we're not fixing to the boom just yet). Then mark the insulating piece through the end holes (two) at each end of the driven element. Remove the driven element, centre-punch and drill 3.5mm **only** holes in the four positions. Tap these holes with a 4mm tap. Solder tags can now be fitted to the ends of the driven element plus the boom mounting bolts, and the insulating piece fitted as shown in the figure.

Mounting The Balun

The balun and connection point will be placed **under** the boom (to minimise weather effects as your Yagi is almost certainly for outdoor use). It's essential to use a good quality plastic box (not metal) with a well fitting lid, preferably one that has a good waterproof gasket.

I used a box approximately 65 x 57 x 35mm that has a neoprene weatherproof gasket. The first step is to drill two fixing holes on the lid. The box will be arranged lengthways – on the side of the boom where the gap is in the driven element – as shown in **Fig. 2.8** and the **photograph**, so mark out the two holes in the lid at suitable positions.

These measurements are not critical except that they should be in the centre of the lid measured from the narrow side. I drilled mine, 15mm from each end along this centre line. Arrange the lid squarely on the boom, about 10mm from the driven element, on the side carrying the reflector and next to the gap in the driven element. Then mark though the holes onto the boom, centre-punch and drill 3.5mm **only** holes and tap them with a 4mm tap. You can then secure the lid to the boom with two 4mm bolts. This will be the bottom of the boom if the antenna is used in a horizontal mode.

The Balun

The balun is shown electrically in **Fig. 2.9a**, it's a standard 4:1 coaxial type. Turning now to the balun box itself, mark the centre of the large face of the box and drill to accept the BNC (or N type) bulkhead feed socket. This will be 10mm for BNC. Next place a bulkhead socket in the hole, line up the flange and mark through onto the box.

My BNC socket had four holes in the flange that were a little under 3mm. I had to drill them out very slightly – a tricky process that requires the flange to be held strongly, preferably in a machine vice and the 3mm drill **very** gently applied, being alert for signs of 'grabbing'. (You may be luckier with your bulkhead fitting!).

We are going to need two 5-6mm holes at one end to accommodate 50Ω coaxial cable about 10mm from the edges of the narrow end. On the face of the box we'll also need two 4mm holes that will carry the driven element connection bolts and at the other end another 4mm hole for the earthing lead. These are all shown at **Fig. 2.9b** and the photograph **Fig. 2.9c**.

Next, fit 3mm bolts for the bulkhead socket, using shakeproof washers and solder tags where shown in the diagram. Fit 4mm bolts similarly, with solder tags **inside and outside** the box. Inside the box, bend up the various tags to right angles.

Cut a piece of coaxial cable about 250mm long. (You will need to strip the outer jacket of this coaxial cable back at each end, leaving 227mm between the ends of the jacket. Now thread the cable loop through the holes you have cut for it, strip and form the shield at each

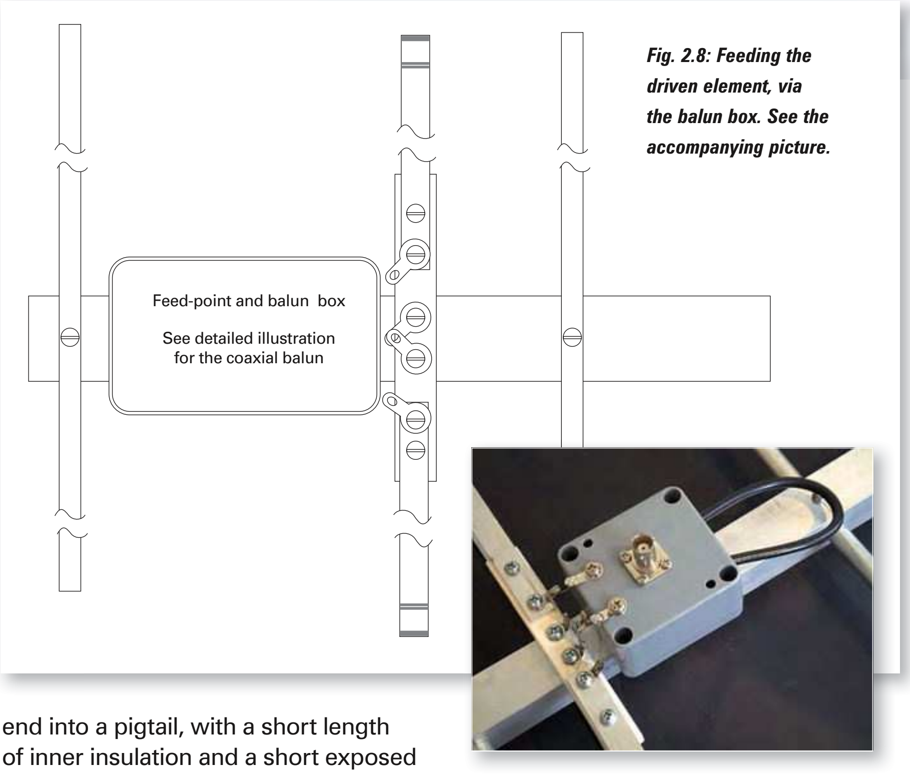

Fig. 2.8: Feeding the driven element, via the balun box. See the accompanying picture.

end into a pigtail, with a short length of inner insulation and a short exposed length of inner conductor.

Solder the connections with the connection from the centre tag of the bulkhead connector to one of the end connections (later to be made to the driven element). **Note:** It doesn't matter which one! Also solder a connection from the earth tag to each of the bulkhead tags that have the pigtails fixed to them.

Connecting Up

Next, bolt the balun box to the lid. You will then have a driven element with two 'floating' solder tags at the ends, plus a balun box with two 'end' solder tags on the face and another earth tag on the end.

Of course, each end of the element in turn is now connected to the balun, which can be achieved by two short lengths of tinned copper wire, or even hook-up wire (not too thin). Then the side mounted earth tag on the balun box can be soldered to two tags mounted through the insulating piece to the boom. Refer again to Fig. 2.8 and to the photograph.

When everything is finally checked and working it can be quite handy to fill the balun box with clear silicone to keep moisture out, but for experimentation it is probably enough to bolt the box to the lid firmly. Another weatherproofing measure for the Yagi is to fit plastic plugs to the ends of each element and the boom.

The Yagi is of course fed with a length of 50Ω coaxial cable terminated at one end with a BNC (or N) plug, with the other end to suit the transceiver. For low power work, BNC plugs/sockets are adequate, but an N type connector could be used, with the appropriate drilling required (by the way, the PL259/SO239 combination is much too lossy for 435MHz use).

The finished Yagi can of course be mounted horizontally or vertically. If vertically, do not use a metal mast in the centre as it will interfere with the antenna characteristics; this is why we have left a length for mounting at the reflector end.

A Working Antenna!

Phew! As is often the case, the whole process is much more complicated to describe than it is to make. But you should finish up with a working 430MHz antenna which can be mounted at the end – or if horizontally polarised or using a non-metallic mast – in the middle.

If at first your effort is not attractive, don't be discouraged as the materials are sufficiently inexpensive to have a second go.

After I had carried out a great deal of experimentation – during which the method of making the driven element using a jig was refined plus balun measurements tested, the final prototype gave encouraging results. The v.s.w.r. was below 1.5:1 from 433 to 437MHz, with less than 1.2:1 right on the design frequency of 435MHz.

Enjoy building yours! ●

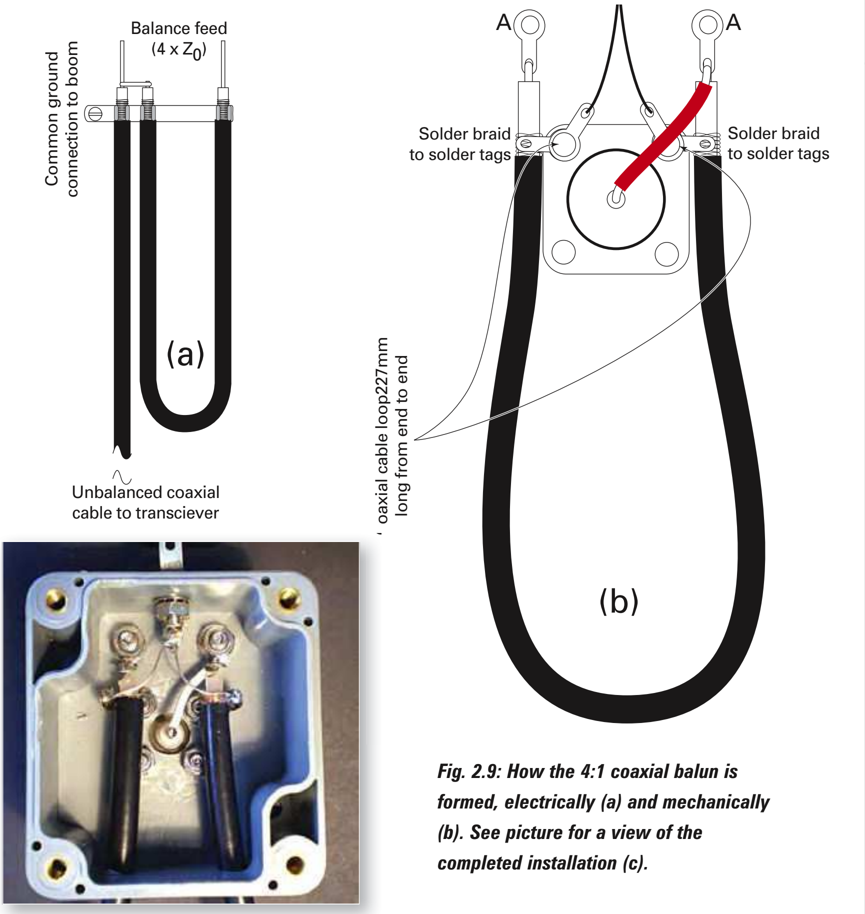

Fig. 2.9: How the 4:1 coaxial balun is formed, electrically (a) and mechanically (b). See picture for a view of the completed installation (c).