The PADAT137

an RQH Antenna

Translation by Chris van Lint

Developing the PADAT 137

A new, rugged, aluminium strip RQH Antenna

Part 1 - The Design

by ***Ruud Jansen PA0ROJ*** *- ranslation by* ***Chris van Lint***

This article is a follow-up to my earlier one relating to the PITA137 [1] weather satellite antenna. The 137 MHz signal transmitted by a weather satellite is directed towards the Earth's surface with circular polarisation and our antenna must therefore be able to receive this signal without noise bands regardless of the position of the satellite above the horizon. The PITA137, which was constructed using lengths of steel from a measuring tape, was intended to be taken along on holidays or to hang up in an attic indoors. This antenna is not particularly storm resistant and during my visit to Brazil in December 2004 [2], when I took along my complete receiving equipment, gusts of wind made my nice antenna look more like a tangle of messed up measuring tapes than a cylindrical RQHA (Resonant Quadrafilar Helical Antenna). Since I was (and still am) very satisfied with this type of antenna—which in comparison to the Turnstile, Lindenblad and other designs, frankly stands out as the best—I wanted to build a rugged outdoor version of the RQHA. I call this the PADAT137.

Copper Tube Design

My very first solid-state antenna was constructed from 12 mm copper tubing. In contrast to antennas based on large and small loops [3], I wanted to construct my antenna with two *equally* sized loops. The required 90° phase shift would be achieved by making one loop effectively 'longer' by connecting an inductor (coil) in series with it while making the other loop effectively 'shorter' by means of a series capacitor (similar to the PITA137 design). Since I wanted maximum sensitivity at the horizon, I opted for a long, thin design with a diameter/length relationship of about 0.25 [4], and duly constructed the antenna from copper tubing.

Unfortunately, it turned out that the impedance of this rather thin antenna was around 15 Ω and it was very sensitive to its design specifications. Minor mechanical alterations (making the antenna flatter or rounder) changed the impedance; additionally, the phase shift between the loops was no longer 90°. Soldering was also quite challenging due to the critical shape requirements and I had to construct a complete mechanical jig to hold all the pieces of copper tubing in place during the soldering process. Following a couple of weeks of effort I decided to design a less critical antenna.

To construct a good antenna for my own use was no problem and after a considerable amount of effort I did obtain a useful result. However, the purpose of my design was to allow others to copy my antenna successfully, even those without access to the electronic measuring equipment I had at my disposal. My account of how the PADAT137 aluminium strip RQHA was developed now follows.

Aluminium Strip Design No 1

The PADAT137 was to be a storm-resistant aluminium version of the PITA137, using 12 mm aluminium rod for the horizontal sections of each loop and 15 x 3 mm aluminium strip for the vertical parts. My first design consisted of two equal loops, each making a ¼ -turn, and using a capacitor and an inductor to obtain the 90° phase shift between them. An advantage of this design is that the dimensions of all the horizontal elements are identical, as are those of the vertical ones. A disadvantage was the requirement for two different components (capacitor and inductor) to achieve the 90° phase shift.

Aluminium Strip Design No 2

My second design utilised two equal *extra-long* loops, in which one loop was effectively 'shortened' by means of a small series capacitor. By making the dimensions of both loops *extra-long* (giving a resonant frequency lower than 137.5 MHz) and then rendering just one of them shorter in this way, I was able to dispense with the inductor.

I measured out the vertical components to be a couple of centimetres longer than those of the older PITA137 then shortened the vertical strips until, at

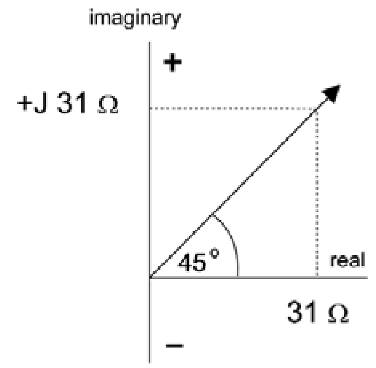


Figure 1 - Phase shift

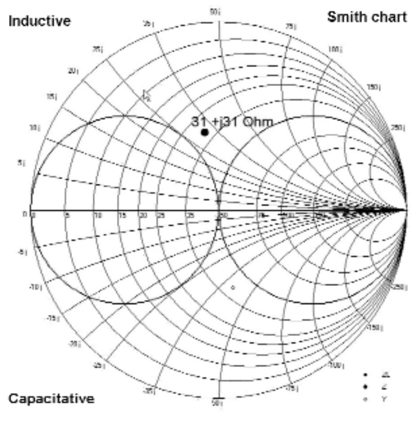


Figure 2 - Smith chart

137.5 MHz, the phase shift between the real resistance and the imaginary resistance was +45° (figure 1). This is only true when the real resistance value of this loop is equal to its positive imaginary value. Refer to the measurements in the Smith chart (figure 2).

The impedance value I determined in this case consisted of a real value of 31 Ω and an imaginary value of +j 31 Ω. The formula is Z = 31 + j 31 Ω. The loop is inductive and hence too long (as we knew already). I then measured the resonant frequency (pure impedance) and resistance of the loop at resonance. Although the Smith chart initially looks very complicated, this method of presentation exceeded expectations [5].

I next mounted a second loop, with the same dimensions as the *extra-long* loop, parallel to the first one. In order to obtain a 90° phase shift between these two loops we have to make this loop 'shorter' (i.e. capacitive) by inserting a 19 pF capacitor in series with it. Connecting the two loops in parallel ensures that, at a frequency of 137.5 MHz, the antenna represents a pure impedance and the phase shift between the currents in both loops is 90°.

A major disadvantage arises from the critically low 19 pF series capacitance. Any mechanical deviation, however small, or any variation in the connecting cables and/or capacitor value, will result in a considerable difference in the phase shift and impedance between the two loops. In practice this was really an unusable design.

Aluminium Strip Design No 3

Another attempt to obtain the required phase shift was to *really* make the second loop smaller. When I constructed a test antenna in which the heights of both loops were identical, but where the diameter of the second loop was smaller, it caused problems: the real impedance of the smaller loop was less that of the 'fatter' one, so that the impedances of the two loops were not equal at the resonant frequency. Additionally, the diameter/length relationships for the two loops were no longer equal, resulting in a non-symmetrical radiation pattern. Since the radiation pattern is determined by the diameter/height ratio, among other factors, the radiation patterns of the loops were not the same.

Aluminium Strip Design No 4

In my final test antenna I modified both the height and diameter of the small loop so that the diameter/height relationship of both loops became identical—giving rise to identical radiation patterns. The two loops also shared the same centre point. This solved the problem of the differing radiation patterns. The difference between the real impedance of the 'thin' loop and the 'fat' loop were now less than for Designs 2 and 3 at less than 2 Ω. The disadvantage of this design was that the horizontal components of the two loops were now at different heights and had unequal (plus and minus) impedances at resonant frequency, although the difference was smaller than in Design No 3.

The Action Plan

I decided to build all four designs and carry out measurements on them. One problem is that I can make general antenna measurements in my attic; however because of the adjacent walls and electrical wiring, etc. such measurements are not reliable. For a frequency of 137 MHz I should ideally have a free space of several dozen meters around the antenna: but unfortunately I don't. I had therefore to wait for a few dry days in order to set up my measuring equipment in the garden (figure 5).

In order to build these four designs and perform measurements on them I constructed an antenna where the height of both loops and their diameters, as well as the relationship between the loops, could be adjusted by means of interchangeable horizontal and vertical components (figure 6). To reduce or extend the vertical strips, I started off with strips which were all *extra-long*, but which, by means of pre-drilled slots or holes, could be mounted 'shorter' (figure 7).

To adjust the loop diameter, I prepared a number of short lengths of aluminium rod which could be used to extend each existing 240 mm horizontal component (figure 8). By using a larger or smaller piece of rod every time, I was able to reduce or enlarge the diameter in 2 mm steps.

Measurements

Years ago, I measured my first RQHA's in the HF-laboratory of the school where I worked (The Haarlem College of Advanced technology). The complete measuring set-up consisted of *General Radio* gear, most importantly their *1602 UHF Admittance Bridge.*

The measuring process is very involved and results have to be corrected to adjust for the electrical cable length, a process which has to be repeated following every change to the antenna. In order to be independent from the school equipment, I have managed to collect similar equipment of my own from flea markets and second-hand shops. Although reasonably happy with my measuring equipment, the measuring methodology was too complicated. After searching for a couple of years, I managed to track down an *HP 8410-C/8411-C Network Analyser* with *8414A Polar Display unit*, which produces a graphic representation of the resonant frequency and the impedance (figure 9), and an HP 8620 sweep generator.

Once the dry weather arrived, I moved my measuring equipment from the attic to the garden and set the gear up. I made sure that all co-axial cable was as short as possible, as cable attenuation influences the measurement results.

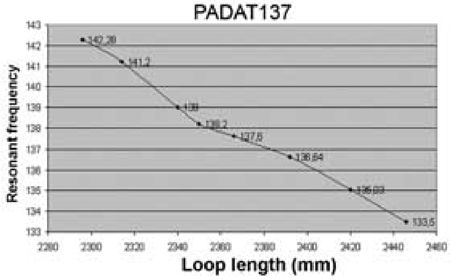


Figure 3 - First results (graph)

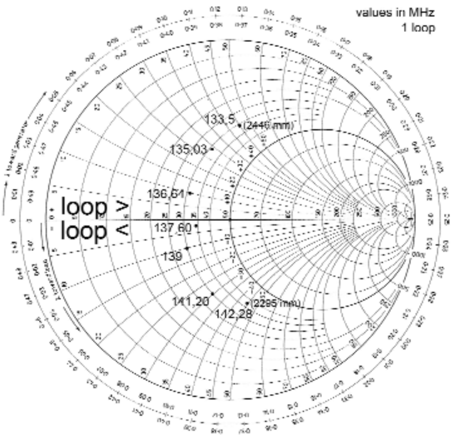


Figure 4 - First results (Smith chart)

For my first measurement I chose an antenna with a diameter/height ratio (D/h) of 0.33. On the one hand I wanted to have as large a D/h ratio as possible (with real resistance between 30 Ω and 38 Ω), whilst on the other hand there was a need for a small D/h ratio to allow for greater sensitivity at the horizon [6,7,8].

I started with a diameter of 360 mm and measured the resonance frequency and impedance at 137.5 MHz. Next, whilst maintaining the D/h relationship, the loop was shortened step by step and more measurements made. The results appear as a graph in figure 3 and as a Smith chart in figure 4. After a few days of assembling and measuring, I had collected dozens of tables with measurement results, which I could use to construct the four types of antenna, viz.

1. An antenna with two equal loops (resonant frequency 137.5 MHz), one loop with a series capacitor and the other with a series inductor (± 45° phase shift).
2. An antenna with two large loops, one loop only with a series capacitor (-90° phase shift)
3. An antenna with two loops of equal height, but one with a wide diameter and the other a narrower diameter.
4. An antenna with both a large and a small loop (± 45° phase shift).

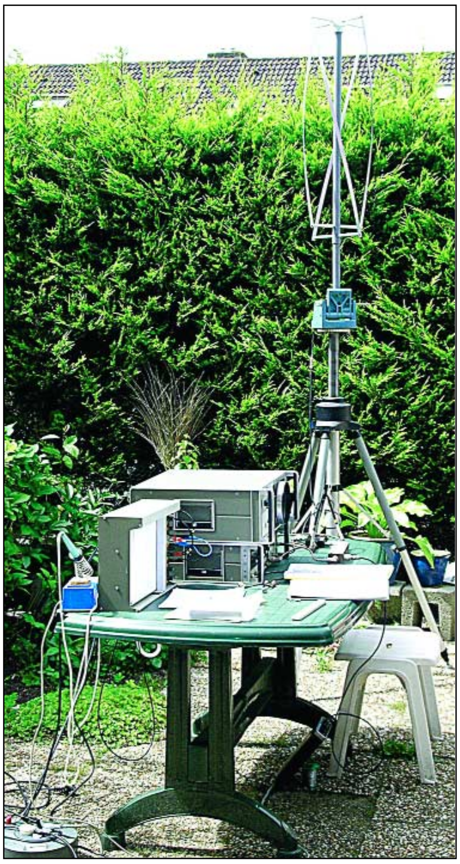
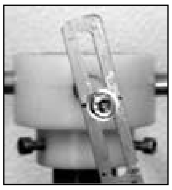


Figure 5 - In the garden

Figure 6 - The adjustable antenna



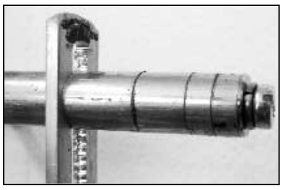


Figure 7 (above, left)
Pre-drilled slots in the ends of the vertical antenna elements allow them to be shortened.

Figure 8 (above, right)
Short lengths of drilled aluminium rod bolted on to the ends of the horizontal elements to make the antenna loops wider.

Figure 9 - The Polar Display

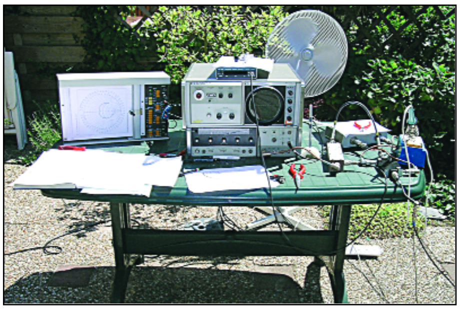


Figure 10 - The Outdoor Testbench

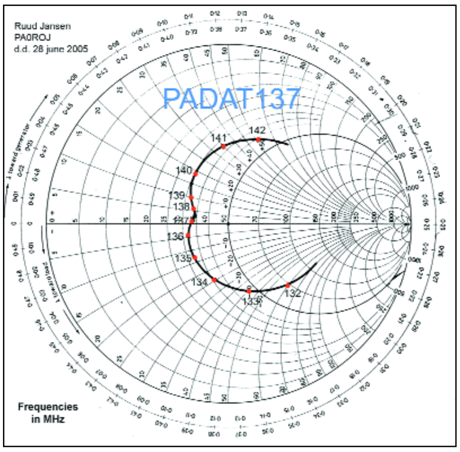


Figure 11 - Impedance on the X-Y Plotter

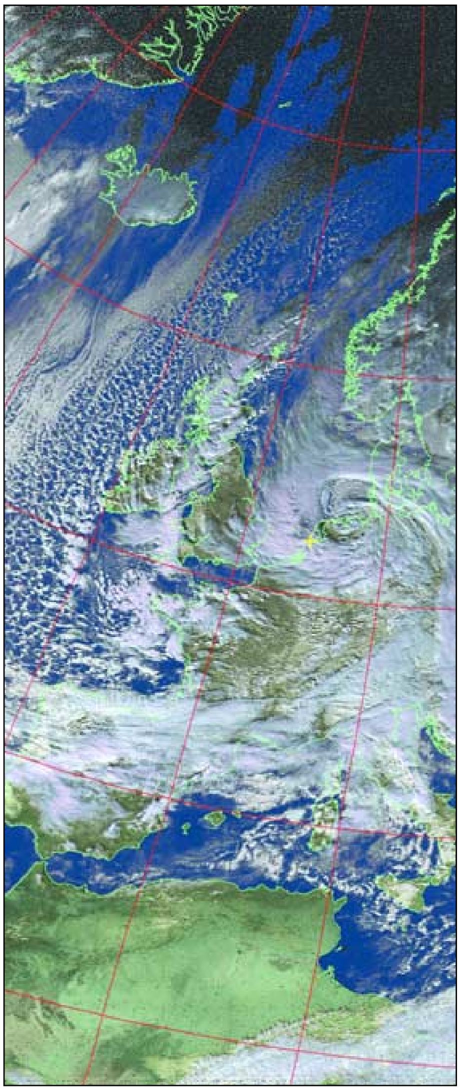


Figure 13 - A section from the 13:06 UT November 11, 2005 **NOAA-18** pass. Despite the PADAT137 antenna being located indoors below Ruud's tiled attic roof, and surrounded by all his electronic equipment, it produced an excellent horizon-to-horizon image.

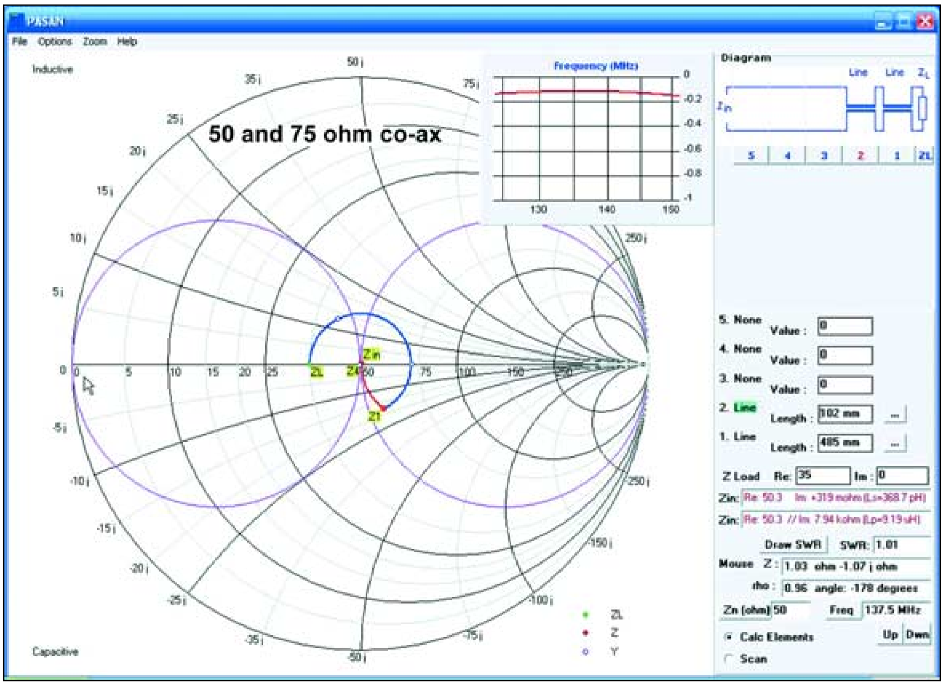


Figure 12 - PASAN screenshot showing antenna/receiver impedance matching

The Final Design

After a further couple of weeks sawing, drilling, turning on the lathe and heaving measuring equipment back and forth between attic and garden, only one design finally remained, No 4.

For this, I left the top horizontal components at equal heights with a distance of 40 mm between the two lower horizontal components; the distance between the mid-points of the two loops was thus 20 mm. This resulted in a very small difference in radiation pattern between the two loops, which in practice could be ignored. The impedance of this ultimate antenna was measured using the set-up shown in figure 10.

By sweeping the signal generator output between 132 and 142 MHz, both the impedance and resonance could be read directly on the display of the Network Analyser; and by connecting an X-Y plotter to its output, the impedance curve was plotted on paper (figure 14). Figure 11 shows the scanned plotting paper with the frequencies written in, indicating clearly that the antenna has a purely resistive value at about 137 MHz (and is consequently resonant) and that the impedance is 35 Ω. The antenna had now reached its final form, and in practice was producing excellent weather images (figure 13). It now remained to match the antenna to the asymmetric co-axial cable and the 50 Ω input impedance of my receiver.

Matching the Antenna

There are two factors that can have a negative influence on the properties of an antenna.

1. The absence of a matching system to achieve a good match between a symmetrical RQHA and an asymmetrical co-axial cable by means of a linking ‘balun’ (balanced-unbalanced).
2. The mismatch between the antenna receiver impedances.

1. Matching to the Co-ax

Why is matching a symmetrical antenna to an asymmetrical co-axial cable so important? If the match is absent or incorrect, a ‘skin’ current will flow along the outside of the co-axial cable (‘i3’ in figure 16). The outside braid of the cable will thus become part of the antenna, as a result of which the antenna will exhibit an asymmetrical radiation pattern. The resultant effect is shown in figure 15. When a signal is transmitted without correct matching it is not distributed in a symmetrical fashion. The antenna would then exhibit rather ‘cross-eyed’ behaviour and in the case of a RQHA it would be directional [9].

Secondly, part of the transmitted signal will be transmitted through the outside of the co-axial cable shield. Since in most cases the antenna co-ax runs from the top to the bottom, part of this signal will be transmitted through the cable in a vertically polarised fashion. When a horizontally polarised signal is received, the receiver input will not only contain the dipole signal, but additionally, the signal received from the vertically acting component in the co-axial cable.

In practice this means that a good (but incorrectly connected) antenna will be subject to considerable interference (usually from vertically polarised signals such as pagers) which will interfere with the desired signal and result in unwanted noise bands. In the case of our PADAT137 antenna this would make it directional and thus lacking all-round circular sensitivity.

The length of the co-axial cable also influences both of these sensitivities. As a result, a well constructed RQHA could turn out to be a disappointment (insensitive and/or directional and noise bands).

Options

There are a number of options to provide a proper match.

<u>*The trifilar wound 1:1 transformer*</u>

This device is used in short-wave applications and a number of types I built for 137 MHz produced good results. The capacitance between the three windings has a considerable influence on the correct functioning of this balun; the best results were obtained with a small ferrite toroid with three 0.1 mm diameter windings (figure 17).

Note: Whilst perusing some *Amidon* documentation, I came across a sentence in the text, which recommended that the three wires should be twisted in order to avoid mutual capacitive influences. This is something I will need to follow up!

<u>*The Bazooka*</u>

The bazooka (figure 18) consists of a copper or tin cylinder, ¼-wavelength long, where the bottom side is connected to the outer shield of the co-

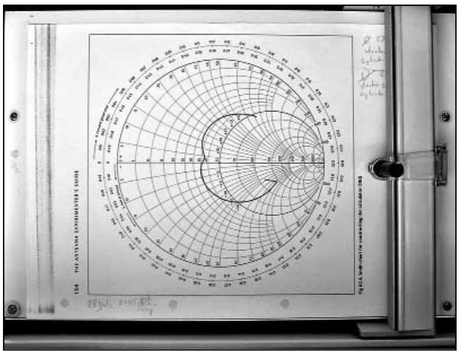


Figure 14 - Impedance on the X-Y Plotter

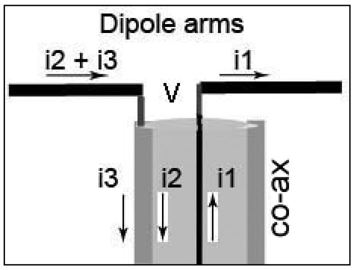


Figure 15 - The Skin Current (i3)

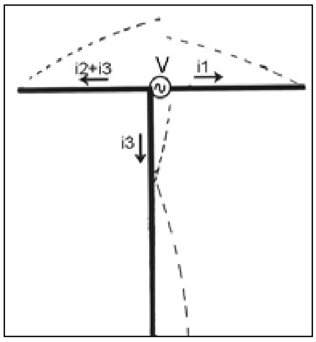


Figure 16 - An asymmetrical radiation pattern

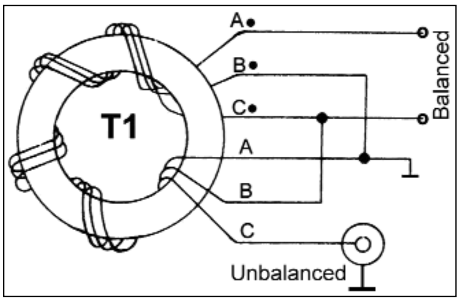


Figure 17 - Trifilar balun

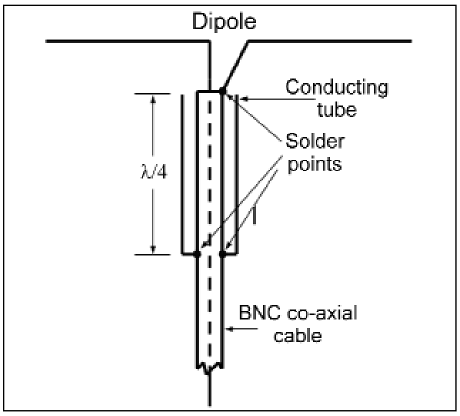


Figure 18 - The bazooka balun

axial cable. When such a cylinder is tightly mounted around the plastic insulation of the co-ax, a so-called velocity factor has to be applied. Depending on the plastic shield (polythene or Teflon) this ¼-wavelength needs to be multiplied by 0.66 or 0.7. If a larger diameter of cylinder is used, so that the space between the cylinder and the co-ax consists of air, there is no need to apply a correction factor. However you must remove the insulation from that part of the co-axial cable which is inside the cylinder.

The 2-Element Bazooka

The 2-element bazooka is another possibility (figure 19). Instead of using a cylinder around the co-axial cable, a second length of co-axial cable (with the same outside diameter as that used for the antenna) is mounted parallel to the co-ax. Since the efficiency of this balun (similar to previous designs) depends on mechanical construction, I have not pursued construction of this type.

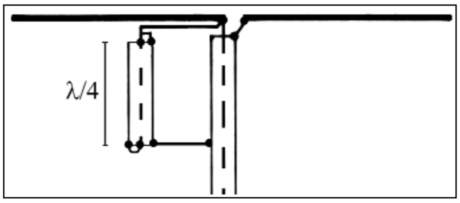


Figure 19 - The 2-element bazooka balun

The Inductively Wound Cable Choke

This type, a balun (RF choke), has quite often been used in earlier published construction notes for an RQHA but is not very effective at 137 MHz. It was often used in short-wave applications but it is less useful at higher frequencies, since the mutual capacitance between the windings has a negative effect on performance. Such windings must not be placed adjacent to one other. After some experimentation I also discarded this approach (figure 20).

Figure 20 A wound cable choke

The Ferrite Toroid Balun

This design does not really constitute a real balun. In reality it is a 'ferrite loaded co-axial RF-choke', but it does effectively result in a 1:1 current balun. The use of ferrite toroids or tubular cores is not cheap but does offer many advantages with respect to other baluns. This balun is simple to construct, is not frequency dependent and its usable frequency ranges several dozen MHz. According to details provided by *Amidon* [10] the appropriate material is designated as '*Type 43*'. This provides the greatest degree of attenuation between 100 and 300 MHz. The total length of ferrite tubes or rings threaded on to the cable will determine the impedance and hence the balun choke function.

Measurements indicate that extending the total ferrite length in excess of ¼-wavelength does not provide any benefit. When RG58 cable is used, many different types of cores are suitable. Since an impedance of 800 to 1000 Ω is sufficient to suppress any skin effect currents, the number of cores to be used depends on the length of the cores themselves. When using *Amidon* cores, 25 of type FB-43-2401 and 12 of type FB-43-6301 are required. The total length of these cores is around 12 cm. You can also use the cheaper *Richcom* cores. The inner diameter of these cores is around 5 mm. If it proves to be impossible to thread them over the co-ax cable, the insulation over the outer shield of the co-axial cable will have to be removed.

I finally decided on using the ferrite ring balun. I have used both ferrite toroids and tubes in my experiments; the use of tubes is cheaper than toroids since fewer units are required. The baluns were constructed from 25 *Amidon* toroids (or 15 *Richcom* tubular cores). At 137.5 MHz, these cores have a per unit impedance of around 35 Ω (Amidon) or 65 Ω (Richcom). When these are connected in series the impedances of individual cores must be added together. Such cores are often offered cheaply at amateur radio field days. Just make sure that the material is *Type 43.*

2 - Matching with the Receiver

The measurement results showed the impedance to be somewhere between 33 Ω and 35 Ω at 137.5 MHz. Most receivers have an input impedance of 50 Ω so, to obtain the maximum transfer of the energy received at the antenna to the receiver, the antenna impedance needs to be transformed to 50 Ω. If the input impedance of the receiver is around 70 Ω (as it is in our HRX137 and many home-brew receivers), an effective match can be obtained by simply adjusting the co-axial feed cable to a multiple of ¼-wavelength (electrical). No actual impedance adaptation should be necessary as the impedance at the end of the cable should be around 71 Ω.

A further possibility is to use an antenna amplifier, though not generally needed except when a very long length of co-ax is in use. By adjusting the impedance of the RF input to 70 Ω, a good match can be obtained.

Further possibilities involve the use of stubs, lengths of co-ax sticking out from the main downlead. The length and correct placement of these stubs can be calculated [11]; their efficacy depends on their precise dimensions and positioning, which is very difficult to achieve without appropriate measuring equipment.

Another solution would be the use of an impedance transformer. Such a device consists of a ¼ electrical wavelength co-axial circuit. The impedance of this circuit may be calculated from the formula

Zt = Za x Zl

where Zt represents the impedance of the transformer, Za that of the antenna and Zl the combined impedance of the co-axial cable and receiver input (figure 21).

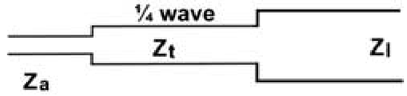


Figure 21 - Impedance transformer

Example

Z antenna is 36 Ω
Z line is 50 Ω
Z transformer is √ (36 x 50) = 42 Ω

The dimensions of the impedance transformer can be calculated with the formula

Zt = 138 log b/a

where 'b' is the inner diameter of the outside conductor and 'a' is the outer diameter of the inner conductor (figure 22).

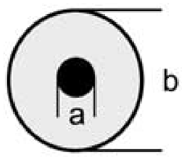


Figure 22

Using Pasan Software

The first impedance matching system I used consisted of pieces of 50 Ω RG58 U co-axial cable. I used the '*Pasan*' software to explore a number of possible matching approaches using combinations of 50, 75, and 93 Ω. *Pasan*, developed by Marien van Westen, is a great aid when calculating and constructing such a matching device.

A basic guide to using Pasan for impedance matching can be found in the sidebar on page 6.

I recommend first aiming to use a 0.101 wavelength piece of 50 Ω co-ax for '*Component 1*' and a 0.038 wavelength piece of 25 Ω cable for '*Component 2*'. If we assume a co-ax velocity factor (Vf) equal to 0.67 we will need a 147 mm length of 50 Ω cable and a 54.6 mm length of parallel-soldered 50 Ω co-ax.

Note

Although it is very difficult to obtain co-axial cable of 25 Ω impedance, you can join two 50 Ω pieces in parallel to obtain 25 Ω.

If desired, you can use a longer piece of 50 Ω cable at the top of the antenna so that more room is available to facilitate installation of a bazooka or ferrite ring core balun. A possible alternative solution to the matching problem would then be to use a 505 mm length of 50 Ω cable (0.349 λ) together with 62.4 mm of 93 Ω network co-axial cable.

It is also possible to make an impedance-matching circuit with a combination of just 50 Ω co-ax and a capacitor or coil (inductor). In my latest experiments I decided on a combination of 487 mm of 50 Ω and 101 mm of 75 Ω cables.

Note

In all the above examples, I am assuming a velocity factor (Vf) of 0.67 (for RG58 and RG59). If a 75 Ω satellite cable is to be used (which gives less attenuation), be aware that Vf would be increased to around 0.70.

If you have any questions related to the *Pasan* program (operation, adjustment etc.), please contact me at

ruud@farbridges.net

For those of you who are keen to learn a bit more about baluns, Smith charts and RQHA's, Walter Maxwell W2DU has written a book [12] on this subject. He is also the designer of the Quadrafilar antennas on board the TIROS, ESSA and NOAA weather satellites.

References

1 Ruud Jansen - De Pita137, De Kunstmaan, April 2000 www.jendela.nl en www.kunstmanen.nl
2 Ruud Jansen - De Kunstmaan, February 2005, p 16; GEOQ 6, p 24.
3 Rob Hollander - RQHA, Technote 1999-1 (www.kunstmanen.nl)
4 Rob Hollander - Article on radiation patterns, GEO Q3, page 26.
5 http://www.microwaves101.com/encyclopedia/smithchart.cfm#smith
The ARRL Antenna Book, chapter 28. ISBN: 0-87259-904-3
The Antenna Experimenter's Guide, G3LDO. ISBN 1-872309-36-4
6 H.S.C. Wang - IEEE transactions on antennas and propagation, vol. 39, No 8, August 1991

7 C.C.Kilgus - The Microwave Journal, December 1970
8 Rob Hollander - Technical Note 2004-1 ftp://ftp.kunstmanen.nl/pub/technotes/RQHA/RQHA 2004-1.pdf
9 http://www.poynting.co.za/tech_training/tut_balun.shtml
10 Amidon (http://www.amidon.de/ferritrinkerne.htm) and ELECTRON, September 1991 page 468-469 (VERON).
11 http://www.circuitsage.com/matching.html and http://www.ee.surrey.ac.uk/Personal/D.Jefferies/jefferies-stub.html.
12 'Reflections II' By M. Walter Maxwell, ISBN 0-9705206-0-3

A Simple Guide to Impedance Matching with *PASAN*

You can download *Pasan* from Marien van Westen's website:

http://members.home.nl/mvanwesten/

Click the link to *Electronics* in the menu panel, then *Pasan*. Be sure to download the new version of the program, *PasanSE*.

Define your circuit in the *Diagram* panel at the top right of the *Pasan* screen; it will consist of two components—the two lengths of co-ax you need to match. Click the **right** mouse button once on the empty square above '*1*' then once in the box above '*2*' to define components 1 and 2 as lengths of co-axial cable (figure 23).

Select **<Options → Preferences>** from the menu-bar and fill in the fields from Table 1, as illustrated in figure 24.

Check the *Save current settings* box then click 'OK' to store these values as your default *Pasan* settings.

You are now ready to start the calculations to match the two impedances. In the data panel at lower right of the main Pasan screen (figure 25), under 'Z load', enter '0.35' for '*Re:*' (followed by the *Enter* key) and '0' for '*Im:*' (this is the antenna impedance). You will now see that a green dot has appeared on the horizontal mid-line of the Smith chart, with the value '35' (figure 12).

Click on the button with the ellipsis (...) beside the entry labelled '*1 Line*' in the data panel (figure 25). This opens the *Transmissionline data* window (figure 26), where you must enter the *Characteristic impedance* as '50' and the *Velocity factor* as '0.67' (this value applies to RG58 cable). This

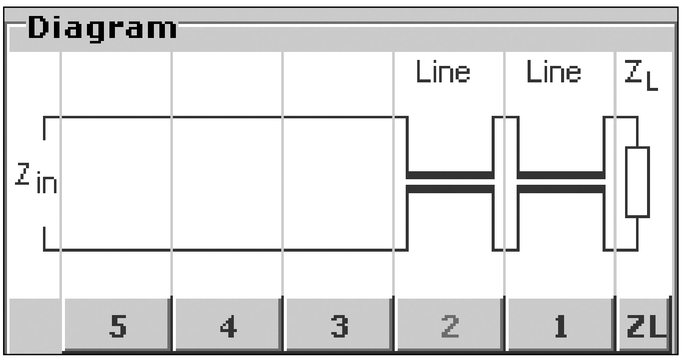


Figure 23 - Defining the circuit in *PASAN*

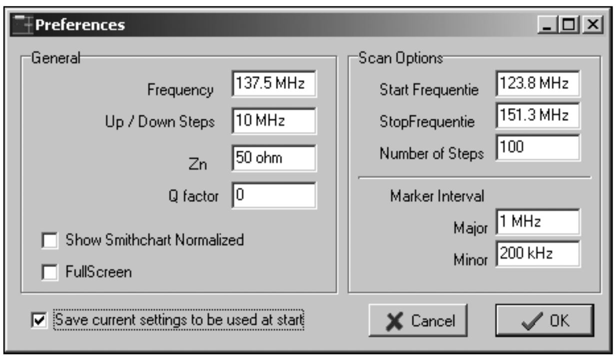


Figure 24 - PASAN default parameters

window shows a length for the co-ax and the equivalent electrical length in λ. (these will be adjusted correctly later: you don't need to change any of the other fields at this stage). If you click **<Options → Bode plot>** you can view the circuit attenuation in a pop-up window.

Click on the ellipsis (...) button labelled '*2 Line*' and this time enter the *Characteristic impedance* as '25' and the *Velocity factor* as '0.67'.

The Smith chart display now shows the curves for the 50 Ω line and 25 Ω line (figure12). The selected component is shown in red, any other ones blue.

Making the Match

Now comes the final trick! Click the mouse on the number '1' below the 1st graphic (figure 23), then move the mouse over the Smith chart (figure 12) and click at various positions inside the upper hemisphere of the left-hand purple circle until *Length* in the '*1 Line*' field is approximately 150 mm.

Next, click on the number '2' below the 2nd graphic (figure 23) and click the mouse on the very centre of the Smith chart (on the value '50').

Repeat these two steps, making small adjustments, until the values on both the '*Zin*' fields (figure 25) show exactly '50'. Once you achieve this the value for SWR should be exactly '1.00'. Any final adjustment is most easily made by editing the actual value in the '*1 Line*' field in figure 25.

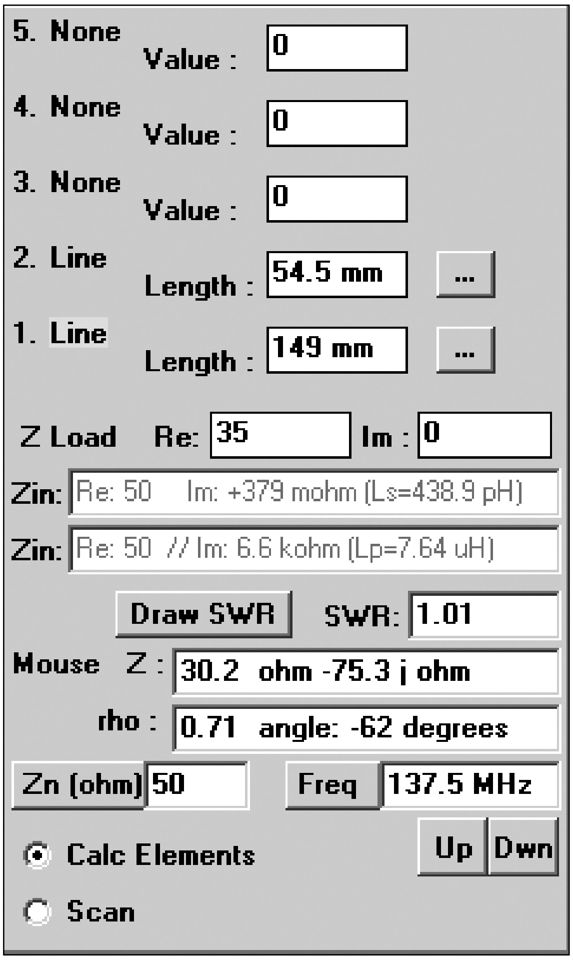


Figure 25 - Calculation panel in *PASAN*

You can now read off the two co-ax cable lengths required for matching (and their associated electrical wavelengths) by clicking the ellipsis buttons and referring to the *Transmissionline data* windows (figure 26). You can also view the total attenuation in the *Bode-plot* window.

Because the antenna impedance has been converted to 50 Ω you can now use a length of 50 Ω co-ax as the downlead to connect your antenna to the receiver. If you use 10 metres of downlead, you can add a third 'line' element to *Pasan*, enter its length as 10 m, and determine the overall attenuation due to all three lengths of co-ax from the Bode-plot window.

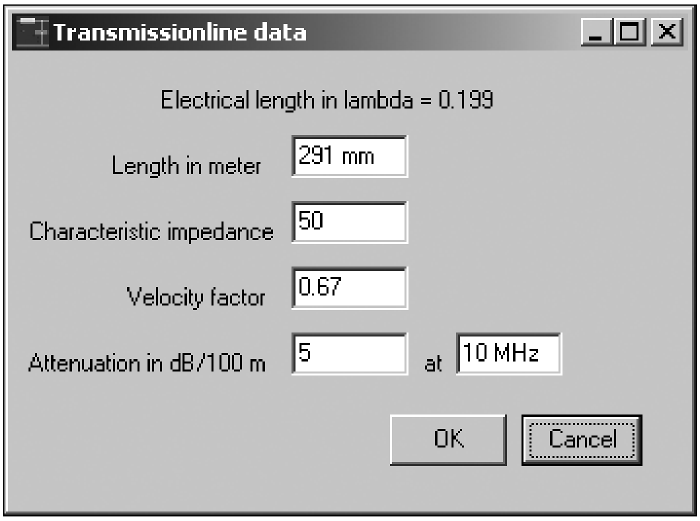


Figure 26 - Transmissionline data panel

Frequency	137.5 MHz
Up/Down steps	10 MHz
Zn	50
Q factor	0
Start Frequency	123.8 MHz
Stop Frequency	151.3 MHz
Number of steps	100
Major	1 MHz
Minor	200 kHz
Show Smith chart normalised	unchecked
Full screen	unchecked

Table 1 - *Pasan* default parameters

Developing the PADAT 137

A new, rugged, aluminium strip RQH Antenna

Part 2 - Construction

Ruud Jansen

Last issue I explained the design process that led to the development of the PADAT137 RQHA. Now it's time to describe how you can actually build such an antenna yourself.

The Headpiece

The most difficult part of this antenna is the headpiece, which should be constructed from polyoxymethylene (POM), a plastic with excellent HF properties. POM is water resistant, wear-resistant, very strong and easy to machine. It is supplied under the brand name *Delrin*.

Starting with a 55 mm length of 70 mm diameter solid POM rod, use a lathe to cut a 32 mm diameter hole the full length of its axis. This will accommodate the vertical length of PVC piping which functions as both mast and loop support. At the top, expand the hole to 42 mm diameter for a depth of 23 mm (figure 1).

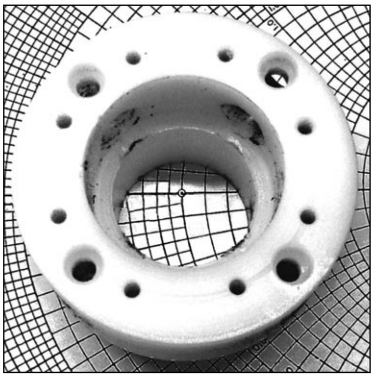


Figure 1 - The headpiece mounting block

Next, drill the four 12 mm horizontal holes needed to accommodate the aluminium rods of the antenna elements. This is **very** precise work because these rods **must** be mounted perfectly horizontally. A deviation of only a few millimetres at the end of a length of rod results in a change of a few centimetres in the diameter of the antenna—and hence the impedance, as well as the phase shift between the two loops and the radiation pattern.

Another four holes (5 mm) must be drilled from the top to allow fixing of the lengths of rod with M5 bolts, along with eight 2.4 mm holes which should be tapped with M3 thread and used to secure the lid (figure 2 - opposite page).

The lid itself is just a simple disc of POM or *Lexane*, anything from 3 to 8 mm thick: and of course this lid must also be drilled with eight 3 mm holes to secure it to the headpiece.

The Rod Components

For the upper cross-members, cut two 127 mm and two 132 mm lengths from 12 mm aluminium rod using a hacksaw. Drill a 4 mm hole with a depth of 25 mm or a little longer into one end of each. You will also need to drill a second 4 mm hole through each rod, 15 mm from the opposite end. Finally, a 2.4 mm hole must be drilled, at right angles to this 4 mm hole, just 4 mm from the end of the rod (figure 3). The eight 4 mm holes must be tapped for M5 thread and the four 2.4 mm holes for M3 thread as shown in figure 4.

Figure 3

For the lower cross-members, cut one 278 mm and one 288 mm length of the same aluminium rod and drill a 4 mm diameter hole, 25 mm deep, into both ends of each. A 3.2 mm hole then has to be drilled at right angles through the mid-point of each piece of rod. Tap M5 thread into the 5 mm holes and M4 thread into the 3.2 mm holes (figure 5).

The Mast

The mast consists of a length of 32 mm outside diameter PVC pipe. You have to bore two 12 mm holes where the two lower aluminium rods must be pushed through the mast and secured. To make this assembly sturdier, two PVC sockets can be mounted over the pipe at these points (the ridge which occurs halfway down the inside of each socket can be removed with a file or rasp).

The vertical distance between the centres of these two holes amounts to 40 mm and they must be drilled at 90 degrees to each other. The respective distances between the centres of the upper and lower of these two rods and the centres of the corresponding rods immediately above on the headpiece are 845 mm and 885 mm (figure 7, opposite page).

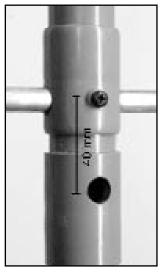


Figure 6

Finally, bore two 4 mm holes through both the PVC sockets and the mast in order to secure the two lower rods using 4 mm bolts (figure 6)

The Vertical Aluminium Strips

Now it's time to deal with the aluminium strips. Cut four strips, two 900 mm long and two 940 mm in length then drill a 5 mm hole 10 mm from both ends of each. Now you have to create a 90° twist in each strip in order that it can be fitted correctly to the cross-pieces. Here's how I do it.

Start by clamping 30 mm at one end of a strip in a vice or fixed clamp. Next, clamp 30 mm at the opposite end of the strip between two pieces of hardwood, and secure them with a clamp (figure 8). Now turn this end about 120° in a **clockwise**

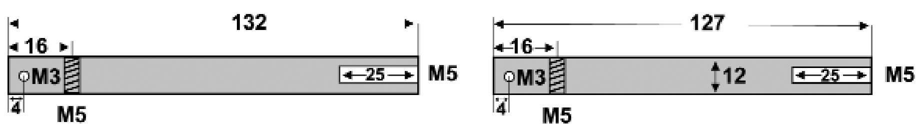


Figure 4 - The RQHA upper element rods

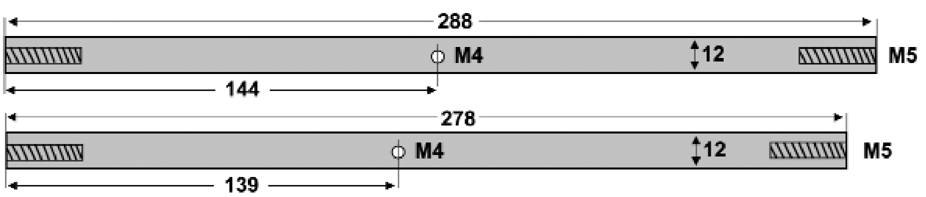


Figure 5 - The RQHA lower element rods

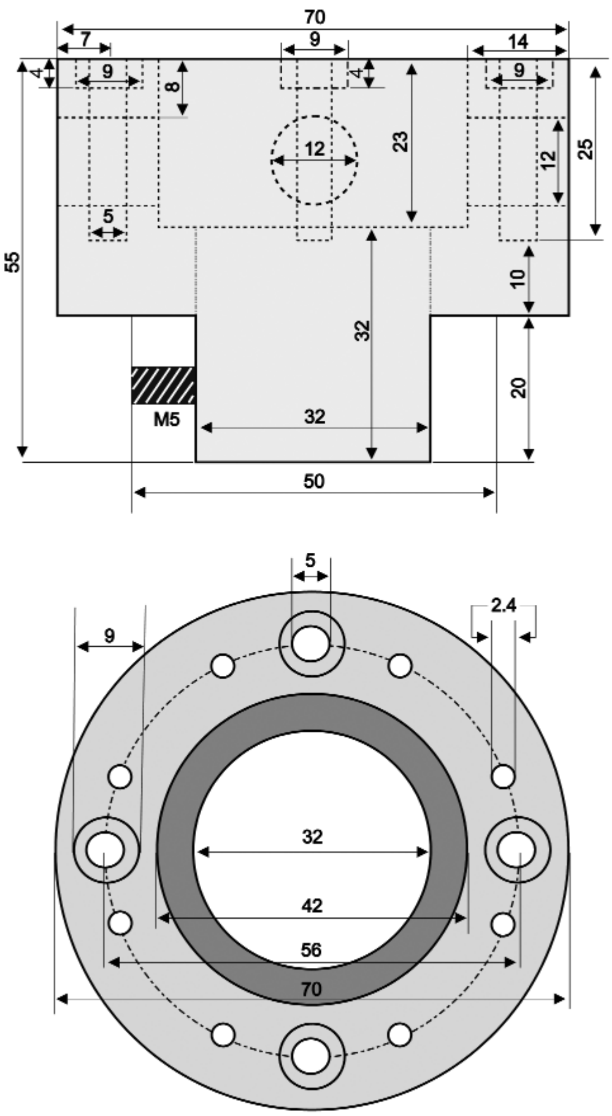


Figure 2 - Plan and elevation views of the upper block

Figure 8 - Twisting the aluminium strips

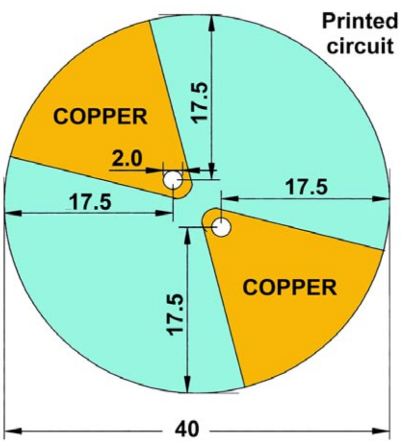


Figure 9 - The masthead PCB

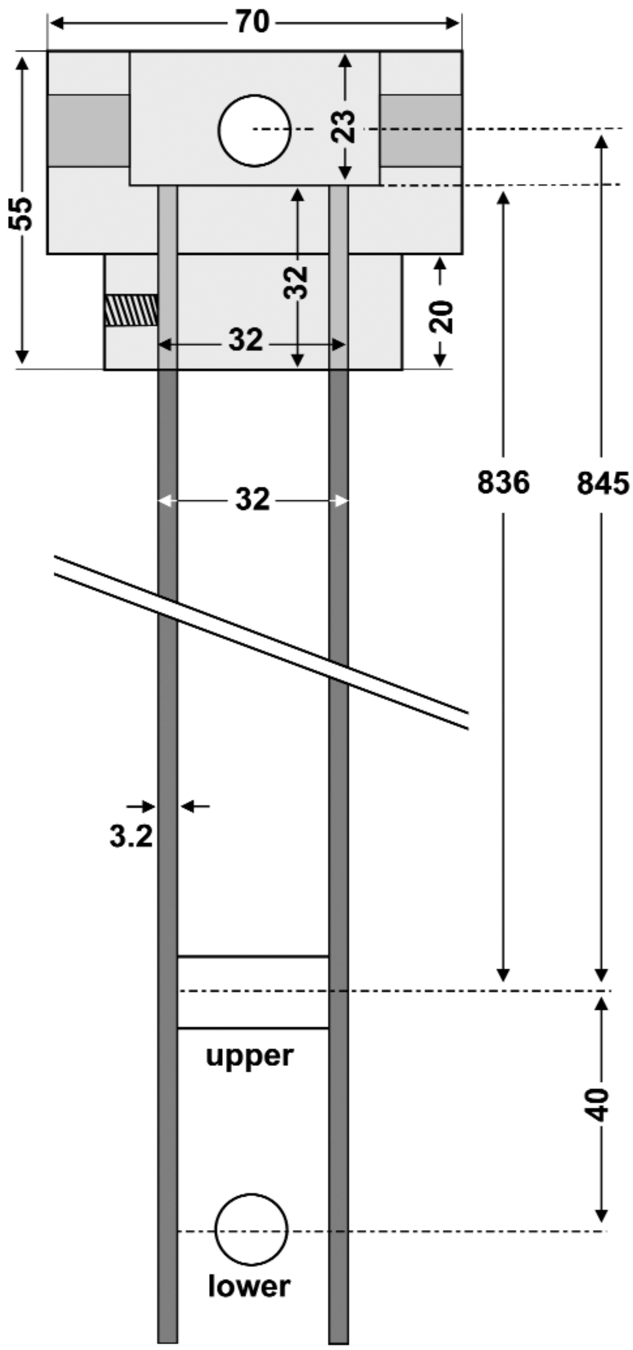


Figure 7 - Mast dimensions

direction, in a single movement. When you release it, the strip will return to about 90°.

If necessary, repeat this turning process a few times: do so as smoothly as possible to avoid tearing the aluminium. Repeat for the other three strips.

The Printed Circuit Board

When the the time comes to connect up the aluminium rods in the headpiece, this will be done using a small piece of printed-circuit board. To prepare this, take a piece of single-sided printed-circuit board and saw or file it to a circular disk; then etch or scrape away part of the copper in such a way that two insulated copper segments remain (figure 9). Later, the upper rod components will be mounted on to these segments with solder lugs.

Constructing the Balun

Start with approximately 520 mm of 50 Ω RG58 co-axial cable and 150 mm of RG59 75 Ω co-ax. At one end of each, make a short slit in each side of the co-ax so that the outer insulation layer and braid can be folded back—but do not cut them off!

Solder the two inner conductors together in such a way that there is a minimum of space between the inner insulation layers of the two cables. Cut a short length of inner insulation from a spare piece of co-ax, split it in half lengthwise, and mount it over the soldered inner conductor. Finally, fold both outer braids back so

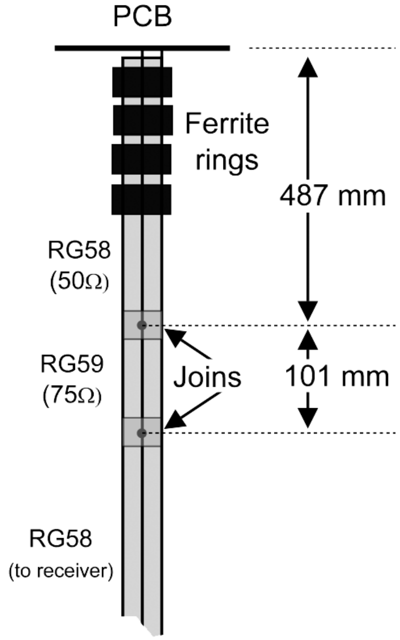


Figure 10 - Balun construction (not to scale)

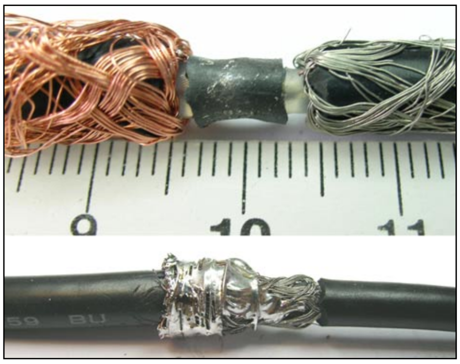


Figure 11 - Making the join

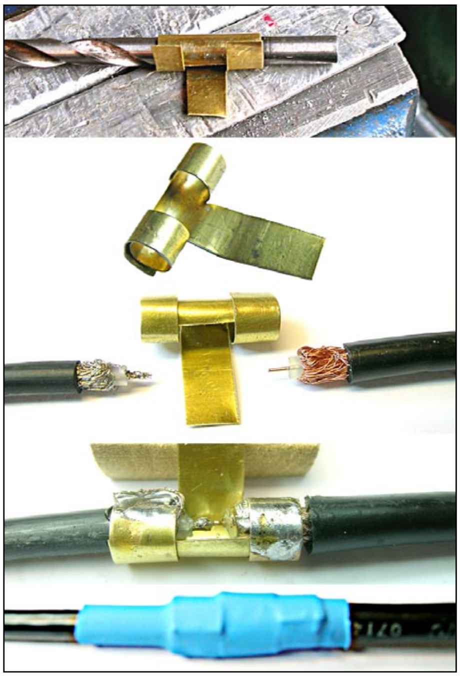


Figure 12 - The join: step by step

that they cover the join and solder them together. Finish these connections neatly with some shrink tubing. Trim both lengths of co-ax to their correct lengths then join the other end of the 75 Ω RG59 cable to the RG58 receiver downlead in a similar fashion. The correct dimensions for the lengths of co-ax are shown in figure 10 (though not to scale) and you can see photographs of the joining process in figure 11.

Another possibility for joining the lengths of co-ax cable is by making a special tool from a small piece of 0.3 mm thick brass or tin sheeting measuring about 25 x 20 mm (figure 12). Cut this piece half-way through in two places, 7 mm from each end then bend it around a 5 mm drill and fold the middle lip back. Now cut the co-ax as shown in the photos, push through both ends of the tube, and solder the braid of the cables to the tube. Use a hot soldering iron with a large tip to ensure that the shield is soldered to the tube quickly and make sure that the inner insulation does not melt away. Both inner conductors can now be soldered together and the protruding lip can be folded over to make a neat cylinder which may be finished with some shrink-tubing (figure 12).

If you find this approach too much trouble, it is of course also possible to use 50 Ω and 75 Ω *Teflon* co-axial cable. Take care however, because the velocity factor for *Teflon* co-ax is 0.695 rather than the 0.66 for RG58 and RG59. The length of the two upper co-ax pieces may be calculated with the *PASAN* software by entering this value in the 'Transmission line' field; both pieces will be slightly longer (512 mm and 105 mm). The use of *Teflon* cable prevents the inner insulation from melting away as a result of the extensive soldering activities.

Now slide the ferrite rings or tubular cores over the 487 mm length of RG58 (use *Type 43* cores with a narrow inner diameter to fit as tightly as possible over the co-ax cable). Should the inner

Figure 13 - Adding the ferrite rings

Figure 14 - Soldering to the PCB

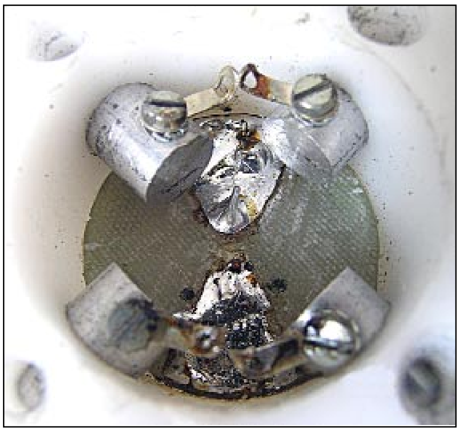


Figure 15 - The solder tags

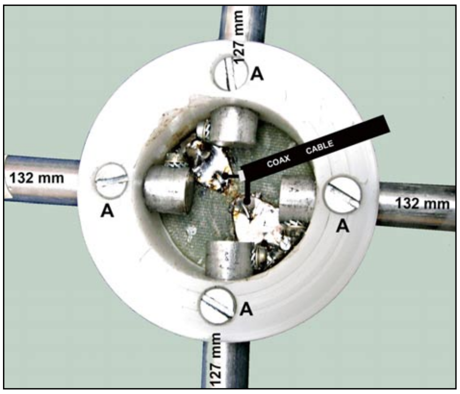


Figure 16 - Connections in the headpiece

diameter of these cores be just a little too tight, there is no problem in removing the outer insulation over the required length since ferrite cores are not themselves conductive (figure 13).

Finally, slide a piece of shrink tubing over the ferrite cores and crimp with a hot air source (hair dryer) to ensue that a rigid assembly is obtained. Complete the job by soldering the PCB to the balun (figure 14).

Assembly

Slide the assembled co-ax cable and PCB through the POM headpiece until the PCB stops on the ridge. Slide the four upper aluminium rod cross-pieces sideways into position as shown in figure 15. Take care: the two long pieces should be positioned opposite each other, as should the short ones. Screw solder lugs to the M3 holes at the end of each rod using a spring washer then bend the lugs in such a way that, when they are twisted by a quarter turn, their ends rest flat on the PCB. Secure the four rods from above by tightly screwing the four M5 bolts (labelled 'A') through the headpiece and into the threaded holes in each rod: then solder the four lugs to the PCB (figure 16).

Note: the short length of co-ax drawn in this figure serves only to illustrate how the balun co-ax, which runs down the mast, is attached to the PCB.

For the time being, slide the end of the co-ax cable through the PVC mast and fit the headpiece on to it till it just touches the PCB.

Slide the longer rod through the lower 40 mm hole in the mast and the shorter length through upper one, taking care not to damage the co-ax cable running through the PVC tube. Now twist the headpiece so that the longer rods (132 mm) are perpendicularly above the short (278 mm) lower rod. The distance between the centres of these rods is now 845 mm. The perpendicular distance between the two short upper rods (127 mm) and the long lower rod (288 mm) is now 885 mm.

Securing the Headpiece

You will need to drill two final holes near the top of the PVC mast in order to secure it to the headpiece. Screw the two M5 bolts near the base of the headpiece against the mast and then unscrew them again. This should leave a slight indentation in the mast. Now remove the headpiece and drill a hole through the mast, a little smaller than 5 mm, exactly where each M5 bolt left its impression. Take care not to drill into the co-ax cable or balun. Replace the head on the mast and screw in the M5 bolts so that approximately 5 mm protrudes through the hole in the mast. Bolts with a thread length of around 15 mm are quite suitable for this purpose. The head is now secure on the tube and cannot move.

Mounting the Aluminium Strips

Mount the four aluminium strips using M5 bolts and washers. Bolt each short (900 mm) strip between one of the short (127 mm) upper rods and one end of the lower short (278 mm) rod, making a quarter turn anti-clockwise around the mast (see top-down view in figure 17). Each long (940 mm) strip should be connected similarly between one of the long (132 mm) upper rods and the long (288 mm) lower rod. All four strips will bow a little when tightened, and assuming that all measurements are correct, they will form an imaginary cylinder (figure 17). The cylindrical shape of both large and small loops may be checked by means of a ruler or a home-made template, by measuring the distance between the mast and strips along the full length of the mast. If everything works well, use eight bolts to fasten the lid to the head. To make the assembly waterproof, a suitable rubber seal, obtainable from your local hardware store, may be added. You could also use a ring fashioned from a bicycle inner tube. Also, the use of a (thin) coating of a suitable sealing compound (**not** silicone) will keep moisture out. To protect the anchor points of the strips against corrosion, they may be treated with a suitable preserving compound such as *Tectyl*.

Figure 17 - Mounting the aluminium strips

Materials List

- 2 aluminium strips, 15 mm wide, 900 mm long and 3 mm thick. Hard or semi-hard
- 2 aluminium strips, 15 mm wide, 940 mm long and 3 mm thick. Hard of semi-hard
- 2 x 127 mm lengths of 12 mm aluminium rod
- 2 x 132 mm lengths of 12 mm aluminium rod
- 1 x 278 mm length of 12 mm aluminium rod
- 1 x 288 mm length of 12 mm aluminium rod
- 1 piece P.O.M. (Polyoxymethylene) 70 mm diameter and 55 mm long
- 1 piece P.O.M. or Lexane (Polycarbonate) 70 mm round and 3 to 8 mm thick (lid)

Match construction

- 1 length of RG58 co-axial cable (520 mm)
- 1 length of RG59 co-axial cable (150 mm)
- 1 length of RG58 co-axial cable - length dependent on distance between antenna and receiver.

Balun construction

- 25 pieces, Amidon FB-43-2401 (FP-43-2401, www.amidon.de) or
- 12 pieces, Amidon FB-43-6301 (FP-43-6301, www.amidon.de) or
- 15 pieces, Richcom RT11-050-090 (www.conrad.nl) or
- 17 pieces, Richcom RT09-050-080 (www.conrad.nl)

  Display Electronics also stocks suitable Ferrite rings and tube cores; however I have not tested these.

- Shrink tubing to put over the soldered connection and the soldered assembly of the shield and ferrite ring cores.

Connecting the rods to the co-ax

- 1 piece single-sided printed circuit board, 40 mm diameter
- 4 solder lugs, 3 mm hole.
- 4 bolts, M3 cylinder head, 12 mm
- 4 washers with 3 mm hole
- 4 spring washers with 3 mm hole

Securing the four upper rod pieces

- 4 bolts, M5 cylinder head, 20 mm
- 4 washers, 5 mm hole
- 8 spring washers, 5 mm hole

Mounting strips on the rod pieces

- 8 bolts, M5 25 mm long
- 8 washers, M5
- 8 spring washers, M5 (above and below)

Fixing loops and lower rods to mast

- 1 piece plastic pipe, 32 mm outer diameter (PVC), about 2 meter length (for mast)
- 2 sockets for 32 mm (PVC) pipe (refer foto).
- 2 bolts, M5 (thread length 15 mm) with washers, to secure upper piece to mast (refer photos).
- 2 bolts, M4 with washers (thread length around 25 mm) to secure the two lower rod pieces.
- 8 bolts, M3 (stainless steel or Nylon) with washers to secure lid.

Please note

All bolts, washers etc. are stainless steel material. Galvanised bolts and washers would result in less galvanic corrosion, as compared to aluminium; however the ss - aluminium combination, covered with e.g. Tectyl is a usable alternative.

If required, a corrosion protecting agent, e.g. Tectyl.

http://tectyl.valvolineeurope.com/nl/

Address details for suitable suppliers of the above mentioned materials may be obtained from the author.

Author's Footnote

Standard POM tubes with 30 mm inner diameter and 70 mm outer diameter are available at many hobby shops and shops specialising in plastics; you can also find suppliers on the Internet. Mostly they will sell this material in any desired length. I buy this material in 1000 mm lengths. If you have trouble finding a source, I can send you a 70 x 55 mm piece of POM. It is not expensive. Indeed, I can provide all the needed raw materials and send them anywhere in the world for just the basic cost of the materials, postage and administration.

Postscript

I have happily spent a lot of my time on this project and have tried to present a total picture, starting from conception to the point of publishing complete construction details. I would like to thank everyone who has assisted me in making this project a reality, in particular my wife Adri. During the multitude of 'garden' measurements, the required testing equipment was often parked in the living room waiting for a dry spell of weather. I would also like to thank her for the use of her sewing room, which I used to make dozens of drawings and photos of the various components—as well as bringing me snacks and drinks in the attic when there was no time to go downstairs.

Also thanks to **Chris van Lint** for the translation of this article. Without his knowledge of RQHAs, translation of my article would have been very difficult.

When planning construction of this antenna, do make sure that you read this article thoroughly first, and use the correct tools! If any errors have found their way into this article, please e-mail me at

ruud@farbridges.net

so that I can quickly amend the article.