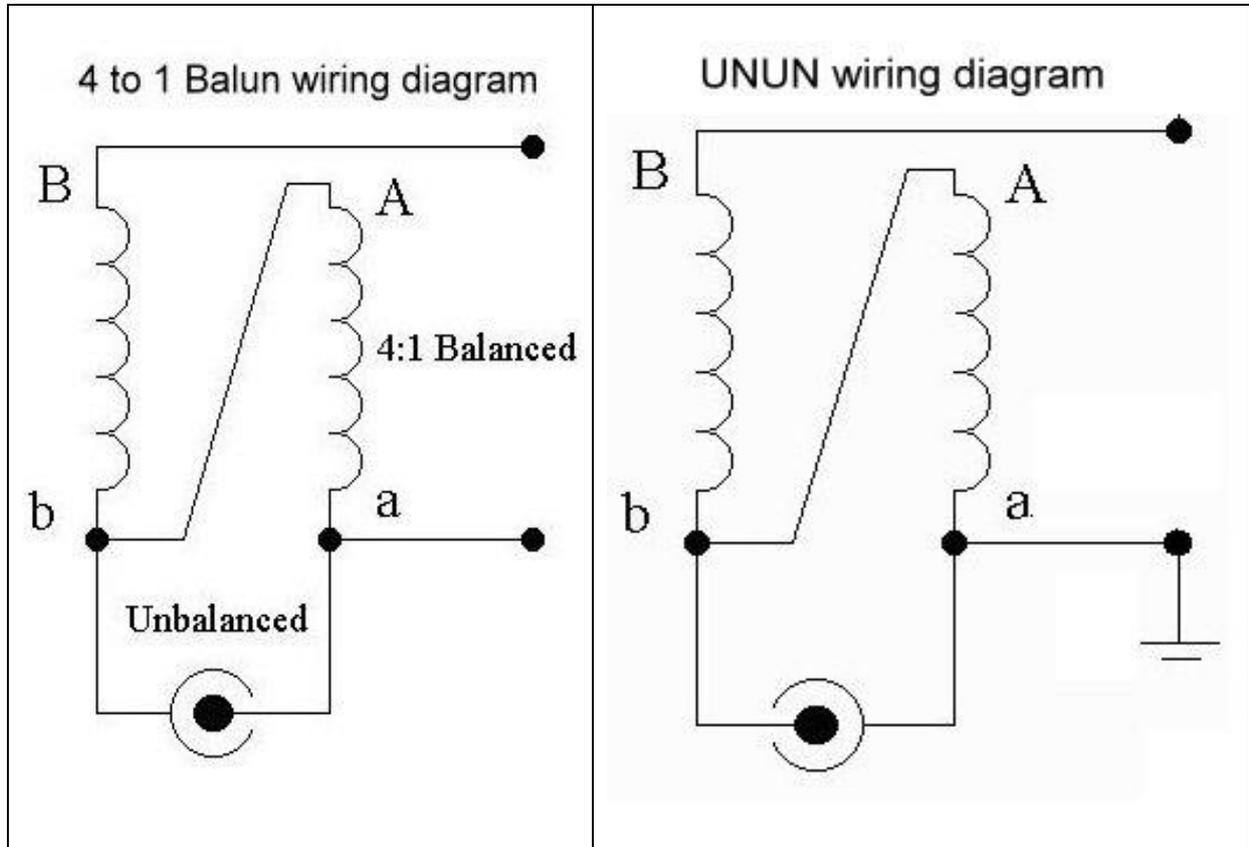


The Balun and The UNUN - page 1

When is a Balun, not a balun, when it is an UNUN !

Balun = "BALanced-to-UNbalanced"

Unun = "UNbalanced-to-UNbalanced"



Looking at the two diagrams above you will see the common terminal for the Balun goes to the HOT terminal of the unbalanced side where as the common terminal in the UNUN goes to the COLD side of both the input and the output.

When we say a Balun or UNUN is a 4 to 1 device it will work just as well backwards. A 4 to1 balun can also match 50 Ohm to 12 Ohms, and a 9 to 1 can match 50 Ohm to 5 ohms.

Working in the forward direction a 1 to 1 is 50 in 50 out.

A '4 to 1' will convert the 50 ohms of your coax to 200 ohms 'ie 4 times'

A '9 to 1' will convert the 50 ohms of your coax to 450 ohms 'ie 9 times'

And now for a few wise words from VK5AJL, John Langsford, visit his web site for the whole story

The Balun and The UNUN - page 2

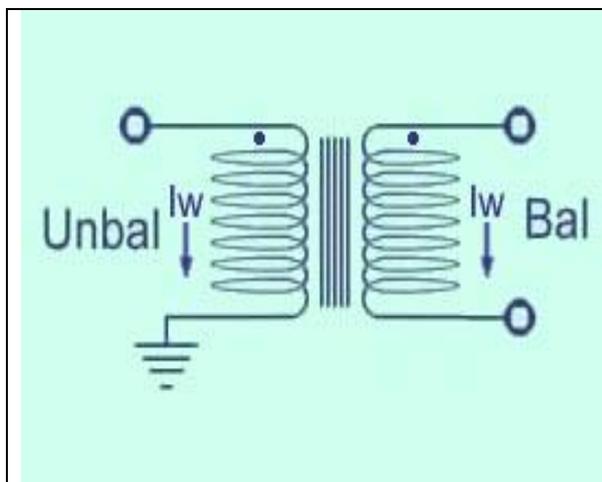
Voltage balun

A voltage balun utilises some form of transformer action to transfer energy back and forth between a balanced and unbalanced transmission line. A voltage balun involves the transformation of a voltage, often using a core type transformer (even if 1:1) but that definition need not be so restrictive and can include a half wave loop. This implies the transformation of impedance (even if the same). It also includes auto-transformers like the Guanella Balun.

Current balun

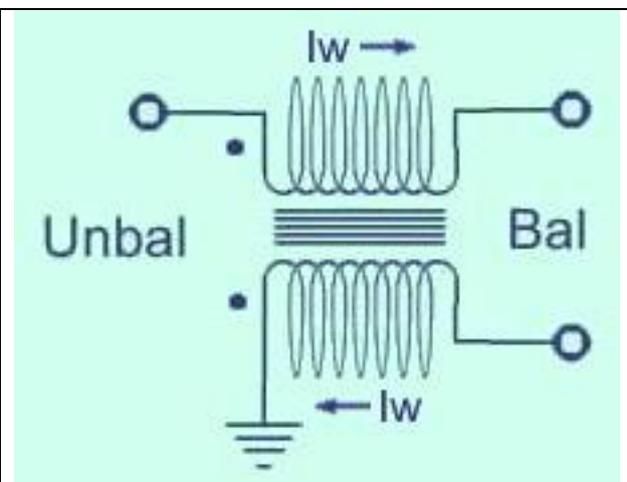
A current balun allows working currents to pass but chokes common mode currents - nothing more. There is no transformer action. Because it is a current controlling device and not a transformer, there can be no such thing as a 4:1 current balun.

Put another way, a current balun controls currents presenting a low impedance, through the device, to desired currents but a high impedance to unwanted ones. See the action described for a [core type current balun](#) below for a description of how such a device works.



Simple 1:1 voltage balun

A voltage transformer type balun uses magnetic transfer (transformer action) to produce a balanced signal at the output. The 1:1 impedance transformation is achieved by making the impedance of each winding the same. If changing the number of turns on one (or more) winding changes the



Simple 1:1 current balun

*A 1:1 current balun controls currents. There is **NO** transformer action. Equal and opposite (balanced) currents cancel each other out and present a low impedance. Common mode currents produce a mutually inductive magnetic field that presents a high impedance to these, unwanted, signals. If the number of turns on one winding*

The Balun and The UNUN - page 3

<p>voltage, it is a voltage balun.</p> <p><i>Working currents</i> flow (indicated by the arrows in the above diagram) are induced through the core, in the same sense in the voltage balun but are in an opposite sense cancelling each other out (are <u>not</u> induced through the core) in a current balun.</p>	<p>is made different to the other, the action will remain the same except that there will now be a small impedance associated with balanced currents but still a much higher impedance for to common mode currents. If changing the number of turns on one (or more) winding changes the current, it is a current balun.</p>
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Common Mode currents

Coaxial cables with shields more than several skin depths thick always carry equal and opposite flowing currents on the inside of their shields and their centre conductors. Current direction and current ratio between the centre conductor and inside of the shield in a non-radiating coaxial line is no different than currents in each conductor of a perfectly balanced ladder line. In both unbalanced coaxial lines and balanced lines, the two conductors making up the line carry equal and opposite flowing currents.

When currents flow without close-by opposing currents, we call the unopposed portion of current **common mode current**. Common mode currents promote or encourage external coupling and radiation. In a dipole antenna, or any antenna for that matter, common mode currents in the antenna element are responsible for radiation. In the ham shack or along a feed-line, common mode current is responsible for unwanted noise ingress, RFI, RF burns, and a host of other maladies. Common mode currents, in effect, bring the radiating system into the feed-line or station equipment.

Common-mode currents, or currents flowing in the same direction, cannot exist **inside** a coaxial cable at any frequency where the shield is several skin depths thick. Shield skin depth serves to isolate the inside of the shield from the outer wall of the shield. Common mode (same direction) currents can only flow on the outside of the coaxial cable shield. Differential mode currents, or normal transmission line currents, flow on the inner surface of the shield wall. Currents entering and leaving the shield and centre conductor at each end of a coaxial line must be equal and opposite or the cable will radiate. If a coaxial line is not radiating, currents in the shield and centre conductor are exactly balanced and opposite flowing. Both types of transmission lines, balanced and unbalanced, will have equal and opposite currents entering and leaving each conductor when they have minimal radiation.

FERRITE vs POWDERED IRON

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Both ferrite and powdered iron cores are ceramic materials. They consist of small particles of either iron (for powdered iron obviously) or mixtures of iron oxides mixed with binding substances and are fired in a kiln like pottery. Both are more efficient than solid iron.

There are advantages and disadvantages to using both. Ferrite saturates (fills up with a magnetic field) at a lower level than powdered iron. After any core saturates, it behaves like just a piece of wire and not like a coil anymore. You must also remember that the relationship between magnetic field strength and ampere turns is not linear so, the closer you are working to the saturation point of any core, the more harmonics (mostly odd harmonics) you produce.

Suppose you have a powdered iron core and a ferrite core of the same size. Suppose the powdered iron core saturates at 12 watts and the ferrite core at 10 watts. If you put 5 watts through them, the ferrite, being more efficient, will transfer more power. If, on the other hand, you put 9 watts through it, although the powdered iron is less efficient, less power is lost in the harmonics. The power transfer at the desired frequency will now be the about the same for both and you won't be disturbing the neighbours TV or upsetting the ACMA anymore.

WINDING DETAILS

The number of turns will depend on the core material. Since there are so many types, exact figures can't be quoted here. For an HF transformer and a powdered iron core, about nine or ten turns per winding is a good place to start. Since a current balun is a type of common mode choke, the more turns the better.

There are several ways of testing it but none of them really easy. If 10 turns works OK, leave it. If you really must be sure, one way to test it is to put power through it at increasing levels and run it into a dummy load. Wind a 1:1 BALUN with extra turns using the desired material connecting the primary to an RF source and ground and the secondary to a dummy load (50Ω). You will need a **BIG** dummy load.

Antenna's, SWR, Antenna Tuners and Balun and UNUN

Many modern HF transceivers come fully equipped with built in tuners. While these tuners are great for changing bands, the manufacturers left out a very important accessory; the 4 to 1 balun. Without a balun the transceiver can only feed an antenna which uses coaxial cable. While this may be satisfactory for some operators, this is a real problem for those of us who prefer the super low loss ladder line or wish to use simple loop or long wire antenna.

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The only other alternative is to buy an external tuner with a built-in balun which is really absurd after spending the additional money to have one built into the radio. Fortunately a Balun or UNUN can be easily home brewed

On the other hand, let us assume for now the idea of using a BALUN/UNUN on a long-wire antenna is simply to bring the SWR within capabilities of some Automatic Antenna Tuning Units, especially the ones built into HF rigs.

For example, the Kenwood TS-570 "Built-in AATU" is listed as only being capable of handling a SWR mismatch of 3to1, whereas a typical external AATU is listed as being happy to address at least 10 to 1. In a typical long wire antenna example, the 4:1 balun on 20m would serve to (maybe) bring that impedance down from 600 ohms (which the above Kenwood Tuner example would not like) to 150 Ohms which, in theory, the Tuner would handle.

And now for some balun designs you can build

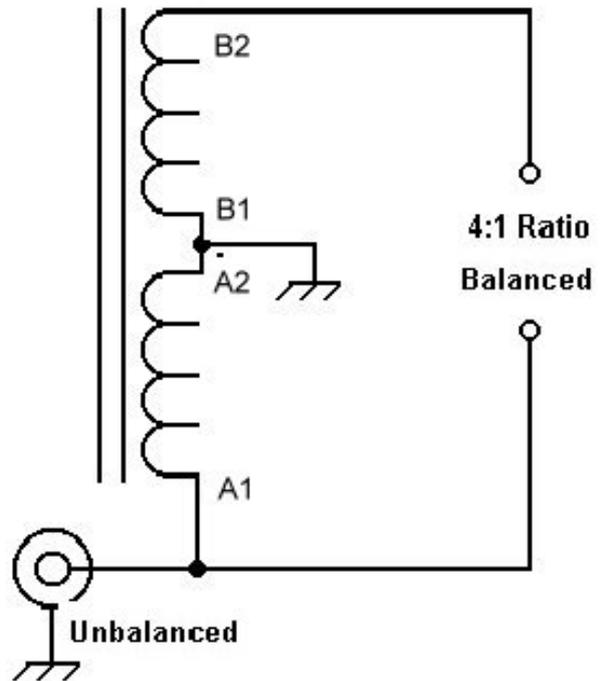
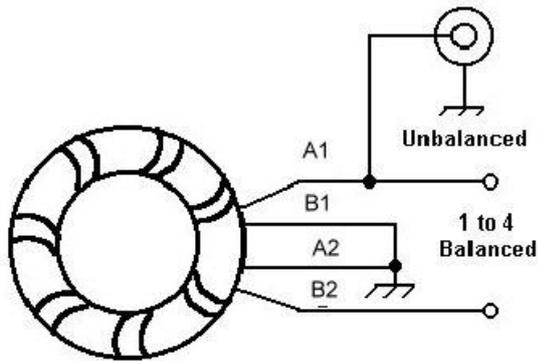
The VK5SRP 4 to 1 Balun (this Balun is usually used as 1 to 4)

In an article later in this paper, Lars mentions using Teflon covered wire but this is not easy to obtain here DownUnder and if you do find it you will have to buy a very large quantity. Regular Enamelled copper wire available from Jaycar and Altronics will work fine and I have found 7/0.25 hook-up wire or 14/0.18 twin (medium duty speaker wire) works fine. Much easier to get a nice even winding using these materials. Each winding should be 10 to 14 turns. The more turns the better the low frequency performance. The winding must also be wound tightly onto the core with no turns overlapping other turns. With the cores we are using you will require about 800 mm of wire for each winding. When you wind the core space the wire evenly round the outside of the core.

The cores that are readily available here are the FT140-61 from Mini-Kits. This core will be adequate for up to 200 Watt and if you wish to have a higher power capability you can use the FT240-61, this should be good to 400 Watt or more.

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The A1 and B1 in these drawing are used to indicate the start of that winding. An alternative method of labelling the start of a winding is to use a dot on the start of each winding.



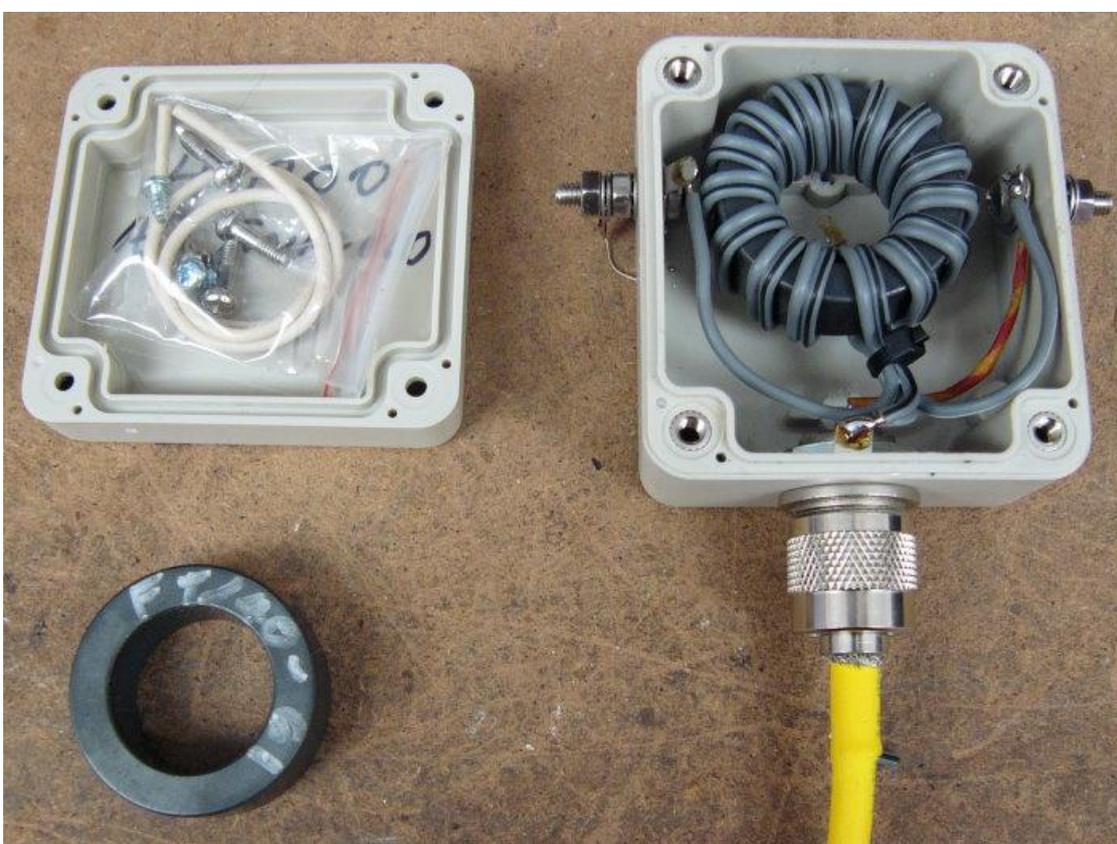
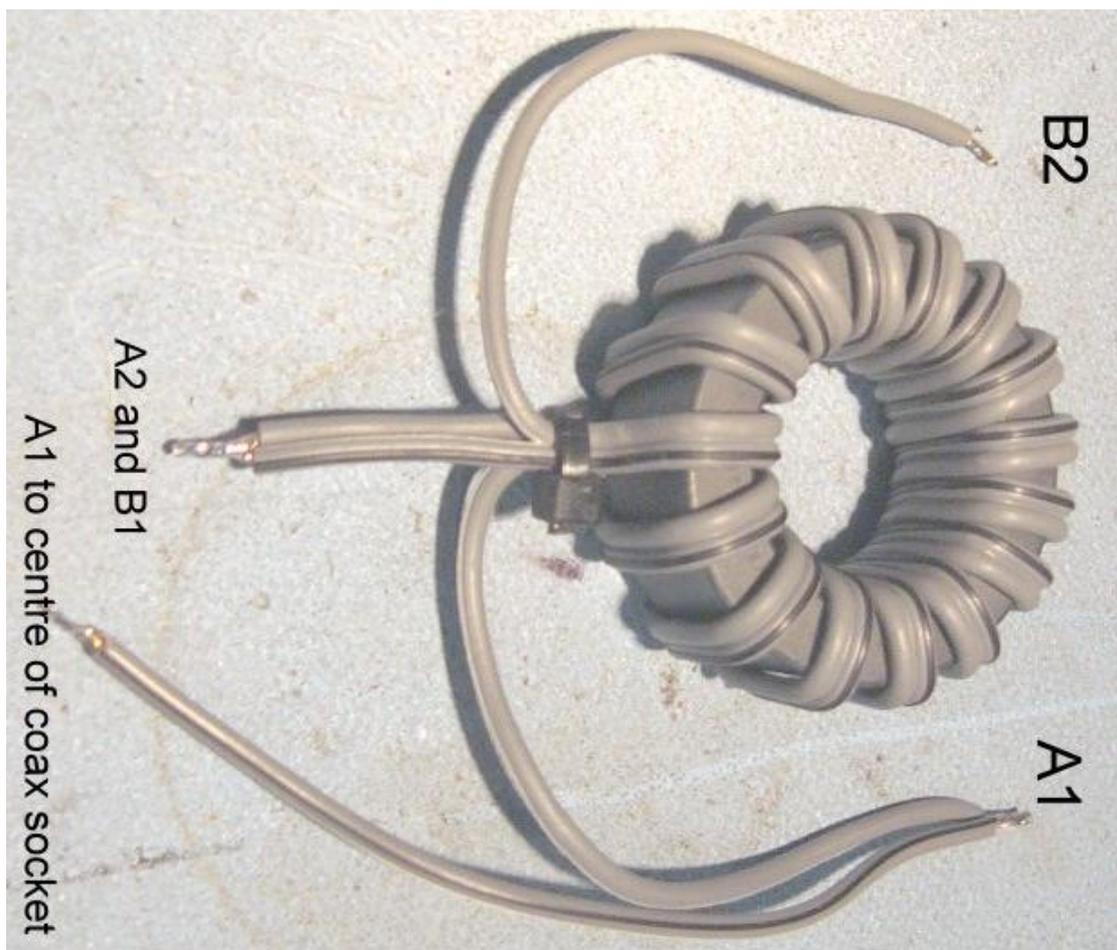
This Balun uses two windings each of 12 to 14 turns and is made with the 14/0.18 twin (medium duty speaker wire) mentioned earlier. The schematic diagram may be easier to understand than the diagram on the left.

The wire must be tight around the core and close together with no overlaps.

The above below will make it easier to work out which wire goes to where inside the plastic box. B2 and A2 come off the top of the core in this picture, A1 and B1 come off the bottom of the core. A short length of wire is used to connect A1 to the centre pin of the coaxial cable.

Fix the core inside the case with a spot of Roof and Gutter sealer, available in small tubes from hardware stores.

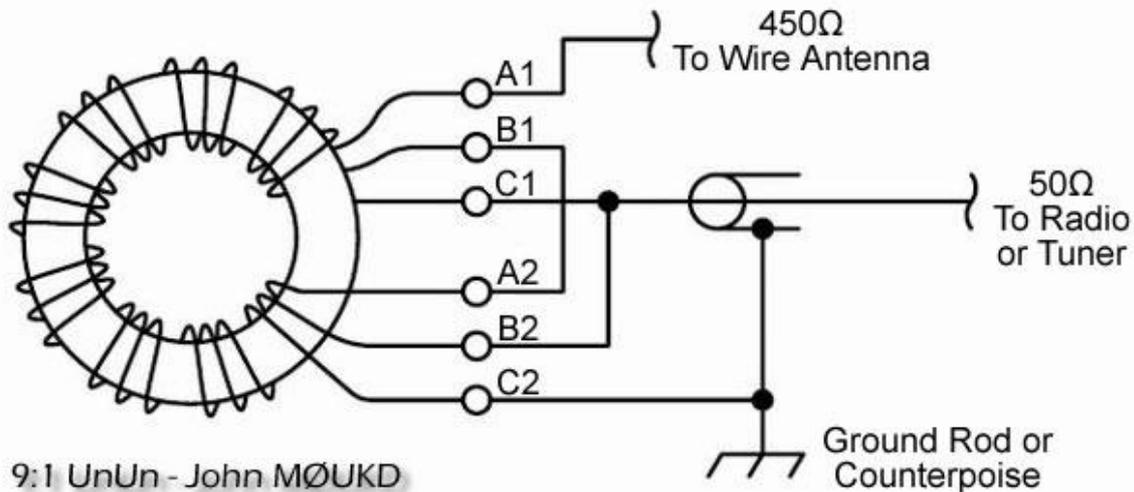
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Here is an example of a 9 to 1 UNUN that can be used with typical long wire antennas, from M0UKD

<http://m0kwr.com/zips/9 to 1 UNUN.pdf>



My version uses an FT140-61 from Mini-Kits (good for 200) Watt and Altronics **24/0.20 Tinned Heavy Duty Hook Up Wire**. An FT240-61 core from the same supplier should be good to 400 Watt.

I used white, black and green wires in my version and here is the colour code of how interconnected the windings:

Start of windings - A1 White to antenna wire terminal, B1 Black connected to A2 other end of the White and C1 Green to the centre pin of the input coaxial connector along with B2, the other end of the Black winding.

The other ends of the three winding connected as follows – A2 White to B1, the start of the Black winding, B2 Black to the start of the Green winding and to the coaxial connector centre pin and C2 to the ground terminal and the ground of the coaxial connector.

The use of insulated wire may be degrading the performance at 20 Metres. I have measured the SWR on 80 and 40 Metres at just over 1 to 1 and on 20 Metres 1.25 to 1. This may be effected by my measuring setup, I have found there is no substitute for putting the device on a transmitter and making measurements under operating conditions. The core material seems to effect the performance on 160 Metre also.

Another version is on the Loughton & Epping Forest Amateur Radio Society web site: <http://lefars.org.uk/WPblog/2011/11/05/91-unun-project/>

They used an (Amidon) Iron Powder T200-2 core. This is rated at 650W SSB and 400W 100% duty cycle (Digital modes etc.). With more and more of us using digital modes the above statement points out an important consideration,

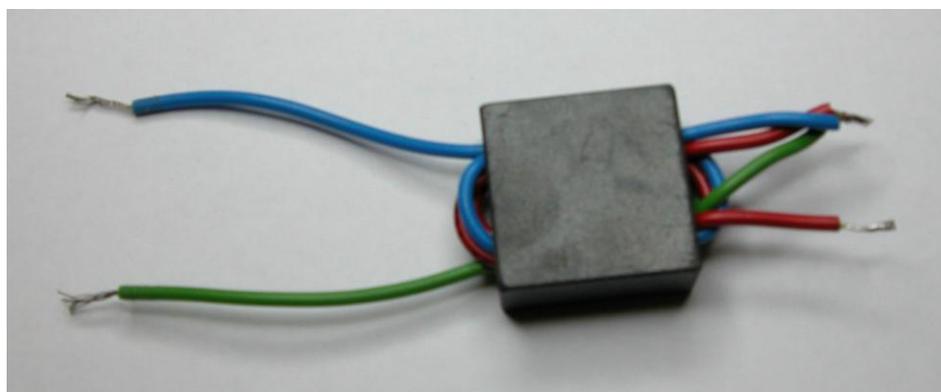
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digital modes have a 100% duty cycle so we must take this into consideration.



A 2 to 1 Balun using a Binocular core by Berndt VK5ABN

This is another example of a 2 to 1 Balun used to interface a loop antenna and the core used is available from MiniKits here in Adelaide.



An Amidon BN43-7051 core was used for the construction. The primary winding has 2 turns whilst the two secondary windings have 1.5 turns each.

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Multiple ferrite cores may be used to increase power handling of the balun. A picture of the balun is shown below.

An isolated 1 to 1 Balun

An isolated 1 to 1 Balun can be handy if you wish to isolate the ground of the equipment from the ground on the antenna.

For this example I used 16 or 18 turns of insulated multi strand 7/0.25 hook-up wire and an FT140-61 core from Mini-Kits.

The winding must be wound tightly onto the core with no turns overlapping other turns. With the cores we are using you will require about 800mm to 1M of wire for each winding. When you wind the core space the wire evenly round the outside.

This Balun can also be centre tapped if you wish to use the secondary side with balanced line. If you do this it may be better to wind the primary and secondary winding on opposite sides of the core.

Why not experiment, you can make a Balun or UNUN test it, try it out, and then strip it and try another configuration, after all we are Amateurs and that is supposed to be the nature of this hobby.



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Testing your Balun/UNUN

You can of course use your transceiver, a dummy load and an SWR meter but this may be quite inconvenient. A better method is to use an antenna analyser and the JST kit available from the Adelaide Hills Amateur Radio Society is the cheapest one of these available: <http://www.ahars.com.au/about/kits/>

It will enable you to analyse your HF antennas from 1.3MHz to 30Mhz and costs Australian Buyers A\$130.00 and International Buyers A\$145.00

Many other alternatives are available and when you look at the cost of the rest of your station this is a small price to pay for being able to know your antennas are performing to the best their design can provide.

To test a 4 to 1 Balun you will need to put a 200 Ohm resistance on the secondary (use non inductive resistors) and then you should read an input impedance of close to 50 Ohm. A one to one Balun will need a 50 Ohm resistor, six to one 300 Ohm and a nine to one will need 450 Ohm.

With a suitable Antenna Analyser you can test your handy work at the various Amateur Band frequencies and see if it performs.

The Ugly Balun - The Coax Choke balun:-

When you connect centre fed antennas, like dipoles, V's, Triangles, Yagis, Rhombics, Loops and so on, to coaxial cable, unless care is taken, it is not difficult to end up with feed line radiation. Not only can the loss in power be quite significant, but the radiation characteristics of the antenna system will also be seriously compromised. In laymen's terms, it won't be what you are expecting from the pattern of your antenna.

As the feed-line becomes part of the antenna, currents can flow from the line into the power mains and on Television and other communications cables, metal masts and Yagi booms, causing a variety of EMI problems that can be very difficult to trace. Frequently these problems are simply due to unbalance - and the solution is the humble Balun air cored choke.

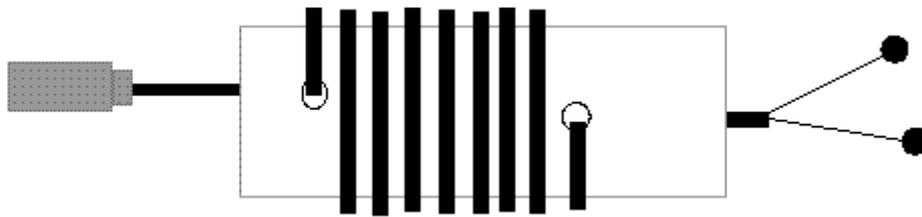
If an antenna system is fed at centre with a parallel conductor line (provided that correct installation procedures are followed) balance will be maintained, USING A BALUN, with currents in equal and opposite phase cancelling each other out.

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When the connection is to a coaxial cable, WITHOUT A BALUN, this cannot occur because currents flowing inside the cable from the connection to the inner conductor are separated from those flowing on the outside from the connection to the shield, and the result is unbalance causing feed line radiation. However, if the two electrical circuit elements (antenna and coaxial cable) are coupled using a Balun, balance will be maintained. **Enter the Ugly Balun**

The Ugly Balun for VHF and UHF -

At 2 Metre VHF an Ugly Balun is construct with seven or eight turns of (RG58) coax cable close wound on a piece of 55 mm plastic pipe. The choke prevents radiation from the feed coax by presenting a high impedance to ‘coax cable screen currents’ which tend to upset the radiation pattern. There are other methods (such as Ferrite materials) which have their own advantages.



UHF will require fewer turns, low-band VHF will require more. It is important that the adjacent turns touch. Fix the ends with cable ties and seal with heat-shrink or self amalgamating tape. Keep the “ugly little thing” away from metal supports or antenna elements. My 6 Metre J pole has an Ugly Balun with twelve turns on a 55mm plastic pipe.

The Ugly Balun for HF – 160 to 10 Metres

For the HF bands the Ugly Balun is made from six or seven metres of coaxial cable close wound on a piece of 75 or 90mm storm water drain pipe.



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Each end can be terminated in the coax connector of your choice or one end can be terminated in terminals (nuts and bolts perhaps) for connection of a balanced line.

More details at: <http://www.hamuniverse.com/balun.html>

Where do we go from here !

So far we have only scratched the surface of this complex subject, there are many resources on the web that go much further but at least by now you may have a basic idea of what a Balun and an UNUN is and how to make a very basic example.

Some of the web sites go into much more detail and explain there are more types of Balun with strange names than we have covered here.

For example visit Mini Circuits web site at:

<http://www.minicircuits.com/pages/BalunApplicationNote.htm>

To find out about:

- I. Ruthroff Balun Transformers.
- II. Guanella or Transmission Line Transformers
- III. Marchand Balun Transformers

Baluns can be made with coaxial cable wound on PVC pipe, hook-up wire or enamel covered copper wire on a Toroid core, an antenna ferrite rod or a bundle of them. I have even seen a Balun wound on a steel bolt !.



More web sites with Balun information you can visit

Visit John Langsford, web site to learn more of the story:

<http://vk5ajl.com/projects/baluns.php>

Many projects on the web site of Kent Royce:

<http://www.m0kwr.com/downloads.html>

Useful information on Lars OZ1BXM "A Tiny QRP Page" <http://oz1bxm.dk>

And last but far from least, VK5ABN's Multi-Band ALE Antenna article at:

http://ping.net.au/index.php?mode=ale_antenna

Where can I get the parts ?

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The cores can be bought from MiniKits here in Adelaide by mail order only - <http://www.minikits.com.au/>

The sealed ABS box (Altronics H 0300, 65x60x40), a suitable coaxial connector, the wire and the connectors can be obtained from either of the two AZtronics stores here in Adelaide (Altronics agents) and from other suppliers in other states of Australia. Jaycar should also be able to supply the same or similar items. Four mm bolts and nuts are the easiest way to connect the elements of an antenna to the Balun but if it is going to be left outside in the weather for a long time stainless steel bolts, washers and nuts will be the best choice. Some of my Baluns use old fashioned binging post because I have made them for Field Day antenna experiments and they will not be left in use for a long time.

An Internet or Ebay search will also provide many sources of cores but be careful, not all cores are created equal and each manufacturer has their own type number system. Cross reference data is available via several web sites.

Cores from the junk box

The cores used in switch mode power supplies for the transformer and the filter chokes are, as a rule, only low frequency magnetic materials and are unsuitable for High Frequency Radio Frequency use. There is no way of knowing what material a core is made of unless you know the brand name and the colour code or the core has part numbers written on it. This is not common. Some manufacturers do use colour codes but there are no industry standards covering this important information and one "red" core will be quite different to another brand of core coded red.

An Internet search will provide you with ideas on how to test ferrite cores with a signal generator and an RF volt meter probe.

Caution: It is possible to exceed the power rating of a core and the performance of the balun may be degraded during high SWR causing heating of the core. If the core is over heated its magnetic properties will most likely change and your Balun or UNUN will not work efficiently and may even damage your radio or AATU.

These notes compiled by Phil, VK5SRP for technical sessions at the North East Radio Club (South Australia) and last updated 9th May 2015.