Baluns
Part 3

In part 2 we learned by routing the coax feedline through ferrite toroids gave a high resistance to the common mode current flowing on the outside of the coax shield. Some examples of such baluns are seen in **Figure 1.** The two top ones are for QRO power while the bottom one is more for the regular 100 watt.

	
	***Figure 1.*** *Common mode current chokes by leading the coax feedline through ferrite toroids cores.*

The W2DU Current Balun

It is not always necessary to route the coax several times through ferrite cores. Walt Maxwell, W2DU, decided to place several ferrite beads along and around a short length of coaxial feedline, **Figure 2.** Building such a current balun is not a hard task and the required beads are not hard to find. You can order them from various sources.

The W2DU balun increases dramatically both the resistance and reactance for the common mode current. By adding resistance to the reactance improves the operational bandwidth of the balun with no increase in loss. While the two inner conductors of the coaxial cable remain unaffected, the beads introduce a high impedance in series with the outer surface of the braid. This configuration effectively isolates the external output terminal of the feedline from that at the input end.

Figure 2. *The W2DU current balun*

Two ways of construction are normally used. Once the beads are placed, you can seal the complete length with a heat shrink tube or you can enclose the string in a PVC tube closed with two end-caps, **Figure 3,** and **4.**

Figure 3. *The W2DU current balun: the ferrite beads, the string construction and a waterproof enclosure.*

Figure 4. *A W2DU current 1:1 balun waterproof construction for use at wire dipole feedpoint*

Broadband Baluns

At HF and even at VHF, broadband baluns are generally used nowadays. These can be divided into two distinct categories: voltage baluns and current baluns. Each category might have also an up or down impedance ratio, 1:1 and 4:1 are the most common while the 6:1 and 9:1 are rarely needed. Most of these baluns, either voltage or current types, are mostly constructed on a toroidal ferrite core, **Figure 5.** Two main construction principals are normally used: the **Ruthroff** type and the **Guanella** type both named by their inventors.

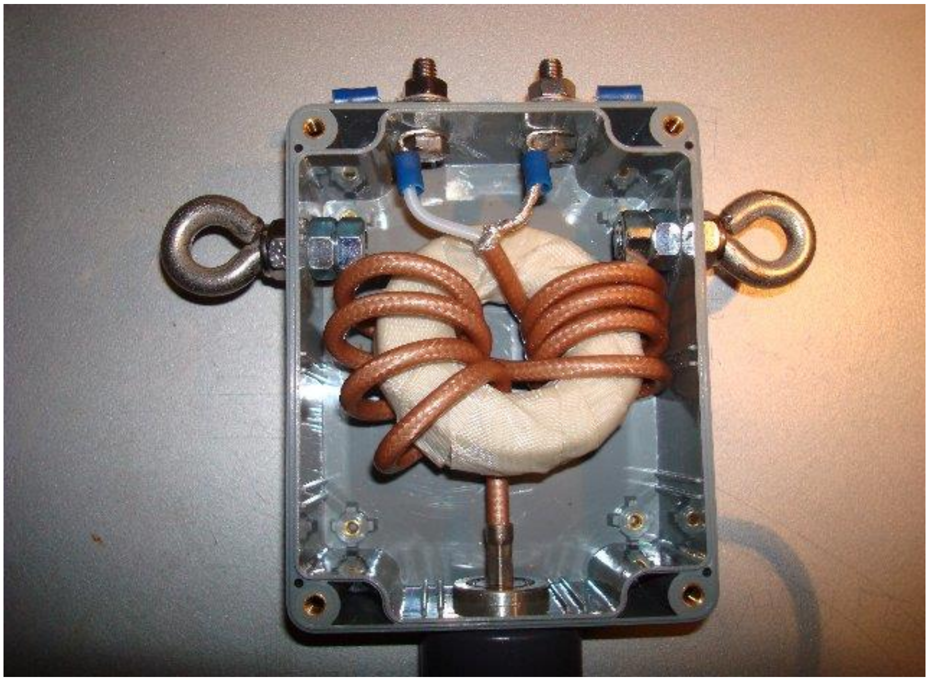


Figure 5. *A broadband current 1:1 balun wounded on a toroids ferrite core.*

The Voltage Balun

The voltage type baluns of **Figure 6** cause equal and opposite voltages to appear at the two output terminals, relative to the voltage at the cold coax cable ground side of the input. If the two antenna halves are perfectly balanced in impedance with respect to ground, the balun will force the voltages to be equal and the current flowing from the balun's output terminals will be also equal and opposite. No common mode current will flow on the feedline and the feedline itself will not radiate. If however the antenna is not perfectly symmetrical, unequal currents will appear at the balun output, despite equal voltage and thus causing common mode current to flow on the feedline, an undesirable condition. Another potential shortcoming of the voltage balun is that the windings appear across the feedline. If the windings have insufficient inductive reactance, the system SWR will degrade, which is a common problem particularly near the lower frequency end range. The 4:1 voltage balun is mostly, but not always used in antenna tuner units for connecting a parallel feedline to the unit.

The Current Balun

The voltage balun does not guarantee equal and opposite currents to flow. Therefore, a current balun is generally recommended to be used at the junction of the antenna and feedline and even elsewhere on the feedline; see later. **Figure 7** displays a 1:1 and 4:1

current balun. These baluns are wound according the Guanella principle and mostly used in amateur radio antenna systems.

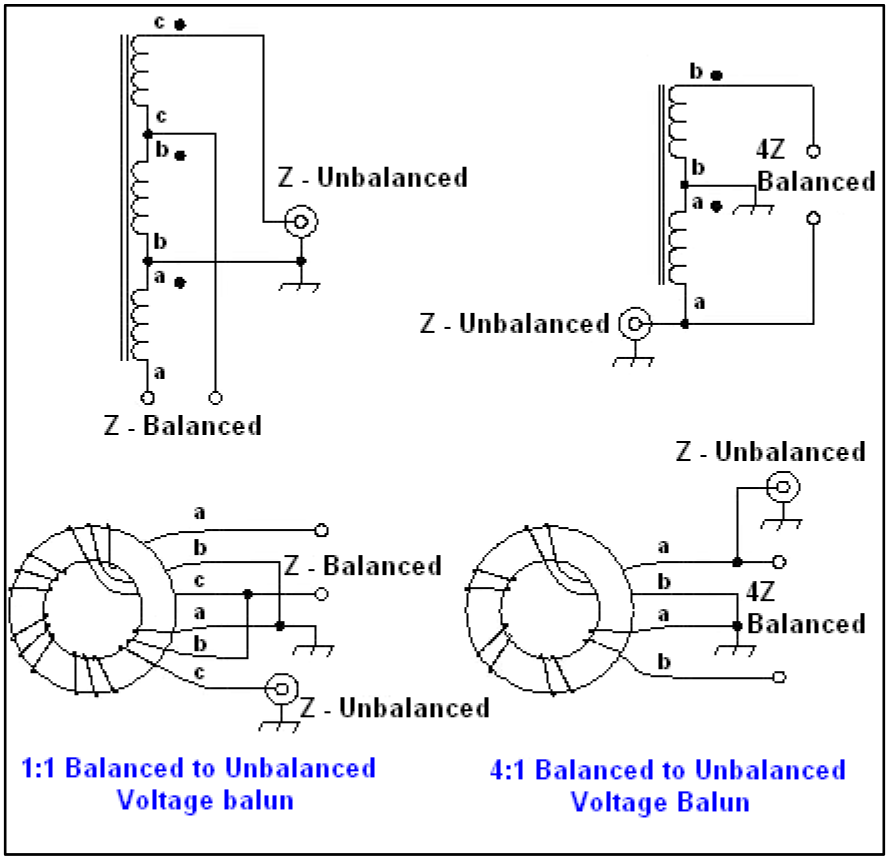


Figure 6. *Voltage balun with impedance ratio 1:1 and 1:4 examples*

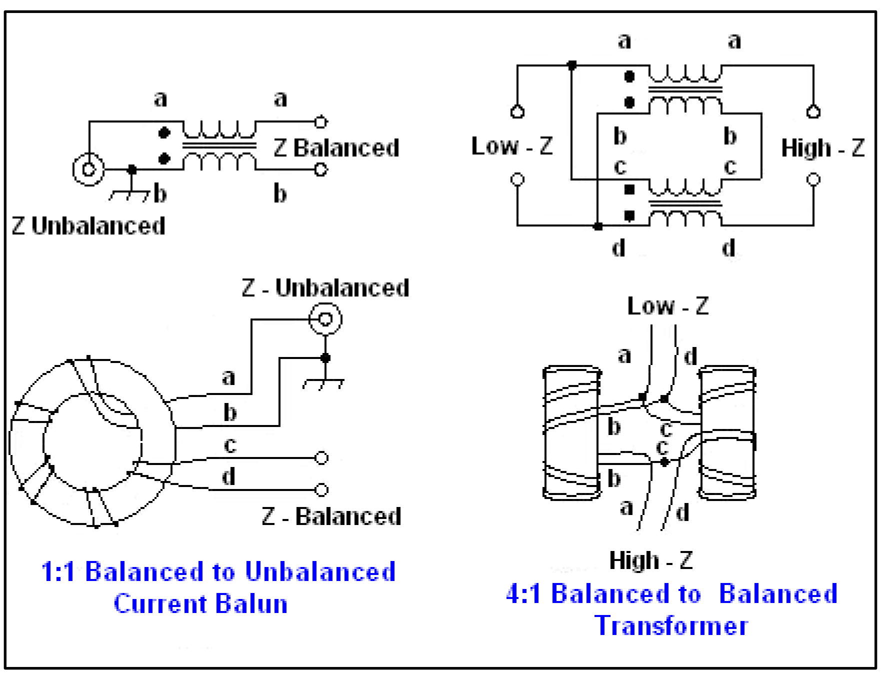


Figure 7. *Current balun with impedance ratio 1:1 and 1:4 examples*

Because the 4:1 voltage balun is not perfect for balanced current flow, a good solution to correct this is by adding a Guanella 1:1 current balun at the low Z side, **Figure 8.**

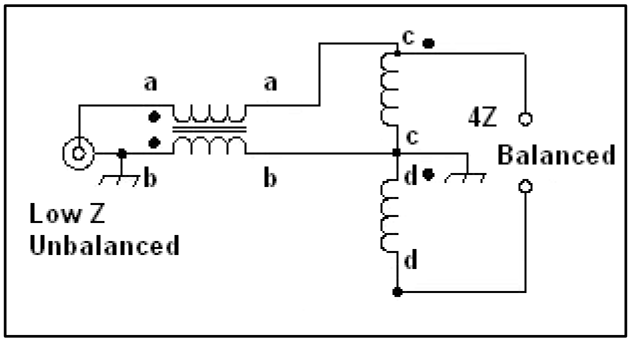


Figure 8. *A better 4:1 voltage balun with an additional 1:1 current balun*

Balun Construction

How to make the toroids? The following instructions are for Guanella current balun construction and are not very difficult to make. First you will need the ferrite toroid core of preferable mix-43 or mix-31. The size depends on the power you want to use but one with an outside diameter of 1.57 inch like I use in the examples below can handle easily a few hundred watts. One with a diameter of 2.4 inch can be used with high power as 1.5 Kw. Two toroids may also been glued together for high power tolerance.

Ferrite toroid cores are indicated as FT-XXX-YY, FT stands for ferrite, with XXX as the OD (outer diameter) in hundredths of an inch and YY the mix. For example, an FT-157-43 core has an OD of 1.57 inch and is made of type 43 material.

1:1 Guanella Balun

To construct a 1:1 Guanella current balun you will need two pieces of 0.5mm to 1mm or AGW #24 to #18 enameled wire. For high power it is preferable to use Teflon insulated wire. With enameled wire, the risk of voltage flash-over is too great. Coaxial cable with Teflon isolation is preferable and can also be used to form the windings and is better for high power. RG-58 is commonly used and with power of 100 watt is fine.

How long do the wires have to be? It all depends on the core size of course. I always use a piece of cord and wind the core with the number of windings in mind or needed, **Figure 9a**. I always add 10 to 15 cm (4 to 6 inches) to the total measured length. For a 1:1 Guanella balun it is not so important to know the specific wire at both ends, but for a ratio of 4:1 and higher, you must know or be able to identify the proper end of the specific wire. You might add a wire number label or color mark at both ends of the wire or make one wire of the two a bit longer; 2 cm or 1 inch longer in total length does the job, **Figure 9b.**

Figure 9a. *How to determine the wire length*

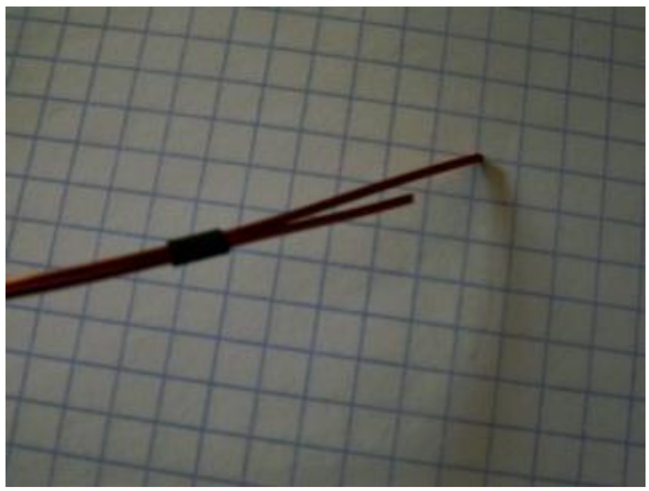


Figure 9b. *A trick to identify the specific wire by making it a bit longer at both ends*

First of all you are **not** winding a transformer! What you will do is to wind a short length of parallel transmission line around a ferrite core. So, the parallel transmission line is formed by the two wires. They have to stay as close as possible to each other; preferably touching each other otherwise the characteristic impedance will alter along the line. The wires also should not overlap. For low power, the wires may be twisted, but I do not recommend this for powers higher than 100W, more danger for voltage flash-over because the enamel isolation may become slightly cracked while twisting them.

The technique I use to construct a decent parallel line is by use of a small short piece of heat-shrink sleeve. Shrinking these short pieces over the two wires at intervals of about 1 inch each will suffice, **Figure 9c**. The heat-shrinking can be done by a heat-gun or above a candle flame.

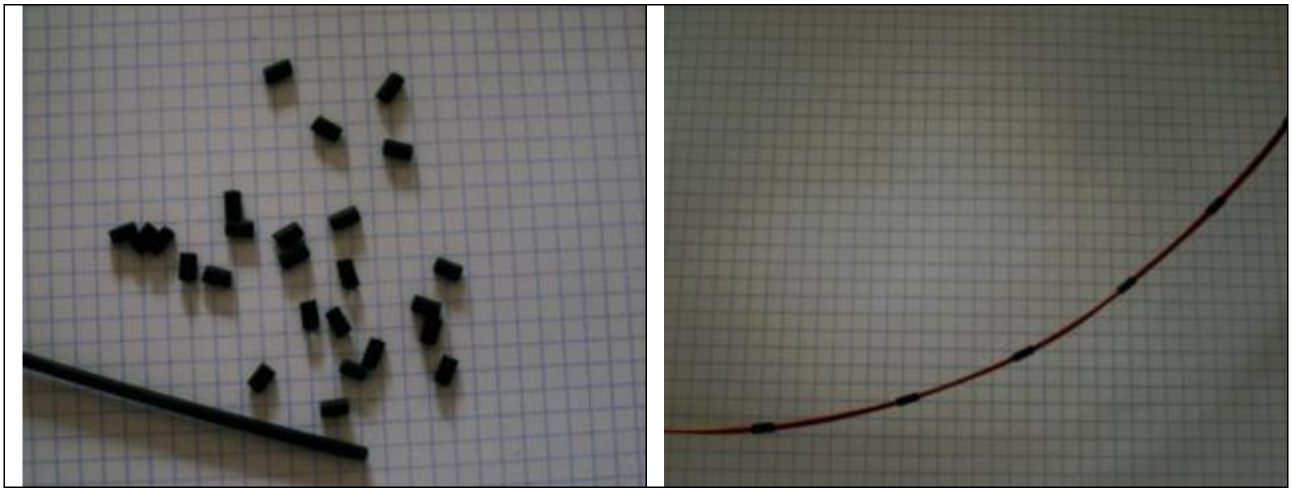


Figure 9c. *Using short pieces of heat-shrink sleeve to construct a parallel feedline*

Winding the balun can be done in three ways: (**Figure 9d)** using only one half of the toroid or using the complete toroid or by the Reisert crossover technique. The complete use of the toroid has only the disadvantage that both the input and output ends are on the same side of the core. This might be more difficult or cumbersome to make the connections for the respective antenna feedpoint terminals and the main coaxial feedline toward the transmitter. Either of the three winding methods give equal characteristics. The method with the cross-over is the most used one. The two ends of the windings are best tightened with nylon cable straps.

Guanella 1:1 balun wound on one half side of the core. Input and output on opposite side.	**Guanella 1:1 balun using the core entirely. Input and output on the same side.**

Guanella 1:1 balun with a Reisert cross-over. Input and output at opposite side.

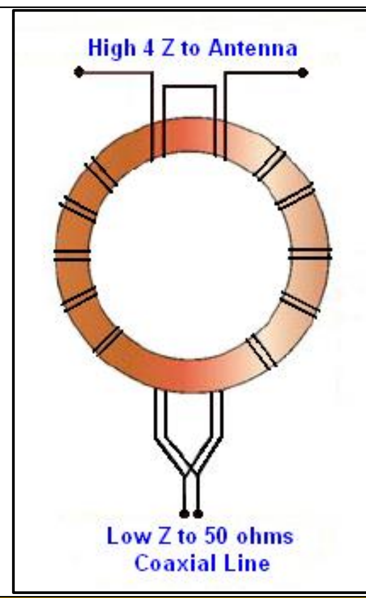
Guanella 1:1 balun with a Reisert cross-over using RG-58 coax cable whereof the outer jacket is striped

Figure 9d. *Four construction types of a Guanella 1:1 current balun*

4:1 Guanella Balun

The above current baluns are for an impedance ratio of 1:1. Other current balun ratios with the Guanella principles are also possible. In **Figure 7** at the right you find the schematic and construction sketch for a Guanella 4:1 balun. The construction sketch shows the use of two ferrite cores. For rather high power that is advisable but you can also wind a 4:1 Guanella balun on a single core and connect the wires as illustrated at the right side of **Figure 10.** At the high impedance side, which will be the antenna feedpoint (an OCF Off-Center Fed or a folded dipole, as example), the two baluns are connected in series. At the low impedance side (the feedline to the transmitter), the two baluns are connected in parallel.

A Guanella 4:1 balun from two 1:1 baluns wound on one toroid.



How to connect a 4:1 balun from two 1:1 baluns.

Figure 10. *A 4:1 Guanella current balun wound on a single core*

6:1 Guanella Balun

A 6:1 Guanella balun can be constructed from two 4:1 baluns. Take care with the connections of the wires in particular where to make connections in series and where in parallel; good wire labeling is a must here, **Figure 11.** It is obvious here at least two cores are needed.

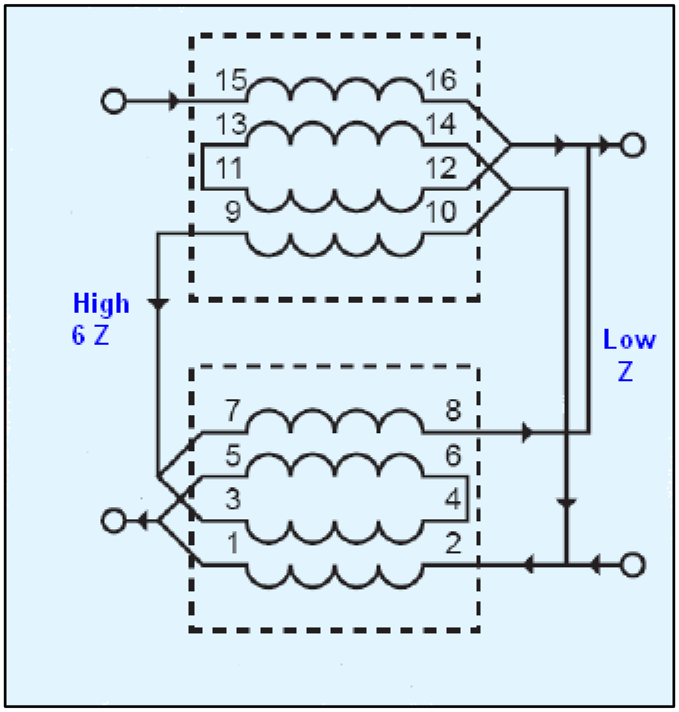


Figure 11. *A 6:1 balun from two 4:1 baluns*

9:1 Guanella Balun

A 9:1 Guanella current baluns can be constructed as seen at **Figure 12.** At least two cores will be necessary; even better is using three. The series connections are at the high Z side. At the low Z side, the connections are in parallel.

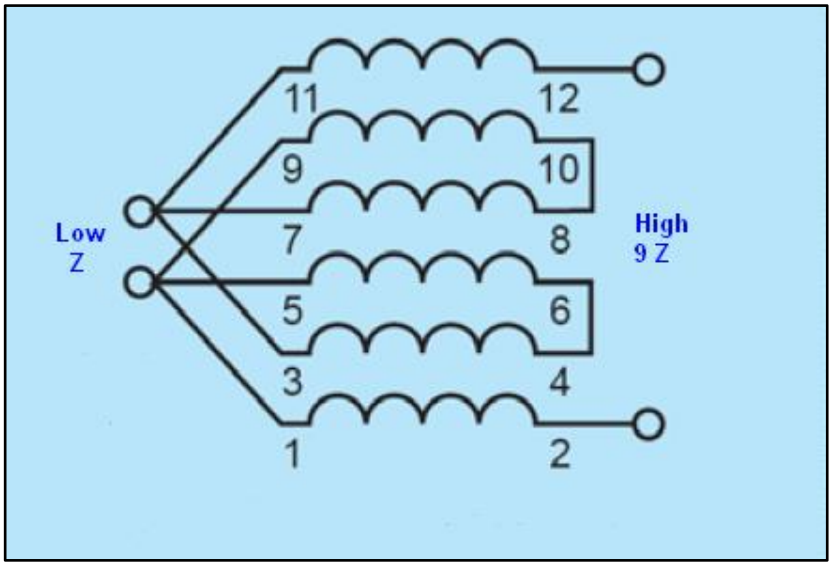


Figure 12. *A Guanella 9:1 balun*

Important Note: In some articles about current baluns, it is mentioned you may use powdered-Iron toroidal cores. This is definitely wrong! Powered-Iron material or mix is completely different in characteristics than ferrite mixes. Powdered-Iron is for sure the right stuff to make coils for tuned circuit low and high pass filters, etc. But for balun constructions it must be avoided as its permeability is far too low.

Feedline Current Chokes

By using a good current balun at the antenna feedpoint, the currents flowing at the antenna and at the feedline is forced be equal and opposite, or at least as much as possible. The current without a balun employed otherwise should flow on the outside of the coaxial outer shield is practically prevented. But at that outer shield of the coaxial feedline, in many circumstances, may also find current to be generated. This may happen if the feedline is in a slanted position (not routed symmetrical at 45° of the antenna halves) or by mutual coupling to surrounding constructions. To prevent this induced current from flowing toward the radio shack is to place an additional current choke. The feedline current choke(s) are placed in between the antenna and the transmitter; the best location being at ¼ wavelength intervals or at least one at the entrance of the feedline into the shack.

The properties and characteristics of current chokes or baluns are also reciprocal. Which means they do also a good job when using the antenna in receiving mode. Manmade noise is also induced at the coaxial feedline outer shield. When employing feedline current chokes, the noise level will be significantly reduced. Using feedline current chokes on HF low band antennas is a must in my opinion.