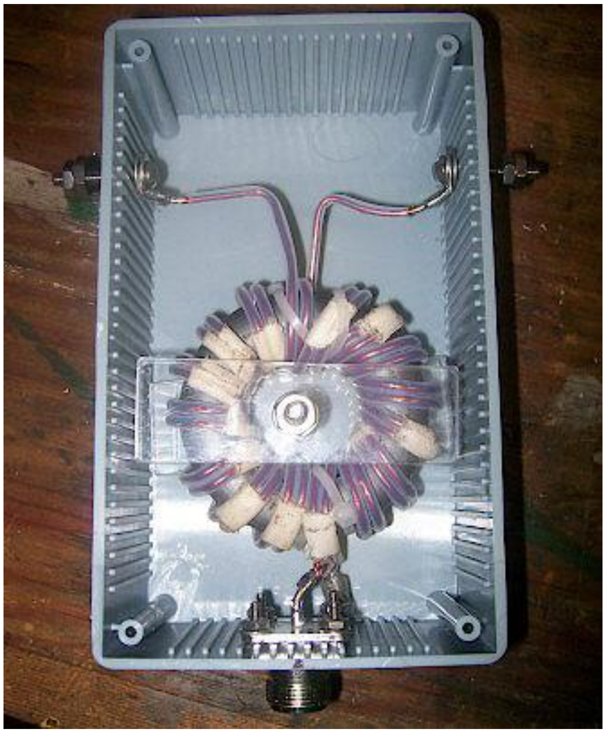
How To Build a 4:1 Current Balun

Written by Bryce Salmi - KB1LQC

This article presents a project to construct a 4:1 (four to one) current balun also known as a "Guanella" balun. The balun I made was constructed in the Summer of 2009 and has been neatly hidden in my engineering notebook since. Antennas are a fascinating aspect of radio and baluns are an integral part to most radio amateurs stations. The term balun "... is a contraction of the words *bal*anced to *un*balanced. It's primary function is to prevent common-mode currents, while making the transition from an unbalanced transmission line to a balanced load such as an antenna"[1] One of my favorite wire antennas is the Off Center Fed Dipole (OCFD) (really a doublet, good topic for another article) for it's solid performance and useful operating characteristics. My balun will be part of an OCFD I plan on having some K2GXT members help construct during the winter along our underground tunnel system as a neat, quick, and fun one meeting side-project.

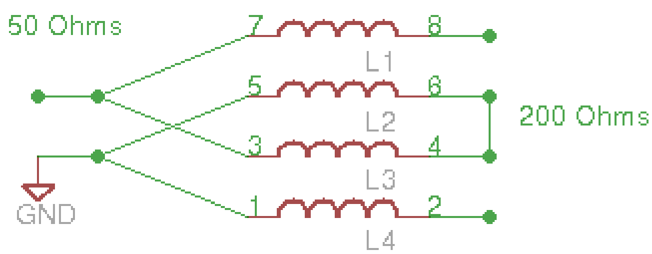


This project can be used for a variety of applications not pertaining to just OCFD's, another popular use is in converting coaxial cable into balanced feed line (200 ohm). Any application where matching 50 ohms to 200 ohms impedance would also benefit from this project. If you have never built a balun before then this might be your invitation to do so. I first built one of these during a local club meeting back in Massachusetts with the Billerica Amateur Radio Society about five years ago. All the transformer parts come in a kit, however you are given the freedom to make whatever style balun that may be of interest.

One thing I would like to stress is that all metal hardware such as nuts, washers, and bolts are stainless steel in this project. Any metal hardware used on antennas should be stainless steel when possible because it will not corrode which helps keep a good electrical and mechanical connection for years. However, you cannot solder to stainless steel which demands other methods of joining the metal such as nuts and bolts.

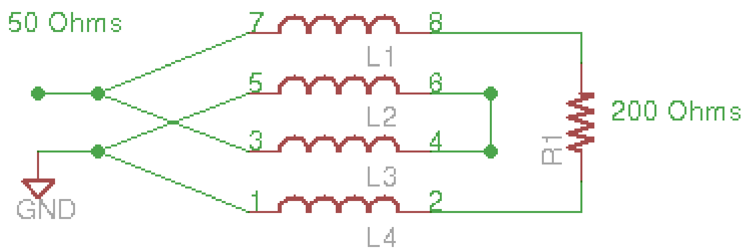
Designing and Building the Balun

The easiest way to start building a 4:1 current balun is to order the



AB240-250 K Mix Balun Kit from Amidon Associates. This kit includes the proper toroidal core, 12.5 feet of #14 magnet wire, 12.5 feet of Teflon tubing, and the Transmission Line Transformer Handbook[2] by Jerry Sevick, W2FMI. Everything you need to build the balun is included including instructions on winding the wire. The current balun I chose to build for my off center fed dipole is the HBM200 on pg. 31 of the Transmission Line Transformer Handbook. With this kit not only do you get to learn more about transmission line transformers but it's hard to beat the price ($25 when I bought mine) when most commercial current baluns can cost several times as much.

The HBM200 can handle 2KW (2000 Watts) of continuous power indefinitely and support peak power levels of 4KW when matched correctly. The largest enemy to toroids comes in the form of overheating which can crack them, rendering the balun useless. This design is engineered by W2FMI to be 98% efficient which means little heat will be created inside the balun during operation. To properly match the 50 ohm coaxial cable to the feed-point impedance the balun performs the 4-to-1 transformation 50 ohms * 4 = 200 ohms and the opposite for receiving which converts the 200 ohms to 50 ohms.



Winding the Toroid

The most dreaded part about building a balun is winding the transformer. To be honest I used to avoid building an electronic circuit if it had a toroidal inductor in it that I had to wind, they scared me.

 It also wouldn't be surprised if I wasn't the only one to be intimidated, then again, I'm in for a surprise every now and then! There is a nifty trick to make winding toroids much easier. To count windings on the core you *only count the windings that go through the center*, it looks like a donut so in all reality it's not hard at all. It is also a good idea to label the end of each wire with a small piece of tape or color marking for future reference. I attached small bits of masking tape with appropriate numbers (shown in schematic) on each wire-end once seperated into two wire-pairs with eight ends total. The reader will see how this approach comes in handy further ahead in the article.

The first step to constructing the transmission line transformer is to prepare the wire for winding. Take the magnet wire and slip the Teflon tubing over the entire length, both wire and tubing should be close in length, but may not be exact. Once this is done fold the wire end-to-end and cut at the crease which is obviously the center of the wire. Pair both wires together evenly and secure with electrical or medical tape which also works good, the Teflon tubing is the dielectric, not the tape which is just securing the wires together. Space the tape several inches down the entire length of wire. There should now be roughly six feet of paired Teflon covered wire-pair ready for winding on the toroidal core. The 4:1 current balun uses two bifilar windings each containing eight turns. A bifilar winding simply means that are two wires following each other. Similarly we would use three wires in a trifilar winding, simple eh? Start by leaving about one inch of wire hanging off the end to connect to later. Make one turn through the toroid as tightly as possible, it doesn't matter what direction you wind in whether it be clockwise or counter-clockwise. After making the winding secure with a wire tie to hold the wire in place. For my current balun design I continued to wind a total of eight turns through the center of the toroid. Try to wind them tightly but not overlapping. Fitting all the wire on the toroid is a tight squeeze at best. Leave a few inches off the end to connect at another time and cut the several feet of wire-pair off to use on the other side of the toroid. Half of the toriod should now have wire on it, the other half should still be bare.

With the first winding done, the hardest part is almost over. Take the remaining paired wire and do the same method on the other half of the toroid except this time wind in the opposite direction. For example, if you wound clockwise first now wind counter-clockwise starting from the same end. There should be enough wire to make both windings tightly with a little left over to make connections with. Don't worry about a little overlap near the end of the windings, refer to the pictures for examples of a correctly wound balun. When it's clear that all your handiwork is correct, secure the end of the second winding with a wire tie.

Now we get to solder the wires together to get a functioning transmission line transformer. Following the schematics shown above, which should make sense since we already labeled the wires before winding (I hope you did!), take wire-end number one and connect it to wire-end number five which should be right next to it. Also connect ends four and six together with short wire leads. Ends three and seven are connected together to make the center conductor wire pair for the 50 ohm side. Ends two and eight should be free and are used to connect to the antenna, they should be left long for now. Be careful not to short the wires out on the toroid which will not end well if power is applied, just keep some of the Teflon tubing long enough to protect the end of each wire. I heat-shrinked the exposed solder connections as can be seen and used appropriately sized eye-hole mounting hardware to attached to the stainless-steel screws.

Connecting it all Together

It's time to put the balun down and focus on where to install it. Since my design was going to be outside I needed to consider weatherproofing the balun. I decided that I was going to use an antenna insulator to hang the balun below rather than use the balun enclosure as structural support.

This is convenient because I don't have to worry about the tension the antenna wires will apply when installed while finding an enclosure. I chose to use a Philmore brand plastic enclosure bought at a local electronics shop called "Electronics Plus" in Littleton, Massachusetts (they still exist!). Alternatively, PVC piping can be used just like some baluns on the market that you can buy. However, I have found by experience that PVC tends to be heavy and causes a lot of sagging on the antenna, very undesirable.

The pictures below show how I decided to mount the balun inside the case. It is really important to keep wires on the coaxial cable side of the balun as short as possible. My connection to the N-type chassis mount connector was about 2cm long. The ground connection was made to a screw holding on the connector with a #8 solder lug (eye-hole) and 4-40 screws while I soldered in a small piece of #14 wire to the center conductor since it was accidentally too short, learn from my mistakes and try to avoid that if possible. I use N-type connectors since they are actually 50 ohms and rather weather resistant unlike SO-239 UHF connectors which are well known to not be 50 ohms due to the soldered center conductor and need considerable help weatherproofing. however, this is personal preference in the end.

Attaching the 200 ohm end of the balun to the antenna isn't as critical with length; the wire are now part of the antenna. I had about 6 cm of the wires left so I went up three centimeters and out three centimeters to make the connection with #8 solder lugs attached to the external bolts. This kind-of mimicked where the wire in the antenna should be, though I am confident that this more aesthetic than practical at HF wavelengths. The 8-32 screws used for the antenna connections were installed from the inside out so they could be locked in place with nuts and worked with easier. Three nuts were used per bolt per side.

The balun is mounted securely by being squeezed between two pieces of Plexiglas and a two inch #10 bolt used to position the balun so that the connectors don't have much tension on them. Squeezing the balun in place protects against mechanical vibrations that could crack the soldered connections over time. I like making projects as failsafe as possible; good electrical and mechanical connections must be accounted for. Additionally, the metal bolt does not affect the baluns performance because an ideal balun contains the magnetic field within the toroidal core.

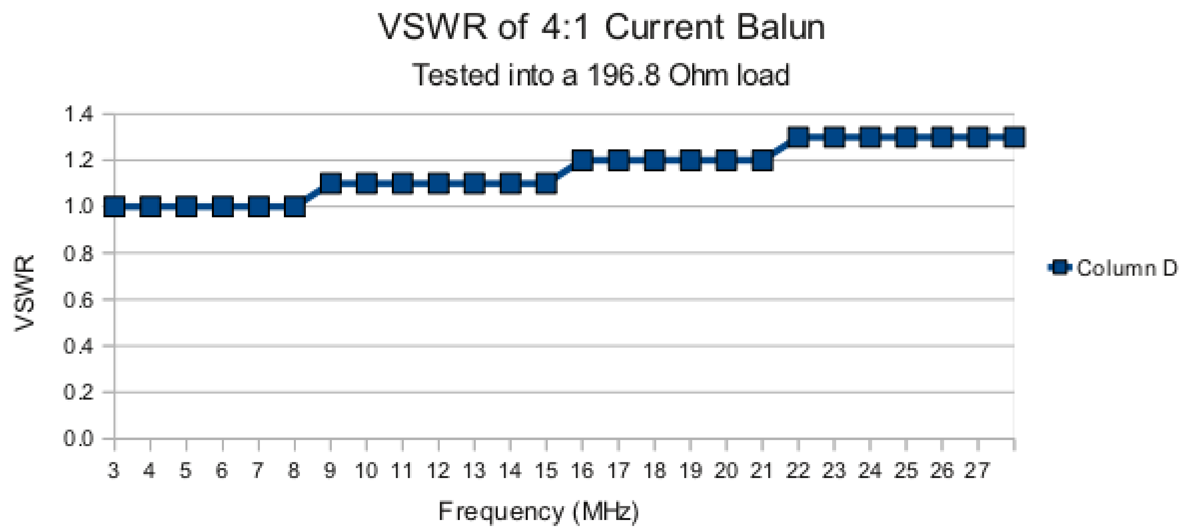
Testing the Balun

The best way to test the current balun is with an antenna analyzer like the MFJ-269 antenna analyzer. While one could hope for the best and just throw the balun on the air, I enjoy testing prior to installation.

Frequency(MHz)	Resistive Z	Capacitive Z	VSWR
2	49	2	1.0
3	49	2	1.0
4	50	2	1.0
5	50	3	1.0
6	51	3	1.0
7	52	4	1.0
8	53	4	1.1
9	54	4	1.1
10	55	4	1.1
11	56	3	1.1
12	56	4	1.1
13	57	4	1.1
14	57	4	1.1
15	58	5	1.2
16	58	6	1.2
17	58	7	1.2
18	58	8	1.2
19	57	10	1.2
20	56	11	1.2
21	56	12	1.3
22	54	13	1.3
23	52	14	1.3
24	51	15	1.3
25	49	15	1.3
26	47	14	1.3
27	45	14	1.3

Testing the 4:1 Guanella current balun is easy to do. Since we are matching 50 ohms to 200 ohms all that really needs to be done is attach 200 ohms across the antenna terminals. The MFJ antenna analyzer doesn't put out much power so two 1/4 watt 100 ohm resistors in series worked fine. For best results keep the connections as short as possible, refer to the pictures for a better idea of my setup.

The baluns' test resistive load measured 196.8 ohms with a multimeter, close enough for me. The total length of the load was about seven inches between the terminals. With RF one must keep connection lengths as short as possible. The table and graph show the resulting VSWR values measured with the MFJ antenna analyzer attached to the 50 ohm connector as shown in many of the photographs. The broadband performance of the balun shows that it's doing its job very well and I was satisfied with its performance of 1.3:1 across the HF spectrum. A VSWR performance of better than 1.5:1 is likely better than other portions of the antenna system such as SO-239 and PL-259 connectors, so I'm not worried about the 1.3:1 SWR at the balun. To further test the balun, connect the ground lead on the coaxial cable side to both sides of the antenna terminals and between the two 100 ohm resistors independently measuring while at each location. If the balun stays relatively stable your in good shape, mine jumped to a 2:1 SWR when doing this which is fine; jumps of SWR greater than 10:1 should cause concern. This is however a rough test so take it in stride.



Final Assembly

This baluns' mechanical design cannot support a large amount of weight or tension alone. I plan on mounting the enclosure by attaching it to PVC, Plexiglas, or fiberglass which in turn takes the tension and of the antenna.

 Some careful thought should also be taken on supporting the weight of the coaxial cable hanging below the balun. Supporting the coaxial cable to take the load off of the Philmore case might end up being crucial. Another consideration would be with the final weight of the balun itself. A heavier balun will cause more antenna sag.

The last step in construction of the balun is sealing it. RV sealant works really well if applied generously. Apply the sealant to the antenna screws by backing them out slightly and working some into the threads, tighten them back afterwards. Seal the eye hook and balun Plexiglass bolt the same way. The best way to weatherproof the N-type connector that I have found is to apply sealant around the edge and over the nuts and bolts generously wherever water can get in. It might be best to let the inside dry before sealing the lid down. The lid on my project box is sealed last with a bead of sealant around the edge of the entire box cover followed by the cover itself and screws to tightly hold the lid down. Some people may prefer to drill a small hole at this time which always faces down allowing condensation inside to drain out but rain to not get in.

Conclusion

This Guanella current balun is practical, relatively easy to construct, and incredibly useful to all radio amateurs wishing to construct a worthy HF antenna such as the off center fed dipole. Antenna performance is considered by many, myself included, to be more important at times than the performance of the radio. A bad antenna system will cause any radio to under-perform. This balun will handle the full U.S. legal limit easily and provides a bit of educational fun during construction. I encourage anyone who finds this article helpful, inspiring, or that may have any questions or corrections to let me know! Email...my call sign at arrl.net. KB1LQC

1: American Radio Relay League. "Coupling the Line to the Antenna." *Antenna Handbook* . Ed. R. Dean Straw. 20th ed. 2005. 26.1-26.28. Print.

2: Transmission Line Transformer Handbook. Jerry Sevick. (You may be able to find this book on the used market or do a search on Google for a download...editor!)