

Fabricating Impedance Transformers for Receiving Antennas

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With the proliferation of local neighborhood noise sources and the growing popularity of wire antennas in configurations other than the inverted L, coaxial cable has become the antenna lead-in of choice for most radio hobbyists. Since the impedance of most commonly available coax is either 50 or 72 ohms and since many wire antennas exhibit impedance of 400 to 1000 ohms or more at the feed point, directly connecting the coax to a wire antenna invites very significant signal losses due to the impedance mismatch. Given this situation in the listening hobbies, it has been a mystery to me why impedance transformers and baluns for receiving antennas have not been more commonly available on the retail market. Further, the few transformers that are available are offered at around \$60.00. While this may be a fair price, considering labor, profit and retail mark-up, *the parts cost for a good weather-tight balun or impedance transformer is well under \$10, paying retail for the parts!* If you own a soldering iron and can make even a semi-reliable connection, you really ought to consider "rolling your own" baluns and transformers. The total labor time is about one hour per unit and the construction is quite simple. Personally, I make mine in front of the TV on Sunday afternoons. Essentially, while making transformers, I'm paying myself \$50 per hour to watch the Dallas Cowboys have yet another terrible season. Not a bad deal, at all.

Selecting Components

You need to obtain some connectors, a weather-tight box, and the guts of the transformer. For the wire connectors, I have come to use the type of binding posts that also accept a banana plug in the top of the post. That way I have several choices of connection methods at the antenna. These parts are all available at Radio Shack. I have fallen in love with one special form of banana plug, though, that is only available from professional parts houses (Mouser #17HR549, #17HR550). The shaft of the male plug has a stiff wire running down it and it makes a VERY reliable connection by actually plowing a shallow furrow in the metal of the female banana socket. The connector for the coax is a normal chassis-mount coax connector of your particular flavor. More and more hobbyists seem to be switching to BNC connectors for their ease of use and better weather characteristics, though only professional-class receivers yet use this type.

Some DXers swear by all-metal boxes for this application. If you fall into this camp, the cast aluminum Hammond boxes are my choice. I buy mine through Antique Electronics Supply (<http://www.tubesandmore.com/>). Those who use metal boxes are usually attempting to maintain the system as RF sanitary as possible, preventing stray signal pick-up by grounding the box, usually to the coax shield. However, the majority of DXers I know, and most manufacturers, use cast plastic enclosures. They reason that the stray signal pick-up is miniscule, compared to the size of the antenna, and let the ease of using the plastic boxes, and their significantly lower cost, make that decision. Personally, if I'm in one of my rare obsessive/compulsive phases, I use metal; if I'm "normal," I use plastic. I've never been able to distinguish between the two designs in actual use.

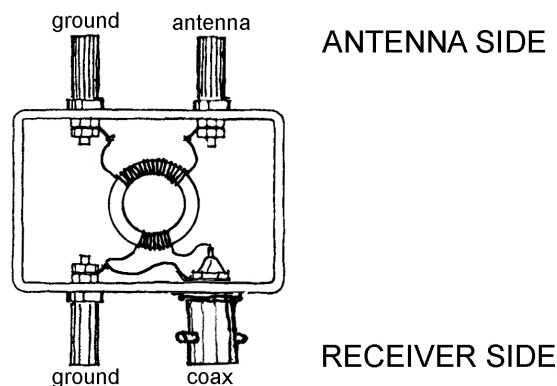
All of the impedance transformers with which I am familiar are based on some sort of ferrite core with windings around it. Several well-known East Coast DXers favor manufactured transformers from Mini-Circuits. and just wire this tiny transformer in the appropriate box and add connectors. The very small 9-to-1 Mini-Circuit transformers are perfect for converting the 450 ohms of beverages and many other wire antennas to 50 ohm coax. I used these small units for several years, before swearing off them entirely. DXing on the prairies North America generally exposes wire antennas to a good bit of static electricity. Both Bill Bowers and I had several random failures of the Mini Circuits units, probably due to the hair-small wire used to wind the transformer. The main problem was that the failures were often partial, making us think - for several nights running - that conditions were really bad. What a waste! After the third such failure, I returned to the tried-and-true "roll your own" techniques based on relatively larger ferrite toroids. These techniques were originally taught to me over a decade ago by Nick Hall-Patch, Technical Editor of IRCA and published in a co-authored article in Fine Tuning's *Proceedings 1988*.

Once the decision is made to roll your own using ferrite toroids, there are just two decisions left: the size of toroid and the specific ferrite mix to be used.

In North America, at least, most of us use the toroids from Amidon. These may be purchased over internet directly from the manufacturers representative at (<http://www.bytemark.com/amidon/>). I've used three sizes of cores over the years. The smallest that I have used is a 1/2" diameter toroid (Amidon's FT-50) which looks like a half-eaten Life Saver candy. To get the proper turn count through the donut hole, you must use very fine magnet wire and a large needle. I found the whole operation overly fussy and I was also concerned about static electricity burning the hair-thin wires. I saw no advantage in using cores this small and I don't recommend them now. The largest toroids that I've used measure 1.4 inches in diameter (FT-140.) These work great, but they are a little heavy and expensive for my taste. **I recommend the middle size, 1.14 inch diameter donuts which are large enough to handle easily and I use 30 gage insulated wire from Radio Shack (# 278-501, 502 or 503) for the windings.** This wire is small enough to make a neat close-wound coil of the proper turns-count on the toroid and yet the wire is large enough and stiff enough to be easy to handle.

The Amidon web page has a great deal of technical data to assist you in selecting the proper ferrite material. However, all of that stuff is rather arcane and will take you a while to wade through. What it comes down to is this: **if you want to work from .5MHz to 30 MHz, select "Type 43" material. This material also gives "reasonable" performance on LW. If you are certain that your interests are limited to LW, MW and Tropical Bands (.2 to 15 MHz), then "Type 75" ferrite is what you need.**

If you've followed me this far through this technical thicket, it's probably time to take a break. Lets hunker down in the shade and let me scratch out an illustration to show you where we are headed:



CALCULATING THE TURNS COUNT

Lets calculate the turns count for impedance matching a beverage antenna with an impedance of 450 ohms to 50 ohm coax. Because this is a step-down transformer, the primary (attached to the antenna) will be the larger winding and we'll deal with that first.

The first formula to use will give us the desired inductance of the primary winding:

$$\text{desired } L \text{ of winding} = X_L / 2\pi f$$

where L = Inductance in millihenries X_L = Reactance in ohms f = Lowest frequency of operation in kHz

X_L may be found by multiplying the impedance of the antenna to be matched by a factor of 4. This X_L would be 4 x 450 ohms or 1800 ohms. To make things easy, lets use 500 kHz. as our lowest frequency of operation.

So, L of the primary winding = $1800 / 2 \times 3.1416 \times 500$ or .573 mH

Now that we know the inductance (**L**) needed for the primary winding, we can apply the following formula to determine the number of turns needed for the primary winding.

$$N = 1000 \sqrt{L/A_L}$$

In narrative, this formula should be read: Number of turns required (**N**) is equal to 1000 times the **square root** ($\sqrt{}$) of the Inductance (**L**) divided by the constant **A_L**.

The constant **A_L** is determined from the Amidon technical literature and takes into account the RF qualities and the size of a Type 43 toroid that is 1.14 inches in diameter. The **A_L** for the FT-114-43 is **603**.

So, working the formula above, **N** = 1000 $\sqrt{.573/603}$ = 1000 x .030825 = **30.8 turns, use 31**

The turns count for the secondary winding (connected to the coax) may be determined by the same method or by knowing that the impedance ratio of a transformer is the turns ratio squared. We are trying to get from a 450 ohm antenna to a 50 ohm coax, so the impedance ratio is 9 to 1. The turns ratio must then be 3 to 1... so, the secondary winding is **10 turns**. Working it out with the formula yields 10.2 turns.

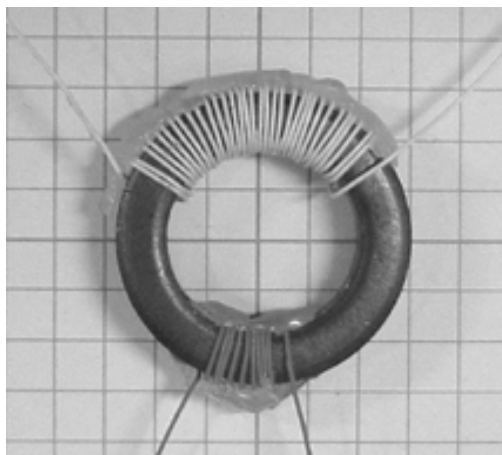
By golly, we have waded clear through the technical thicket. Burn any blood sucking leeches off your arms and legs, rest up in the shade for a while and pop a cool one. You deserve it!

If you want to match one of the currently popular delta or pennant antenna designs, determining the turns count follows the same process. The impedance of pennants and flags is somewhat dependant on the size of wire used and the height above ground. Most seem to fall in the range of 900 ohms to 1000 ohms, so a 950/50 (or 19-to-1) step-down transformer would probably work well for most of this type antenna. The same process as that above can be used to determine the turns count. To save you the effort, here is a chart of turns counts for both Type 43 and Type 75 Material

**Turns Counts
Based on FT-114 Amidon Toroids**

Antenna Type	Antenna Impedance	Ferrite Type	Primary Winding	Secondary Winding
Beverage	450 ohms	43	31	10
Beverage	450 ohms	75	13	4
Delta	950 ohms	43	45	10
Delta	950 ohms	75	20	5

The windings should be placed on the toroid in a "close wound" fashion, with the primary and secondary windings spaced as far apart as possible on opposite sides of the donut.



TYPICALLY WOUND TOROID WINDING

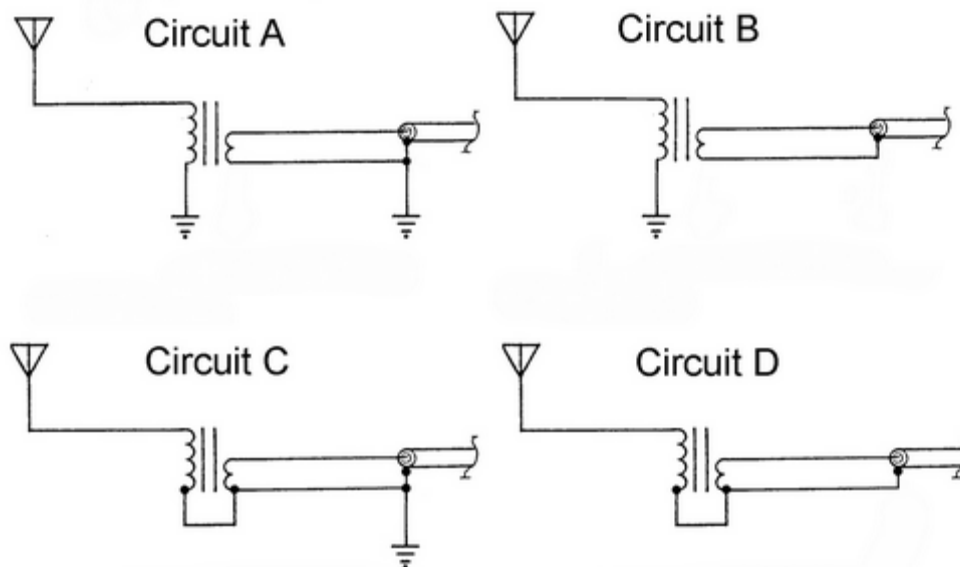
note the series of hot glue dots on the edge of each coil. I use this strategy to keep the windings in place.

IN USE

About all that we have left to discuss is various arrangements for placing the transformer between your antenna and coax. Unfortunately, it is at this point that we leave the world of science and begin to deal with sorcery. It turns out that there are a lot of ways to hook these things up, and most of the controversy centers on various grounding schemes. There are two main circuits to discuss:

SINGLE WIRE ANTENNAS

There are three or four choices of circuit arrangements here and the best one for your application probably should be determined by careful experimentation. The "scientifically superior" arrangement is probably that shown here as "Circuit A." The second side of each of the coils is connected *separately* to ground. Signal current and static electricity flows from the antenna through the larger coil directly to ground. Current between ground and your receiver is induced into the smaller coil. The main argument against Circuit A is that individual grounds must be separated by at least 12 to 15 feet to be electrically separate, or so I've read. Due to connection through the ground itself, what is probably being accomplished, electrically, with Circuit A is actually Circuit C. Circuit B is the one that Nick Hall-Patch has used with excellent results for years. Grounding of the coax shield, if any, is accomplished at some distance from the transformer.



Circuit C recognizes the problem of possible interaction between the two "separate" grounds and simply connects the grounded side of both coils and the coax braid to a *single* ground at the antenna feed point. This is the circuit that I use when the feed point of the antenna is within three or four feet of the ground and the grounding conditions are good. After writing this article and having Nick pound his approach through my thick skull yet one more time, I think I'll be switching my approach to Circuit B.

Circuit D is the arrangement that the "magnetic balun" manufacturers normally use. The grounded sides of the coils are connected together and hooked to the braid of the coax. The grounding that is so vitally necessary for signal flow is accomplished through the coax braid and left totally to the user. This is the circuit that I use for random wire antennas and I ground the braid at least once between the antenna and the receiver. I will confess, though, that I've used Circuit D with good success on occasion with an ungrounded coax and an ungrounded receiver. I know that I'm taking a chance with static electricity build-up, and I wonder whether all of the signal energy is reaching my receiver; but there you are: my guilty little secret.

LOOPS

Luckily, with loops like the KAZ delta, etc., things are fairly straightforward. The larger coil of the transformer is connected directly (in series) into the loop. One side of the smaller coil is connected to the center conductor of the coax. The other side of the smaller coil may be connected to the coax braid, may be grounded, or both. If the loop feed point is within a foot or so of the ground, it is probably best to ground the second side of the smaller coil. However, if you have a poor grounding situation, or the feed point is in the air, the smaller loop ought to just be connected to the coax braid.

CLOSING REMARKS

About the only issue left to mention is physically attaching the transformer to the interior of the box. I'm rather sure that most constructors will have a favorite method. Mine is to simply hot glue the transformer securely to the plastic box. In some cases, I have even totally encapsulated the transformer in hot glue. I have sometimes wondered if I wasn't somehow affecting the magnetic qualities of the transformer with the hot glue. Bill Bowers has run some quite sophisticated bench tests concerning this and assures me that the qualities of the transformers are unaffected by hot glue.

Well, there you have it. For those of you interested in making \$50.00 per hour rolling your own matching transformers while watching your favorite sports franchise get blown away yet again, order some cores, make a quick trip to Radio Shack or your junque box and HAVE AT IT. May the forces (magnetic) be with you!