Designing an Off-Center-Fed Dipole Matchbox

Impedance Transformers

There are many multi-band antennas designs: fan dipoles, trap antennas, end-fed half-waves, etc. Another example of multi-band antenna is the off-center-fed dipole. Instead of being fed in the center like a traditional dipole, this antenna is fed such that one leg of the dipole is longer than the other. Most commonly the offset is chosen such that the impedance at the feedpoint is approximately 200 ohms. In order to match this 200 ohm impedance to 50 ohm coax an impedance transformer is used.

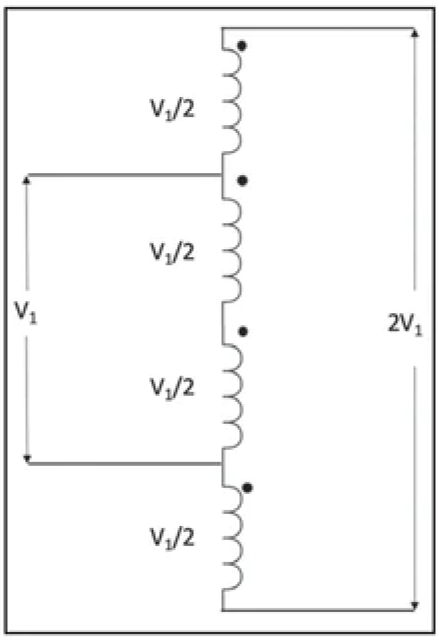


Figure 4. Schematic of 4:1 balun.

One of the most common designs for a 4:1 transmission line transformer is the Guanella balun. This design consists of two 1:1 chokes wired in series. This creates a 2:1 voltage ratio which translates to a 4:1 impedance transformation. This type of transformer can be assembled in two different ways: both chokes wound on the same cores or two individual single core chokes wired in series.

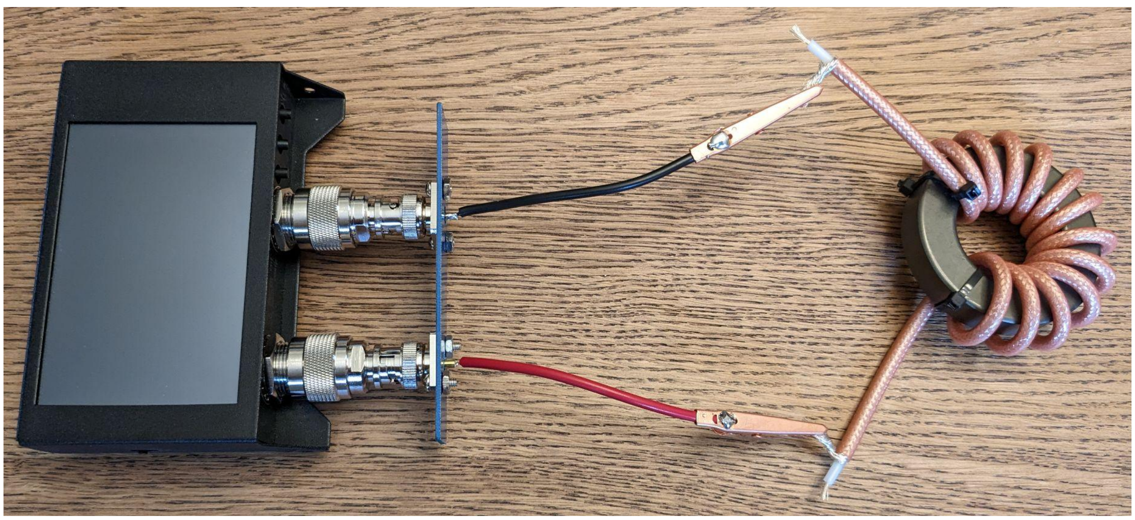
In order to compare the various designs, I wound multiple versions of the transformer using Type 43 ferrite toroids and 18AWG silicone insulated wire pairs. To test the transformers I placed a 200 ohm resistance across the secondary side to simulate the antenna and connected the primary side to Port 1 of a NanoVNA. I then performed complex impedance and SWR sweeps from 3.5 to 30 MHz. When comparing the data I found that they all performed similarly and did a good job of converting the 200 ohm load to approximately 50 ohms.

For the purposes of building a matchbox for use with an off-center-fed dipole I decided that a single core design using 10 Turns of wire for each 1:1 choke was the best option since it produced excellent transformation (49 - 54.4 Ohms), had the flattest SWR (1.15:1 maximum), and only uses one FT240-43 toroid. The primary limitation of this design is that it provides very little common mode choking. Common mode choking is a requirement with any off-center-fed antenna due to the different antenna leg lengths which results in mismatched currents in each half of the antenna. To resolve this the matchbox will incorporate a separate common mode choke in series with the 4:1 transformer.

Common Mode Chokes

Preventing common mode current from flowing on your antenna system feedline helps reduce RFI and noise issues inside your shack and prevents your feedline from radiating. A lot can be found in books and online about how to make an RF choke and there are many commercial products available, but which of these actually work and are appropriate for your application?

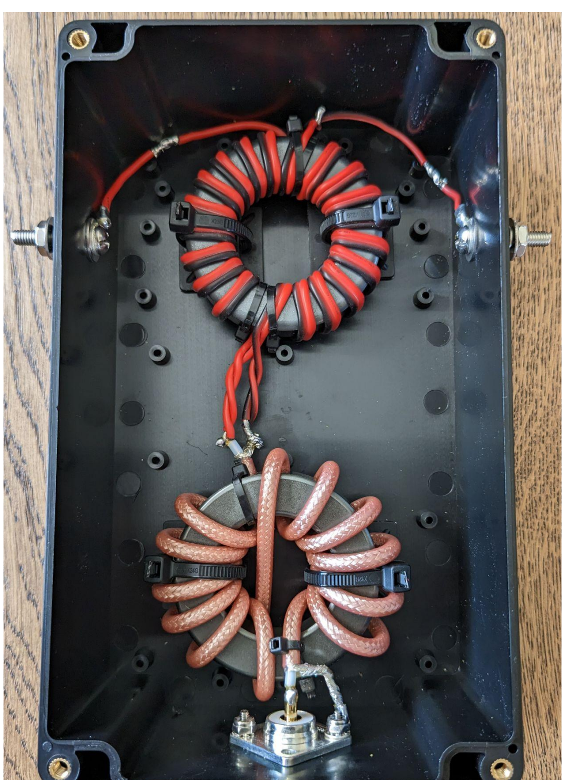
To measure the common mode choking ability of an RF choke we need to measure the reduction in signal strength through the choke. This can be done with a NanoVNA by sending a signal from Port 2 to Port 1 via the coax's shield and measuring the S21 LogMag & Phase data for a given frequency range. Sweeps using this method produce a reading in dB that shows the total magnitude of signal loss (LogMag) through the choke and a phase angle measurement that tells us how much reactance is present due to the choke being inserted into the path between ports 1 & 2. This is important because the reactance could either add to or cancel with the phase of the common mode current. Because of this, when comparing chokes we only look at the resistive portion of the impedance. This value is computed using the LogMag & Phase readings.



As part of this experiment I tested several different choke designs using different ferrite core materials, wire types, winding techniques, and numbers of turns. The results from this were very interesting and confirmed measurements made by others (see references below). Based on these results I drew the following conclusions:

- The best material for broadband choking on HF is type 31 ferrite. Type 43 ferrite can offer very good levels of choking, but only over a much lower frequency range.
- Coiling coax by itself does not result in a very good choke on HF. In fact, it offers very little choking at all.
- Snap-on ferrite beads increase choking fairly linearly (2 beads are twice as good as one, etc.), but you need A LOT (dozens) of beads to achieve a high level of choking.
- Using coax for winding a choke gives the best results both in maximizing the amount of choking per turn and in minimizing the effect that the choke makes to your feedline's impedance & SWR vs using wire pairs.

- Good quality Teflon coax (RG400 for QRO, RG316 for QRP) is recommended due to its robust physical construction, better shielding, and higher temperature tolerance. It is more expensive, however, you only need a few feet to make a good choke, so the total expense is minimal.
- For FT240-31 toroids (QRO Chokes):
    - 13 turns of RG400 provides at least 4000 Ohms of choking from 80 to 17 meters (5400 Ohms peak) and 2700 Ohms on 10 meters.
    - 12 turns of RG400 provides over 4500 Ohms of choking from 40 to 10 meters (5200 Ohms peak).
- For FT114-31 toroids (QRP Chokes):
    - 12 Turns of RG316 provides over 2500 Ohms of choking from 80 to 10 meters (4700 Ohms peak).
    - 11 Turns of RG316 provides at least 3200 Ohms of choking from 40 to 10 meters (4300 Ohms peak).



Combining the 4:1 transformer with the 1:1 choke creates the optimal matchbox for an off-center-fed dipole. The transformer turns the 200-ohm feedpoint impedance into approximately 50 ohms to match with our feedline and radio. The choke prevents excess common mode current from flowing down the feedline and causing problems in our station. The end result is a versatile multi-band antenna option.

References:

- RF Choke Cookbook (K9YC) - http://k9yc.com/2018Cookbook.pdf
- Amateur Radio Common-mode chokes (G3TXQ) - http://www.karinya.net/g3txq/chokes/