N6LF 630m Transmitting Antenna Version 2

July 2017

Introduction

When I first erected my 630m transmitting antenna in 2013 I used 128 150' radials (≈20k') lying on the ground surface. To save money (lots of $!) and because my soil is nearly neutral I used aluminum electric fence wire. Several times a year I mow my fields passing over the radial system. Over the years I found very little corrosion but the weight of the tractor and the mowing action broke a number of the radials, enough to make me wonder if a counterpoise (CP) might not be more practical.

Counterpoises have a long history at VLF-MF and are generally noted as being very efficient. Besides efficiency an advantage of a CP is a lot less wire than typical ground surface/buried systems. The disadvantages are mechanical stress due to ice loading in winter and very high voltages (kV!) to ground even at modest power levels which is a safety hazard. High voltages mean the wires must be kept out of reach, elevated at least 7'-8'. If you elevate the vertical itself along with the CP wires then there is little effect on radiation resistance but in my case the height at the top was fixed at ≈95' so the 8' has to come off the length of the vertical reducing Rr. Rr varies as the square of the length so lopping off 8' reduced my Rr by about 16%. This reduces efficiency but after some modeling it looked like the increase in efficiency using a counterpoise might more than compensate for this. After much modeling and agonizing I decided to give it a shot and what follows is a description of my new antenna, which is really the old antenna with a different ground system. In the discussion I will try to address some of the problems, one of which is the need for an isolated feed system. As I'll show I chose a particular solution but I also want to show some of the alternatives to provide a more general discussion of counterpoises.

One note, this antenna is certainly a candidate for 2200m operation but for the present I'm only concerned with 630m. No doubt in the future I will retune for 2200m!

What's a counterpoise

I think it's important to define what I mean by a "counterpoise". Many of us are accustomed to elevated ground systems for 40m-160m verticals where the radials are very close to λ/4 long and resonant or nearly so. On 630m λ/4≈500' and on 2200m λ/4≈1800'. Very few amateurs will have the space or even the inclination to use such lengths. Typically the radial lengths will be much less, not even close to resonance. A counterpoise is often referred to as a "capacitive" ground system because the wires act mostly as capacitive loading. The CP can be relatively complex like the example shown in figure 1 which was used for the initial amateur transatlantic tests in 1921-22.

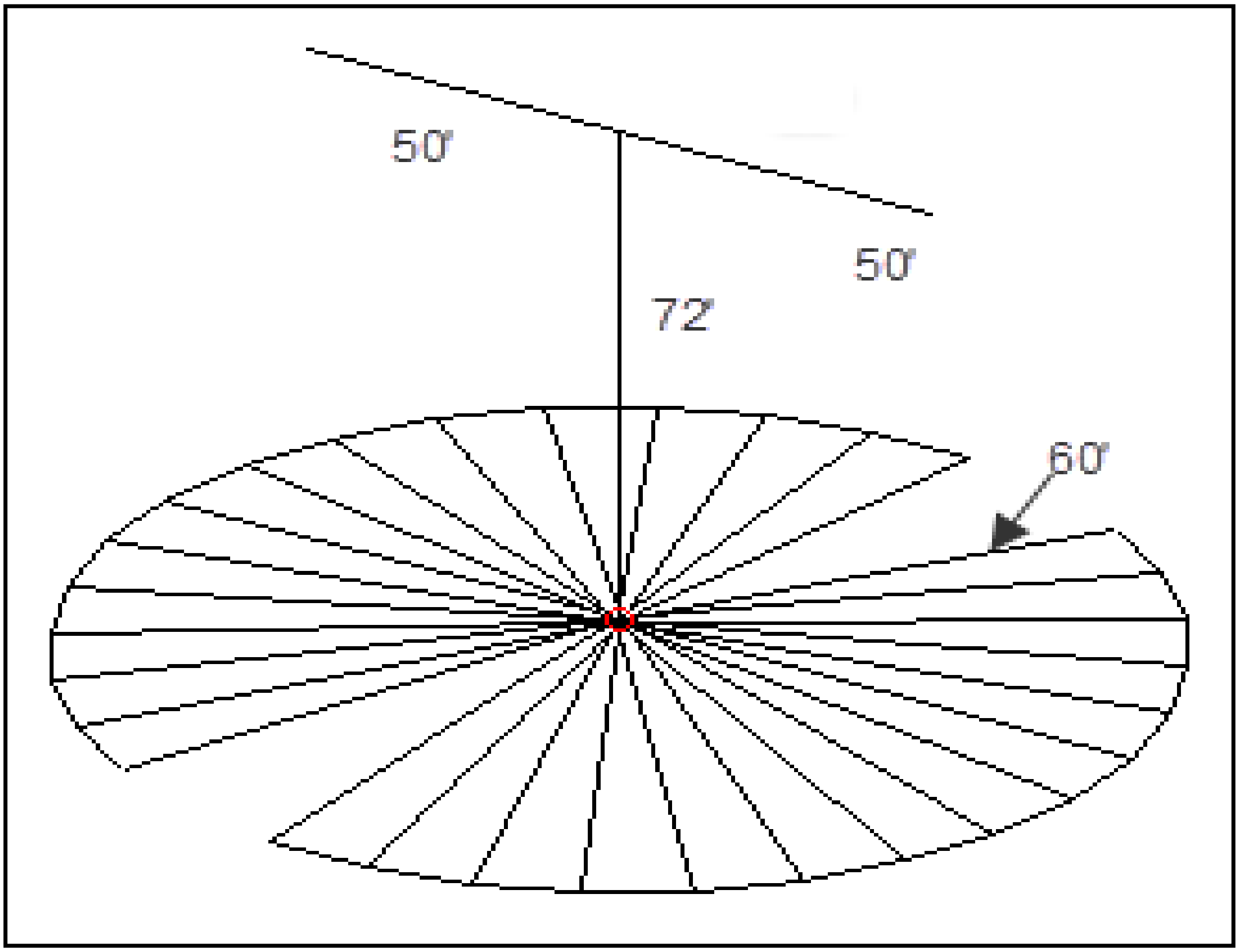

Figure 1 - EZNEC model of the 1BCG antenna.

The CP doesn't need to be that complicated, it can be as simple as a single wire like that shown in figure 2. What we have is a vertical wire of some length, usually much less than λ/4. To help resonate the antenna we add a horizontal top-wire(s) to provide capacitive loading. At the bottom we add a similar wire which we call the CP but that's a bit misleading. The whole system of wires, vertical and horizontal is the antenna which happens to be close to ground. What we have is simply a large capacitor which will radiate if excited. The capacitance has two components: between the top-wire and the CP (C1) and from the top-wire, the vertical and the CP to ground (Cg). Currents flowing in the soil via Cg result in ground loss. the larger we make the CP the small Cg will be. Once we have as much vertical height, top-loading and CP the antenna will probably still not be resonant so we have to add a "tuning" or "loading" inductor (L).

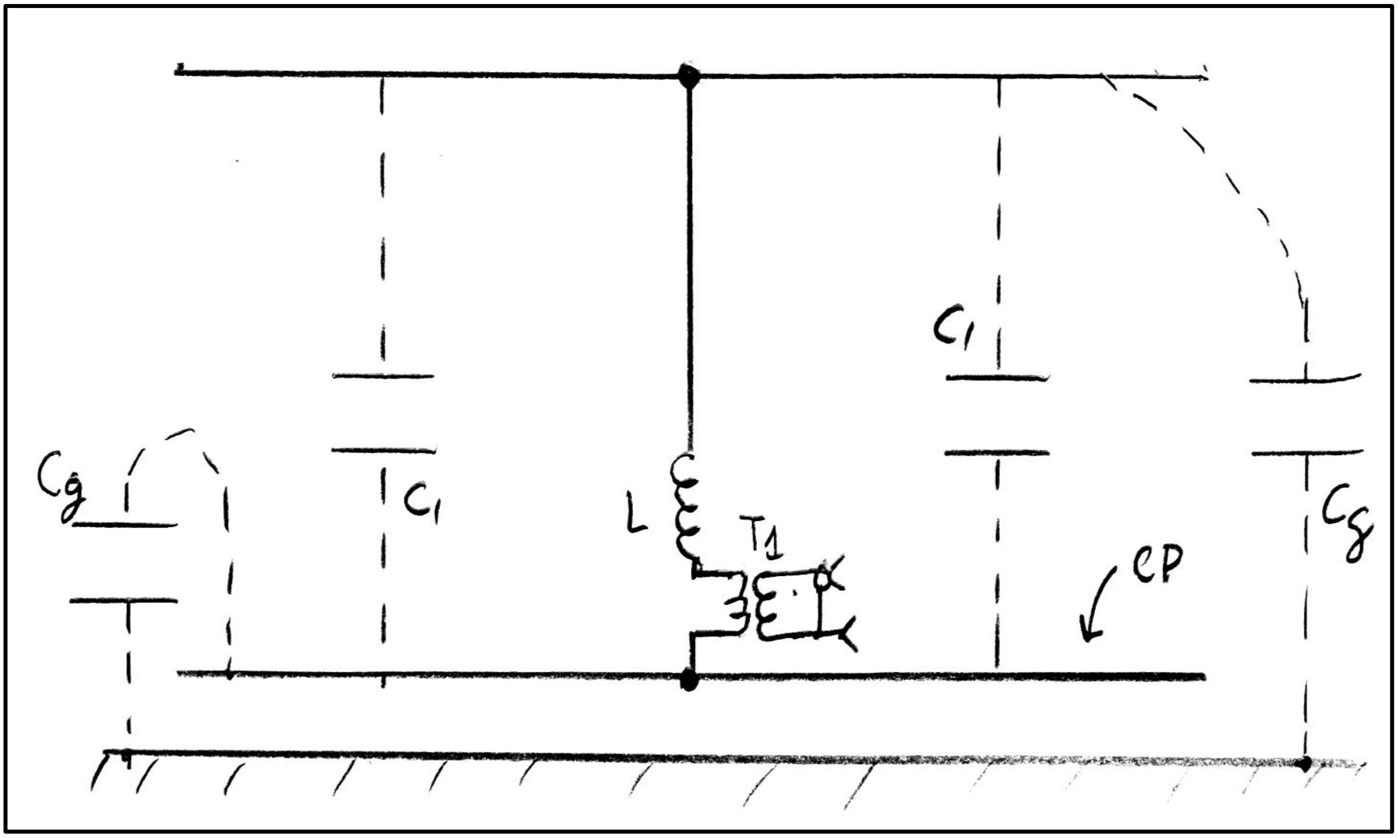

Figure 2 - Short top-loaded vertical with a single wire counterpoise.

We have one more problem: the feed/matching network has to be isolated for several kV from ground! This problem is indicated by T1 in figure 2. There are many different options so T1 just serves as a reminder of the need for isolation. A later section discusses options and my particular solution.

New antenna description

I have installed five support poles (80'-95') arranged in a square with one pole in each corner and one in the center as shown in figure 3. As shown in figures 4 and 5, the antenna is four identical wire antennas connected in parallel at the feedpoint. Figure 4 represents one of the four elements. Wire 1 is vertical (≈82' long). Wires 2 and 3 form a top-wire connected to the top of the vertical. Wire 2 extends radially out to one of the corner poles and then wire 3 extends from that corner pole to another corner pole. The counterpoise wires (4 & 5) are the same as 2 and 3 only connected to the bottom of the vertical. As shown in figure 5, the element in figure 4 is repeated four times to form the final antenna. Although the modeling indicates the use of four sources, in the actual antenna all of the vertical wires are connected at the bottom and all of the CP wires are connected at the center point to form the feedpoint.

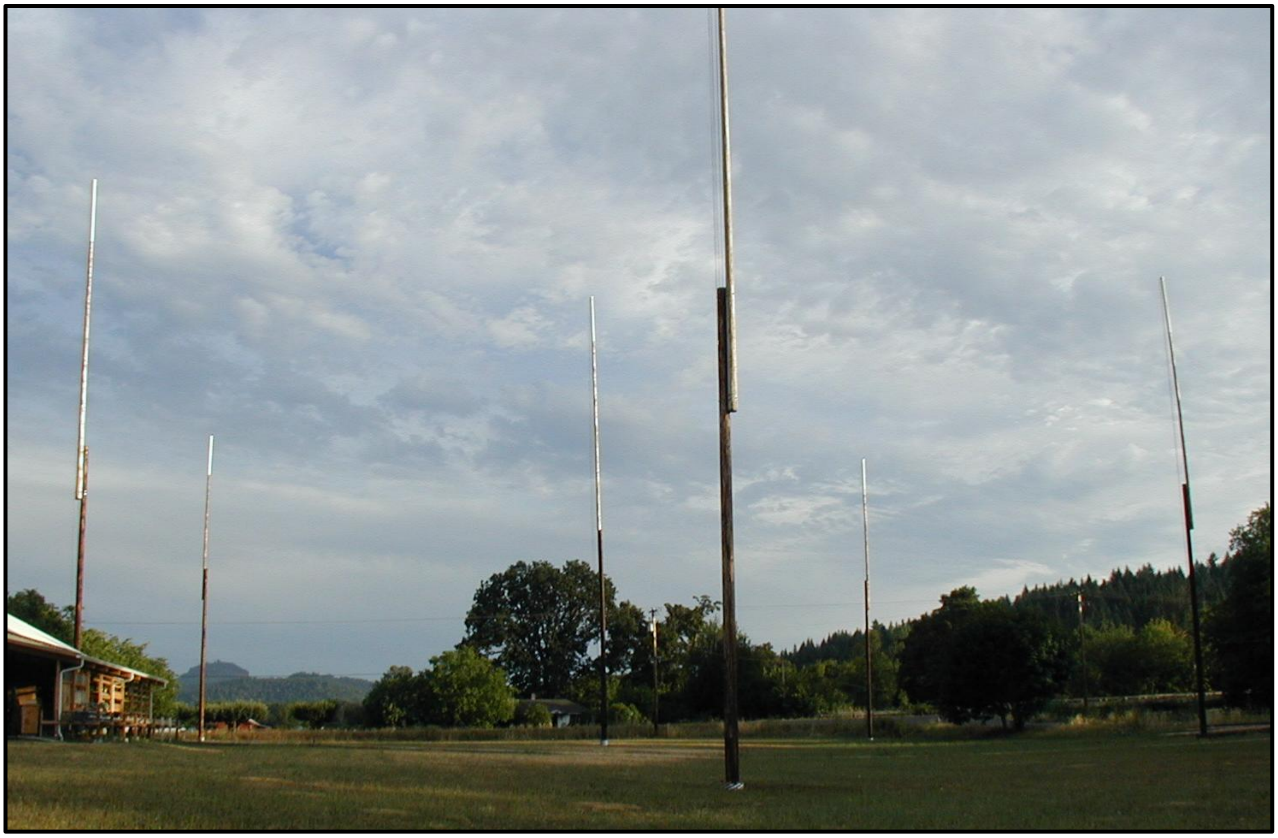

Figure 3 - Photograph of antenna support poles.

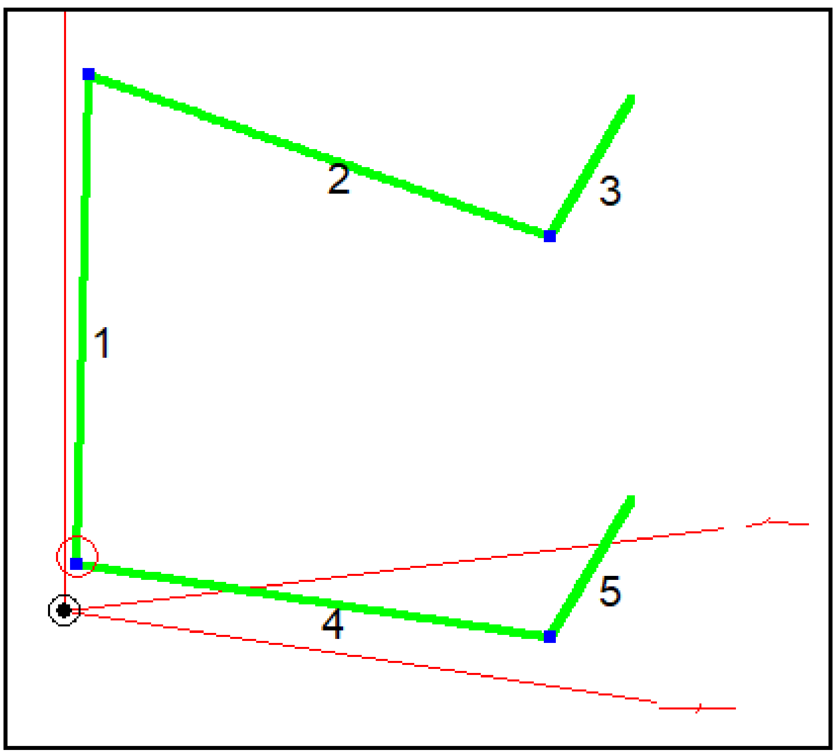

Figure 4 - One of the four antenna elements.

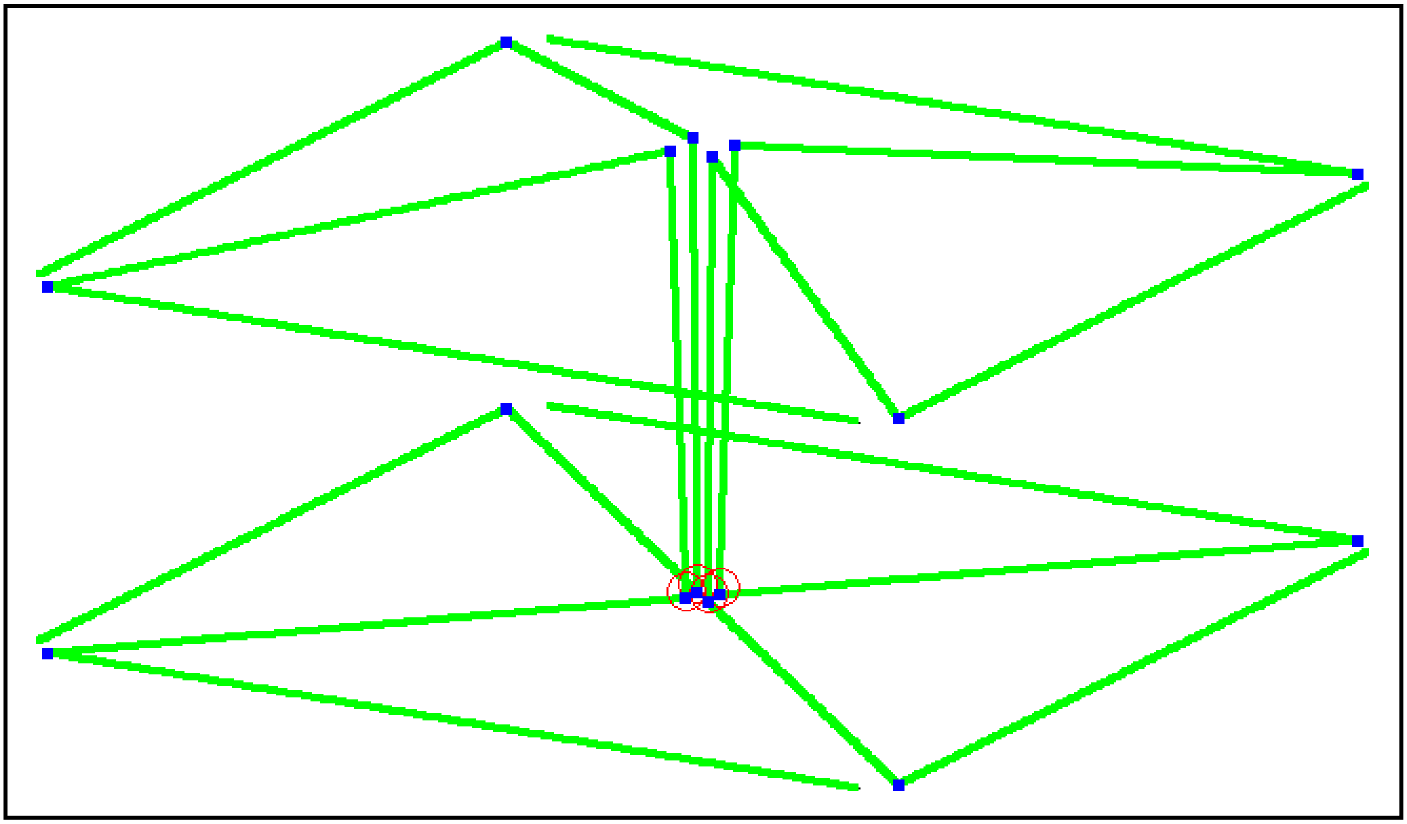

Figure 5 - EZNEC model of complete antenna.

The wires from the center post to the outer posts are ≈117' long. The wires between the outer posts are ≈165' long. For the wire I used #14 aluminum electric fence wire. The conductor loss is higher when using aluminum versus copper but there are some good reasons to use the aluminum. First of course it's a lot cheaper but more important it's appreciably stronger and lighter (for the same wire size) which will help when ice loading is present. Aluminum has drawback besides higher resistivity, it's not easy to reliably solder. For this reason (referring to figure 4) wires 1, 2 and 3 are a single wire with no joints. Wires 4 and 5 are also a single wire with no joints. The only mechanical connections are at the feedpoint ends.

Figure 6 is a photo of the base of the center pole showing the tuning/matching unit enclosure (a plastic garbage can!). There are two long PVC pipes which serve to hold the bottom of the vertical wires away from the pole. Without these the vertical wires ten to wrap around the pole when the wind blows detuning the antenna!

Figure 7 provides a closer look at how the vertical and CP wires are brought in to the pole and then fed down to the tuning unit at the base. Because the feed wires must be kept separate and untangled from the halyard lines (black lines), they are brought down in four separate PVC tubes. The CP anchor points are 9' above ground. 8' is sufficient height for safety but we have to keep in mind that the CP wires are quite long, 120'-180', and require substantial sag to allow for ice loading. The wire ends at the poles were then set at 9' with a maximum sag of 18" so the closest distance to ground for the CP wires is ≈7.5'.

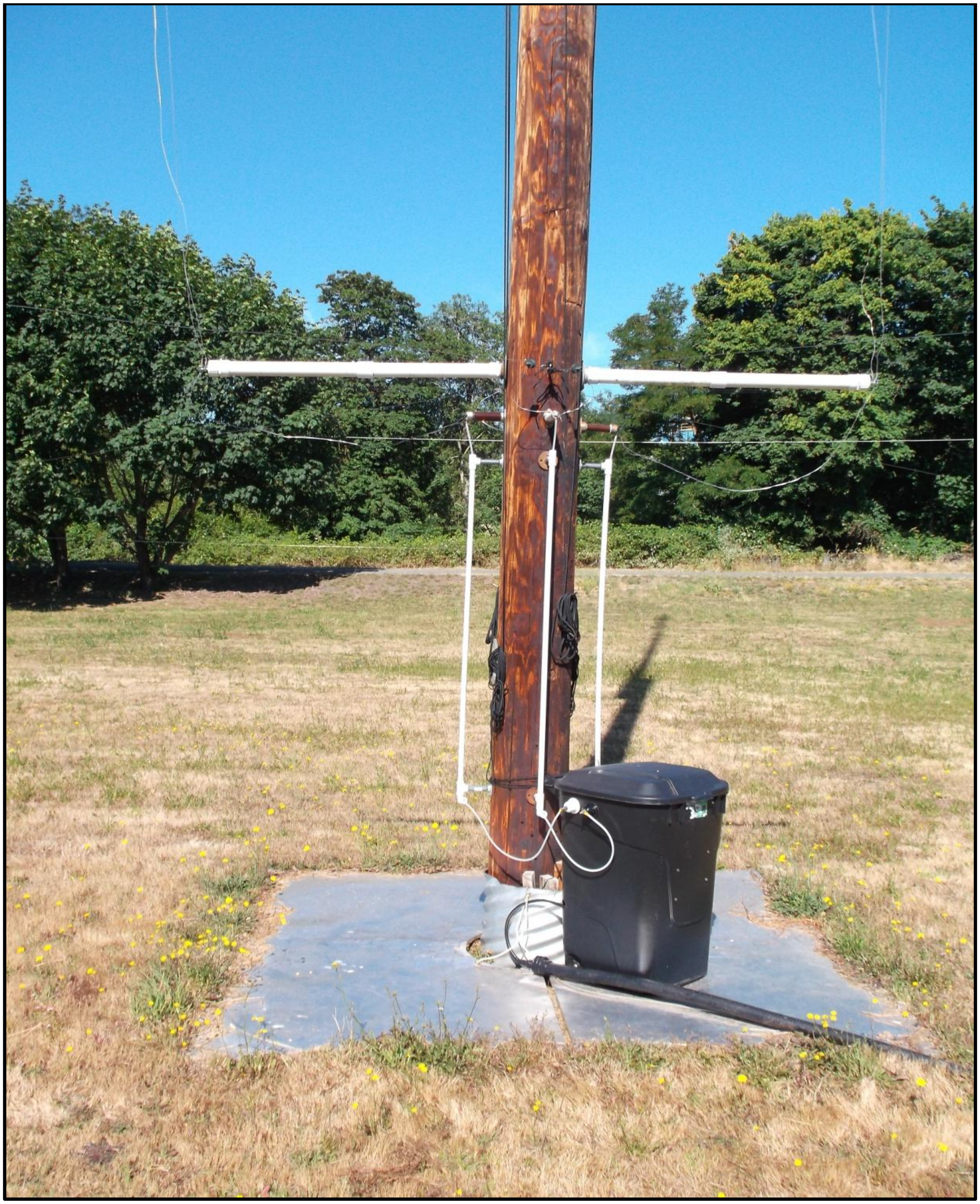

Figure 6 - Base of the center pole showing the matching/tuning unit.

Figure 7 - More detail on the mechanical arrangements.

Tuning, matching and isolation

The antenna feed has to be decoupled (isolated) from ground but still provide a ground referenced 50Ω feedpoint for the transmitter. The scheme I used is shown in figure 8.

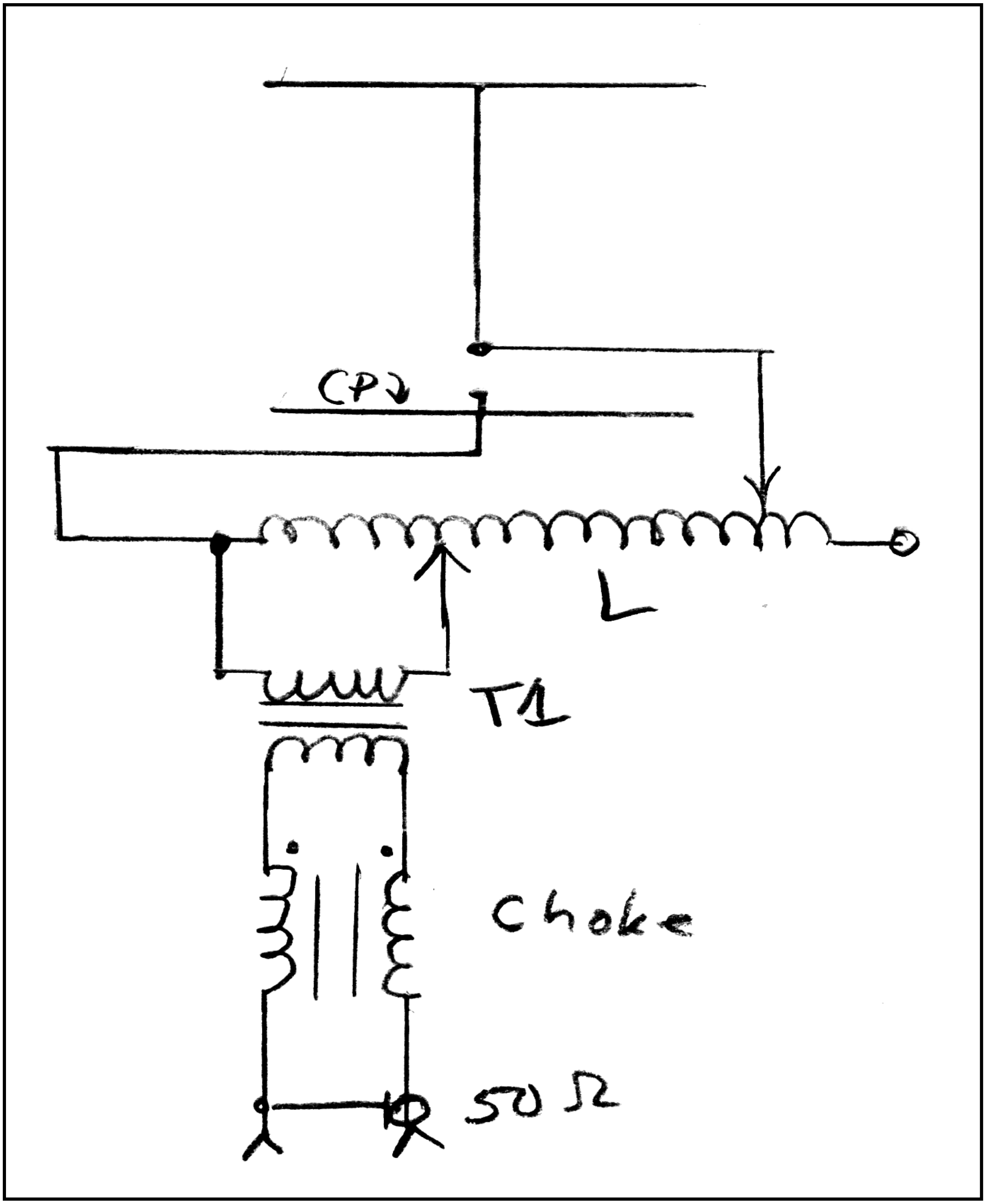

Figure 8 - N6LF matching-isolation scheme.

My inductor (L) is actually two roller inductors in series but one could also use a single inductor with taps to accomplish the same end. One inductor is adjusted to resonate the antenna and the other is adjusted to provide 50Ω across the "tap". HV isolation is provided by T1 which has ten turns for RG8X wound on a stacked pair of 2.4" FairRite type 77 material ferrite cores (Mouser P/N 623-5977003801). The physical arrangement is shown in figures 9 and 10. T1 has a 1:1 turns ratio. The center conductor forms the secondary winding which is connected to the antenna. The shield forms the primary winding which is connected to the UHF jack and then connected to the feedline back to the transmitter. From the coax used for winding there is ≈50pF of primary-secondary capacitance (≈6700Ω @ 475 kHz). The purpose of the choke shown in figure 8 is to help isolate this parasitic capacitance. However, I ran out of suitable cores so the choke is not present figure 10. The cores are on order!

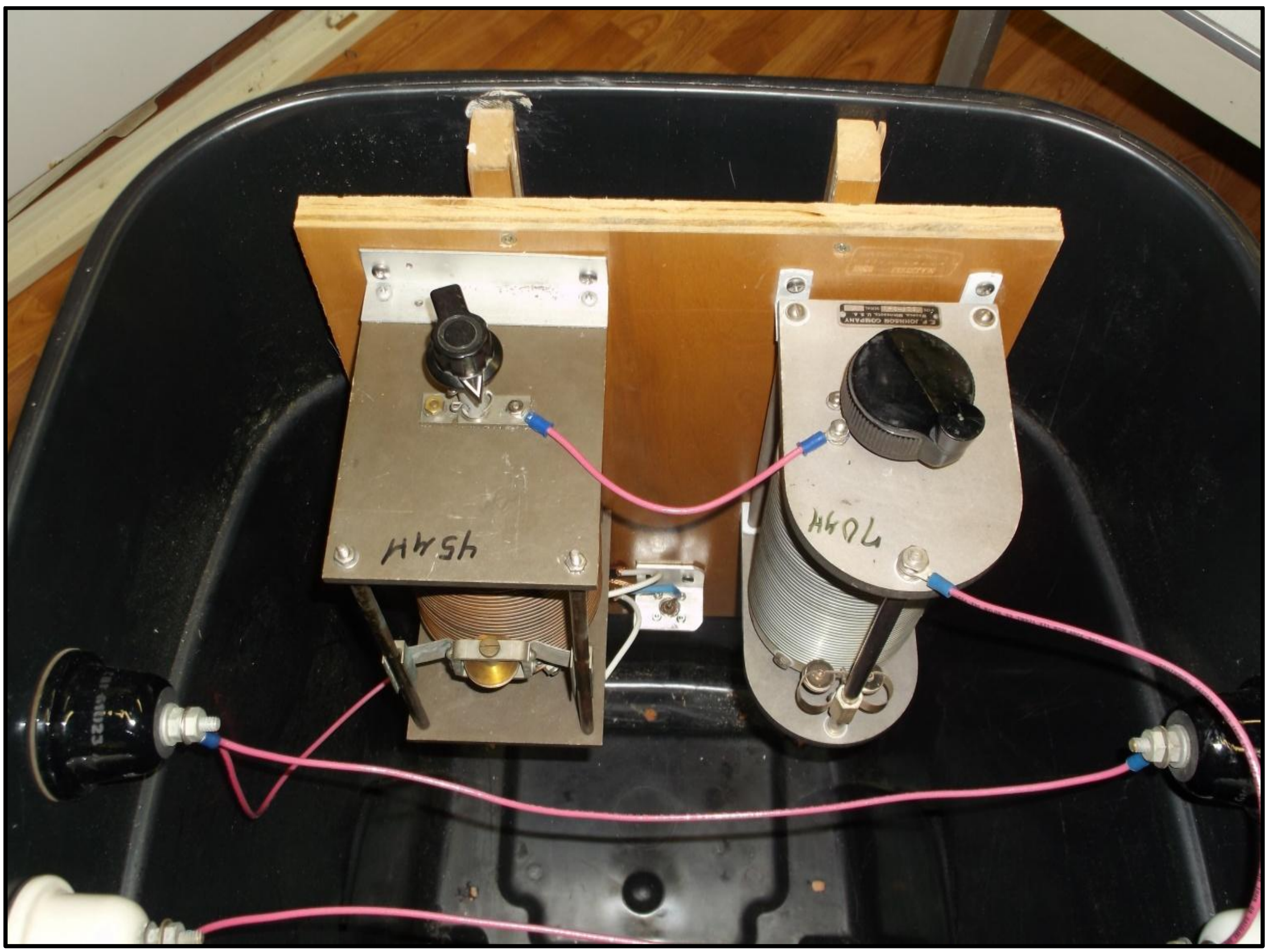

Figure 9 - Roller inductors.

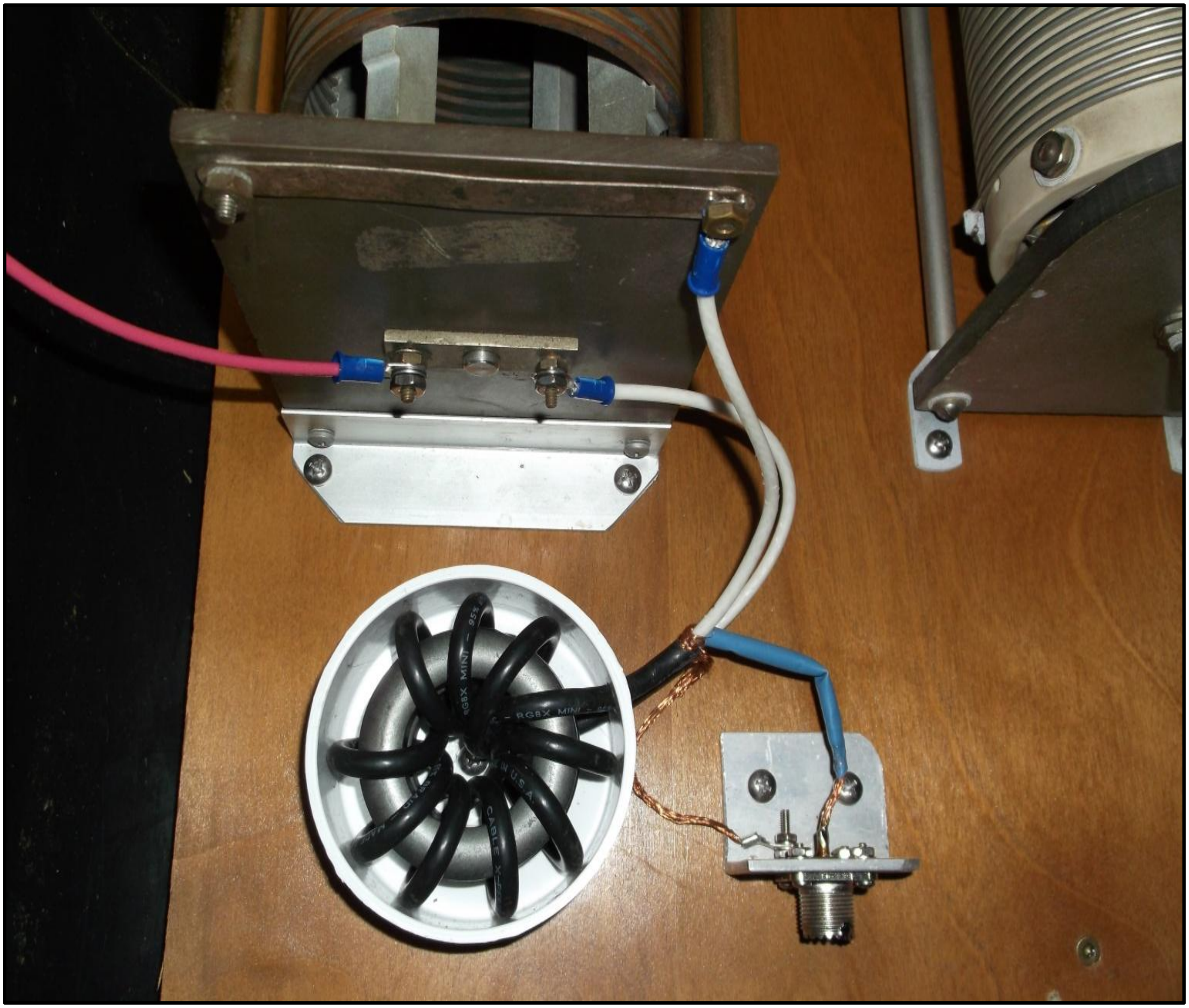

Figure 10 - Close-up of T1

The scheme I chose is not the only possibility. As shown in figure 11, there are other possibilities. To vary L we could use a variometer, i.e. a separate circular winding within the main winding which is connected in series and can be rotated for tuning. For isolation there are a couple of possibilities: another variometer winding not connected in series with the main winding, or we could use a short coil on a arm which can be move the coil into or out of the main winding. Figure 12 shows an inductor taken from an LF beacon transmitter which directly implements figure 12 using two variometer windings. Figure 13 is an end-view showing one of the inner rotatable windings.

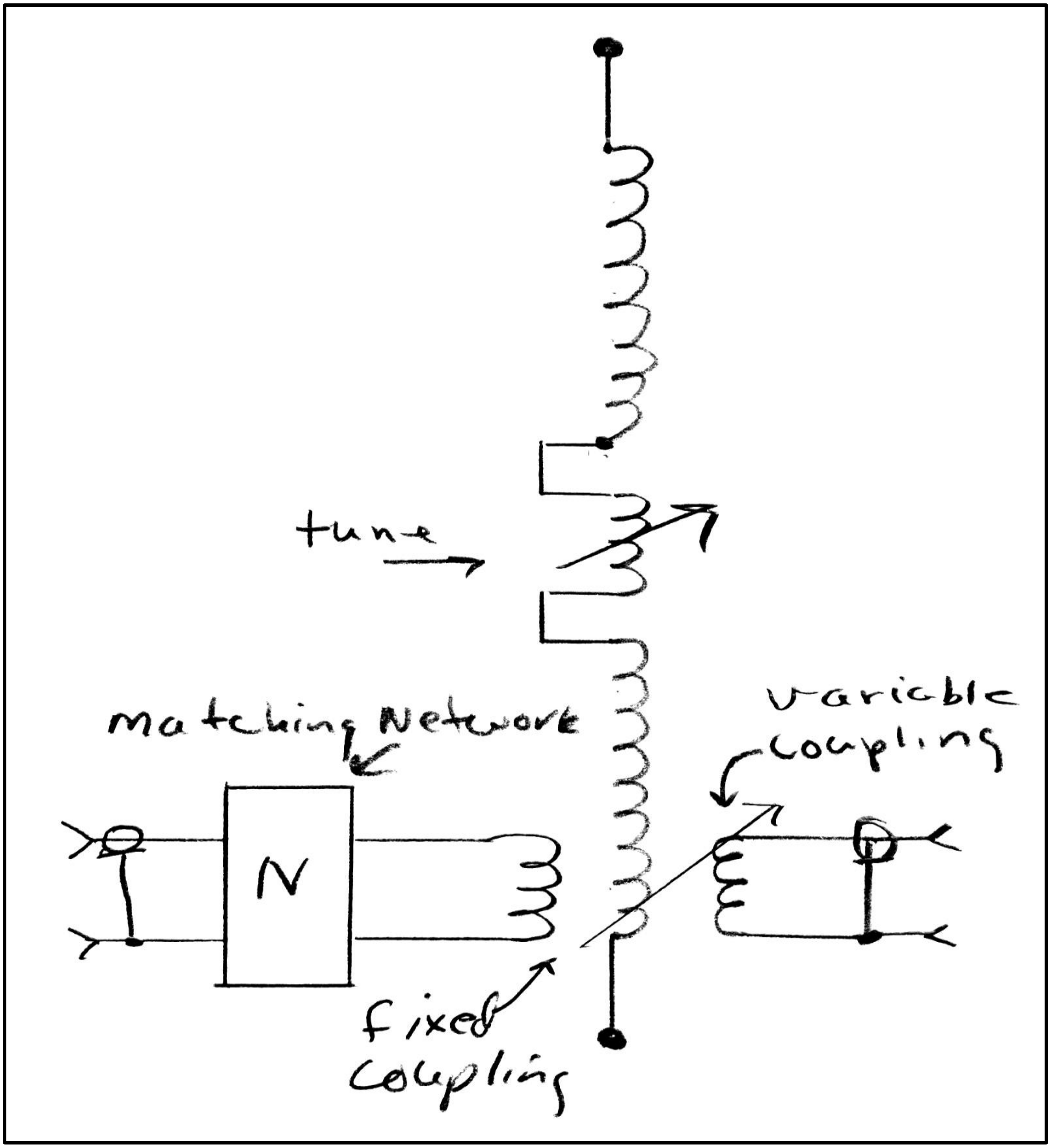

Figure 11 - Generic tuning-matching-isolation scheme.

As an alternative a fixed winding can be used in combination with a matching L-network on the primary side. Mechanically this is the simplest way and if the coupling winding is placed outside the main winding it can be spaced to have very good isolation with very little added shunt capacitance to ground. It could also be mechanically rugged. It's also possible to use a fixed winding which is tapped! Even simpler!

Figure 12 - LF beacon transmitter tuning-matching inductor.

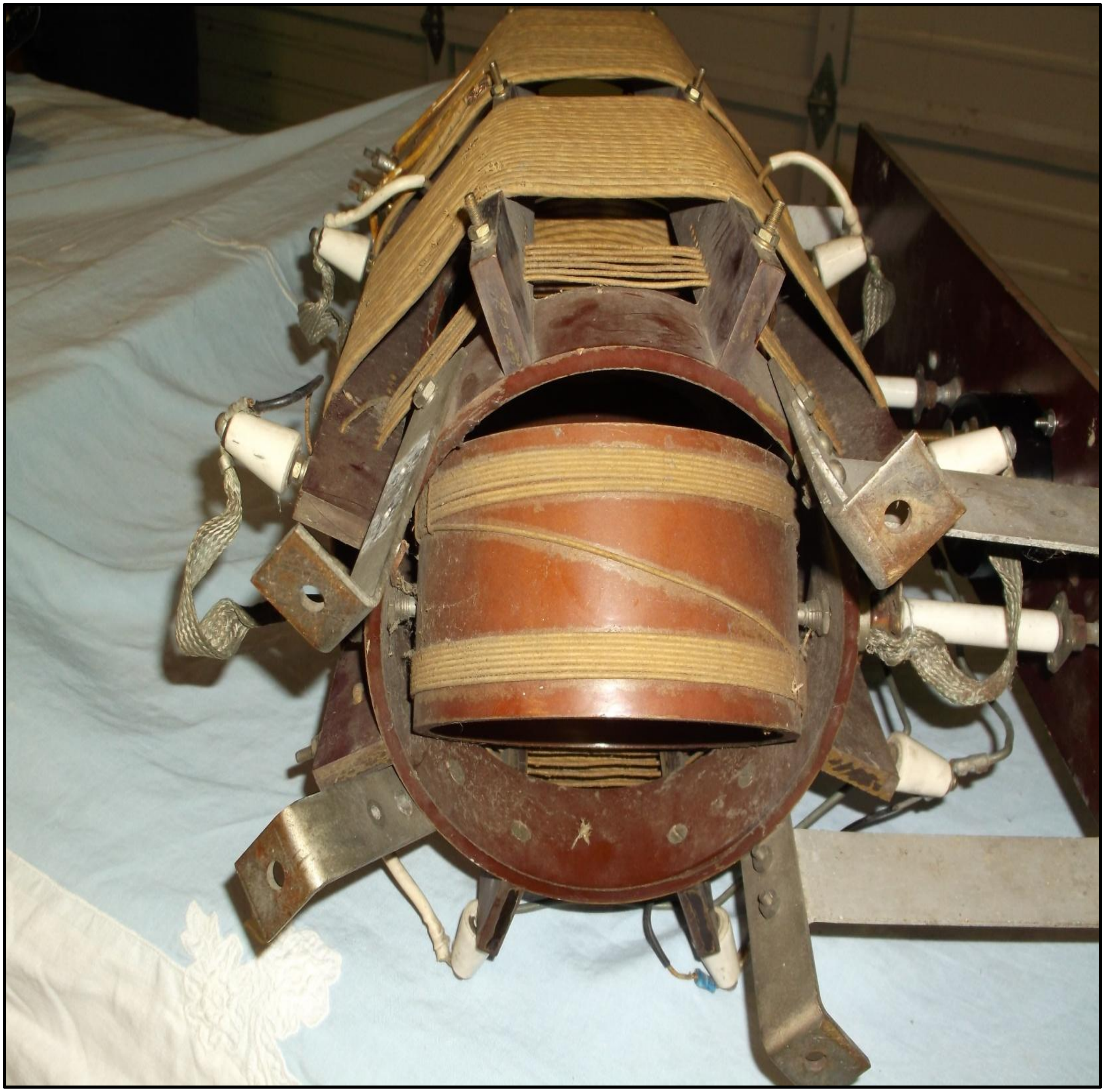

Figure 13 - Inner winding.

Figure 14 was taken from the 1949 edition of the ARRL Radio Amateur's Handbook. It shows an example of "swinging link" coupling where the coupling link (a small coil) is attached to an arm which rotates the link into and out of the winding.

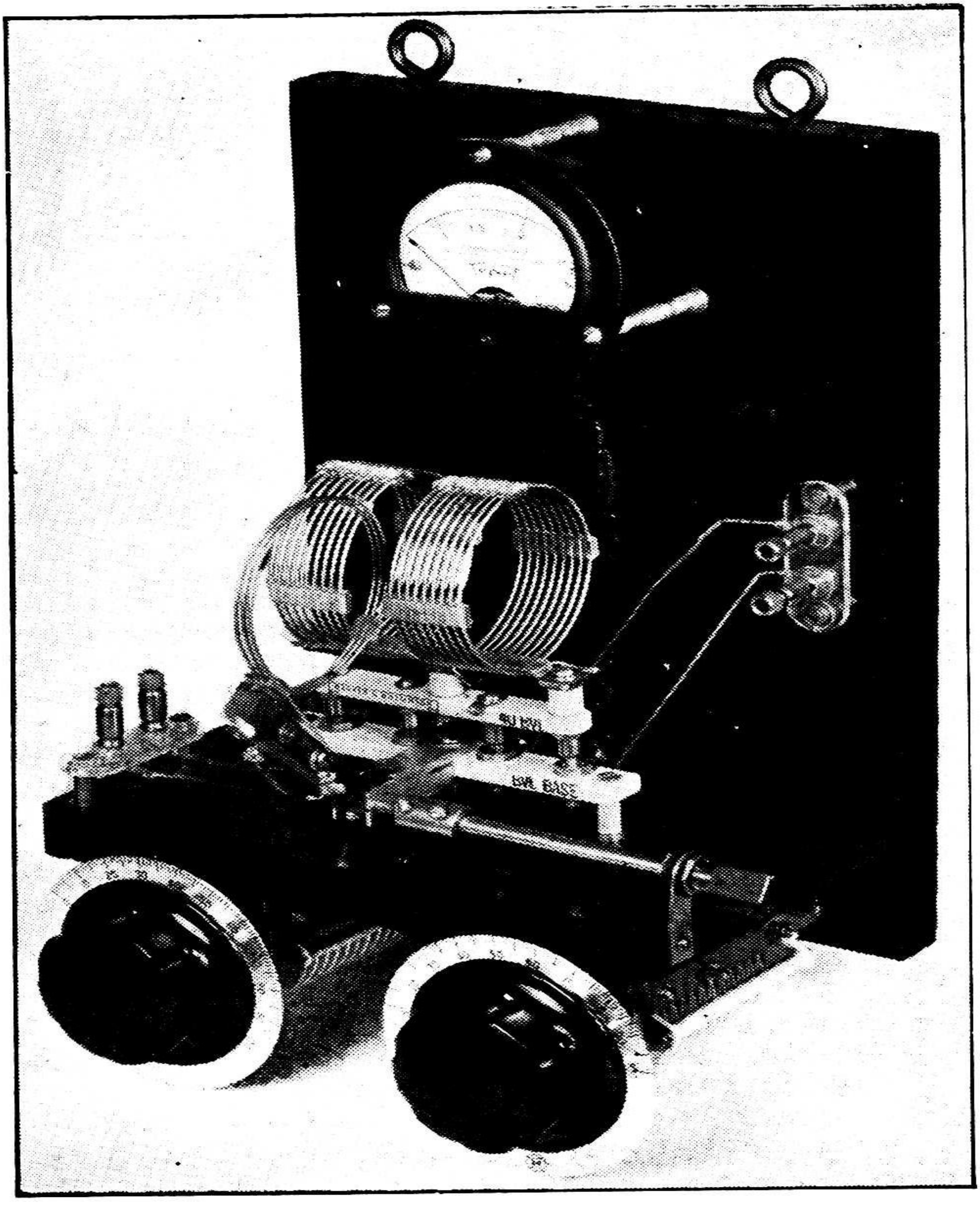

Figure 14 - Swinging link coupling example.

Modeling and measurement

The first step in tuning the antenna was to measure the impedance at the feedpoint over a range of frequencies (0.4-1.0 MHz). A vector network analyzer (VNA2180) was available which can provide very accurate measurements but there is a problem common to all antennas with an isolated counterpoise: the measuring device has to be isolated from the antenna. The VNA is unbalanced and referenced to ground! The answer was to fabricate an isolation choke like that indicated in figure 9. The choke I used is shown in figure 16.

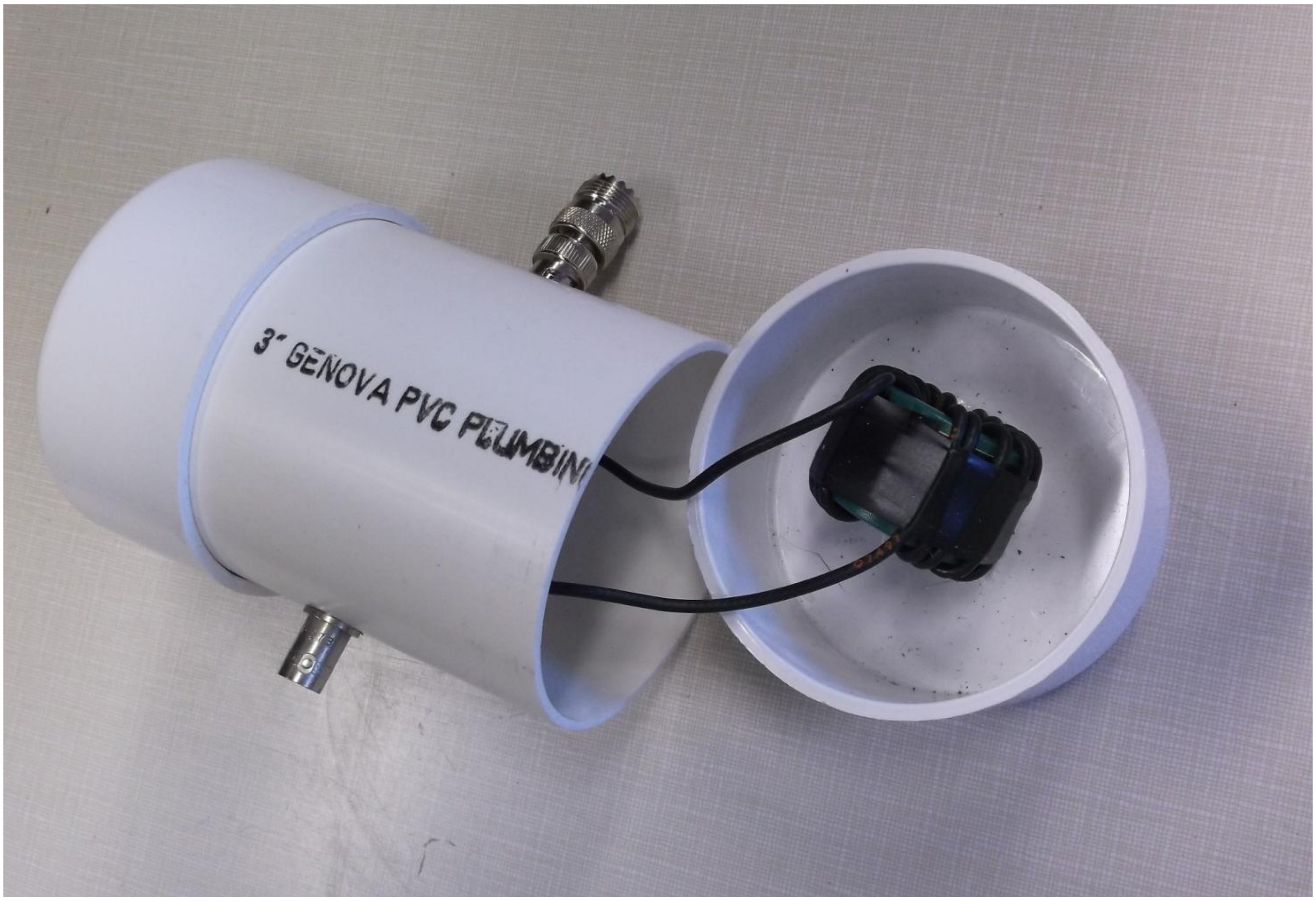

Figure 16 - Isolation choke partially disassembled.

The choke has 17 turns of RG174 wound on a stacked pair of 1.4", type 77, ferrite cores (Mouser P/N 623-5977002721). The measured impedance of the choke from 0.4 to 1 MHz is shown in figure 17. At 475 kHz the impedance is about 6kΩ which should be adequate. The choke is self-resonant at ≈825 kHz.

A measurement of the feedpoint impedance is shown in figure 18 (solid line) along with the prediction from EZNEC (dashed line).

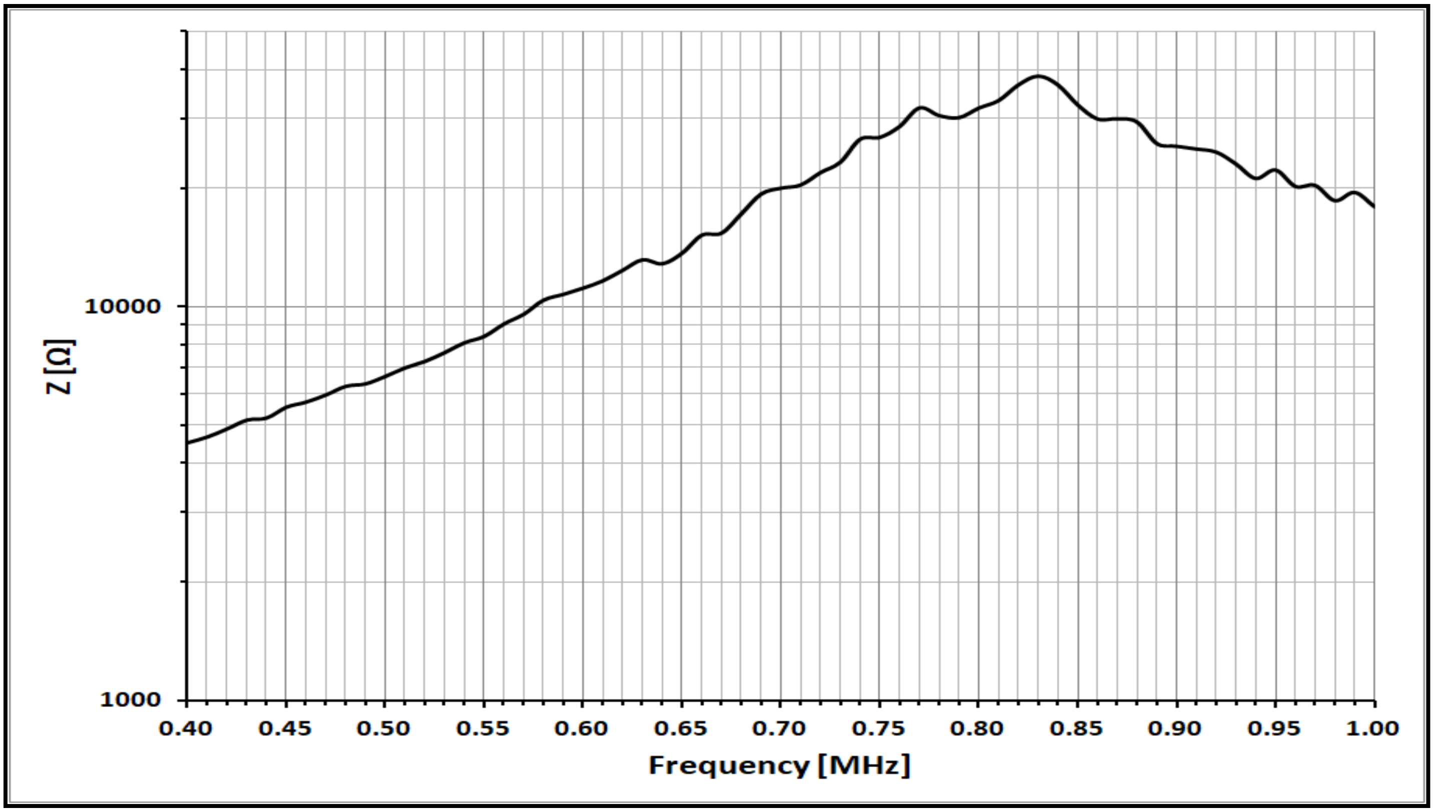

Figure 17 - Isolation choke impedance.

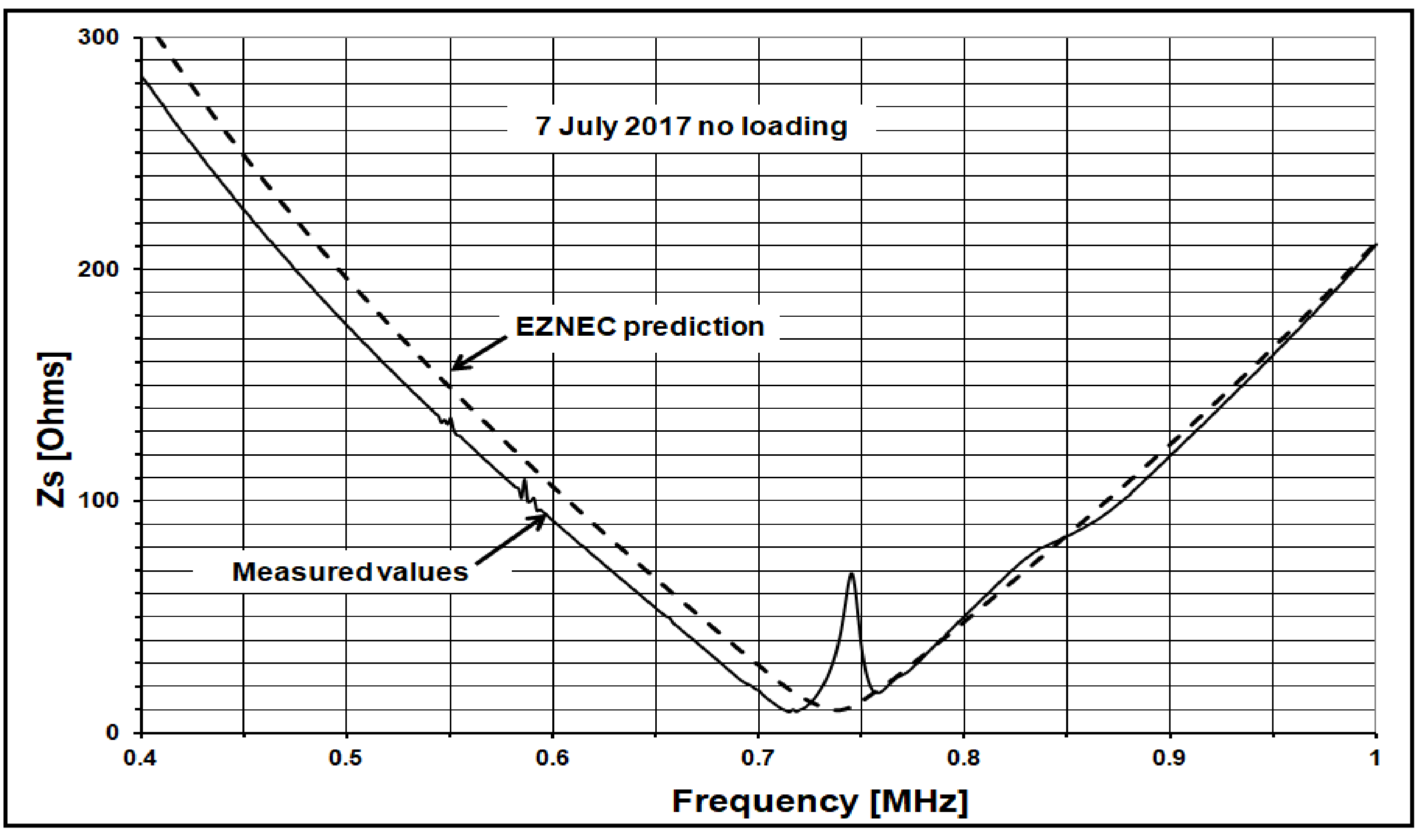

Figure 18 - Measured and predicted values for feedpoint impedance.

The measured and predicted impedances match well. The blip at ≈750-850 kHz is most probably due to the self-resonance of the choke at 850 kHz. At 475 kHz Xi=199Ω which corresponds to a ≈67 uH loading inductor. Table 1 shows the EZNEC predicted parameters at 475 kHz assuming 0.008/20 soil. The predicted value for the impedance was Zi=5.3-j210 Ω. The measured value was Zi= 5.8-j199 Ω. Which is pretty close considering my summer ground characteristics may be worse than assumed.

Table 1 - EZNEC predicted parameters

Parameter	Prediction
Rr radiation resistance	1.6 Ω
Rw wire resistance	1.4 Ω
Rg ground loss resistance	1.1 Ω
RL inductor loss resistance (QL≈200)	1.2 Ω
Ri =sum	5.3 Ω

The efficiency η = Rr/Ri ≈28% which is pretty good. For EIRP = 5W the radiated power is 1.7W which means I'll need only 6-7W from the transmitter. I did some modeling to see the effect of switching to copper wire and a QL=400 tuning inductor. That pushed the predicted efficiency up to 43% or a transmitter power of only 4W but I didn't think that's worth the trouble! As WD2XSH/20 I'm allowed 20W which I easily provide.

Adjustment was very straightforward, first I adjusted one inductor to resonate and then the second for the lowest SWR at the 50Ω side of T1. This process took about 15 minutes. The resulting SWR curve is shown in figure 19.

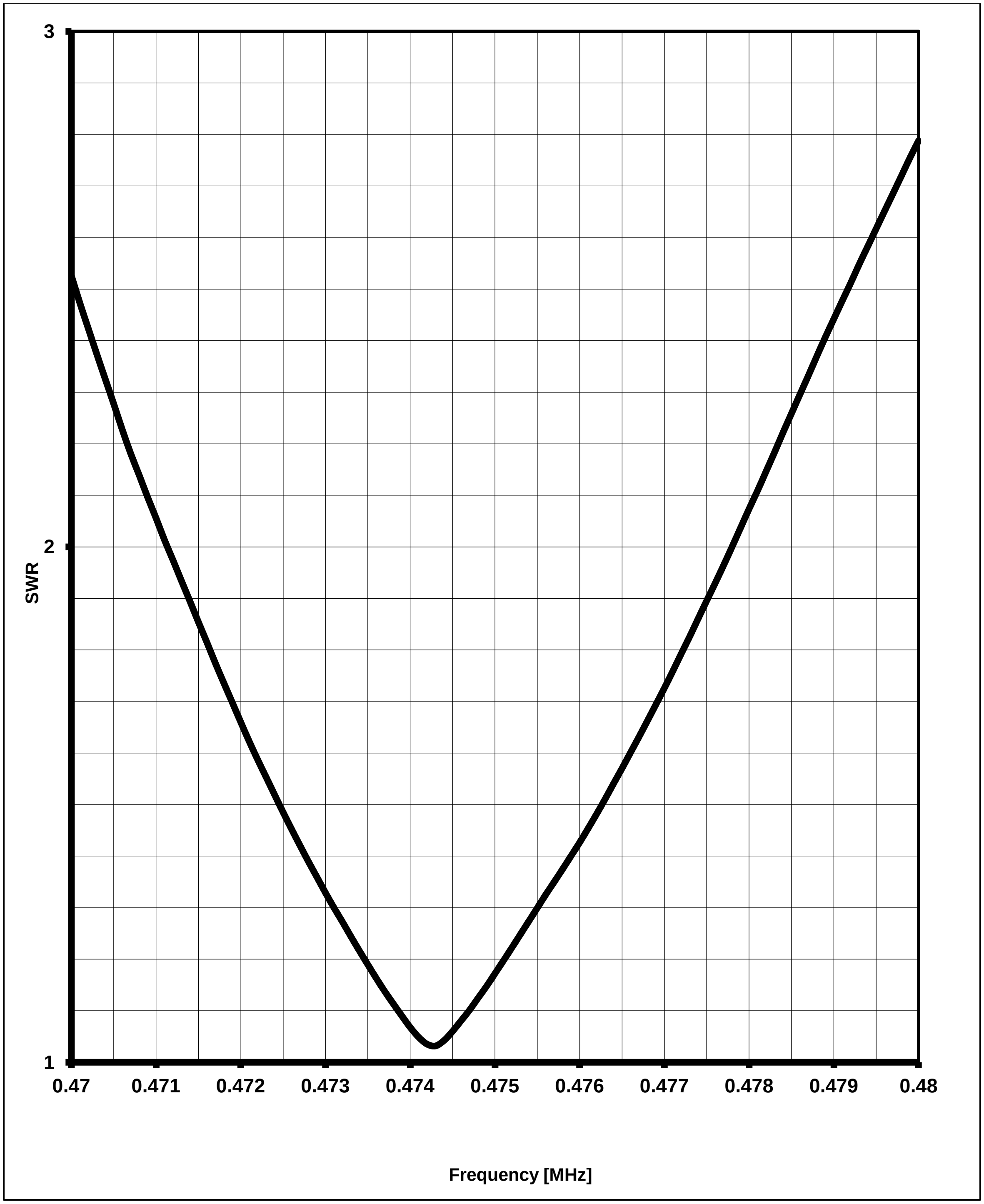

Figure 19 - 8 July 2017 SWR measurement at the transmitter

including the effect of the output power filter.

Some more details!

I happened to have several unused 50’ utility poles left over from a project at my last QTH so I brought them with me when I moved to the new QTH. You need to plant a utility pole with about 10% of its length in the ground. This means if you start with a 50’ pole the top will only be about 45’ above ground level which is not good enough for MF antennas. I repeated a trick from my last QTH: attaching peeled and untreated fir poles to the top of the utility poles.

On the left is a picture of a typical pole assembly. Bolted to the top of the utility pole is a smaller diameter 40-50’ untreated pole with 10’ of 6” PVC pipe covering the top. The PVC pipe serves several functions: it makes the pole taller, it shelters the top of the pole from the weather (the part of the pole inside the pipe <u>is</u> treated) and it puts an insulator at a point which is often at very high voltage in short top-loaded verticals.

The bottom of the pole is inserted into a section of 18” diameter, 7’ long corrugated steel culvert as shown above. The culvert is buried in the ground as shown above. My dense rocky soil allowed me to omit concrete collars at the top of the culverts.

At the top of each pole there are from 2 to 4 blocks (pulleys) with endless halyards like a flag pole. This allows me to raise and lower the wires at will as I play with the antennas. The poles were assembled on the ground and erected with a crane as shown in the photo. It took about three hours to erect seven poles.