

## A 9:1 Balun For Your End Fed Antenna

End-Fed antennas do have their place in radio and other communications work. Like everything else, antennas come in many forms and flavors. It's up to the designer to select the best design for the job at hand and to utilize that design in the most efficient way.

\* \* \* A Bad Rap? \* \* \*

- End-Fed antennas are NOT balanced systems; but neither are verticals, ground planes, discones, windoms, zepps, Marconis, half-slopers, et al. Additionally, the low-impedance antenna port of your transmitter/receiver is not balanced.
- End-Fed antennas are noise magnets. Really? That's because most hams and SWL-ers don't bother to interface them properly.
- End-Fed antennas have wild impedance swings. So do all antennas, but not at the design frequency - there, at the design frequency, the terminal impedance is quite predictable.

To make the best use of an End-Fed antenna, it should be fed with a transformer. Here are some photos of one of my 9:1 baluns. However, when using it with an End-Fed antenna it is wired as a (so-called) "unun" transformer (unbalanced to unbalanced). The raw End-Fed antenna will go through impedance swings as high as 5K Ohms, or more, at even multiples of its 1/4 wavelength design frequency. At every odd multiple it will be at a more civil impedance of between 36 and 90 Ohms. Using the transformer, the magnitude of the impedance swings is greatly reduced. This is due, in part, to the ratio balancing of the transformer's turns (windings), and to a few complex reactance and other physics attributes that I won't try to cover here. Additionally, the unun will eliminate (virtually) all "common mode" currents on the feedline. This is important for eliminating the pickup of local electrical noise from homes and power distribution lines. The coax, being connected to ground through a DC path will eliminate all but the differential currents ... pretty cool, huh? Finally, since the antenna is connected directly to Earth ground through the secondary of the transformer, static buildup cannot occur - the antenna is a dead (DC) short to ground. This is important to sensitive, solid state radios.

The 9:1 transformer provides: 1. a much flatter broadband impedance response, 2. a static electricity-free antenna system (no buildup), 3. common mode noise immunity (if space wound as shown).





#### An Important Note on this Design

I selected the separate (spaced, opposite or complementary) winding format over bifilar or twisted-pair winding in order to minimize the coupling effects of stray capacitance between the primary and secondary windings. This symmetry is important to the quality of common mode noise rejection, which is one of the balun's attributes - and should be exploited as such.

Construction of the 9:1 balun/unun: I used an old plastic box and a type 75 toroid core. My windings, in this case, are for transmitting, using No. 10 and No. 14 solid copper wire. For SWL-ing a smaller core can be used along with No. 18 or smaller wire. The turns ratio is 3:1 for a transformation of 9:1. The impedance is the square of the turns ratio ( $Z=T^2$ ). The antenna terminals are brass speaker terminals and the low impedance side is a standard SO-239. The grounds of the two windings have been isolated but, can be strapped together by the screw

contacts (shown in the top photo). The entire assembly was potted with marine fiberglass. Note that I also added a hanger strap for convenience.

Testing the 9:1 balun/unun:

Properly designed and constructed toroid transformers are not lossey!!!

On the test bench with a 52 Ohm source and a 450 Ohm load the transformer shows a loss of no more than 0.6 dB with about 0.45 dB being average, and the low reading of 0.2 dB.

Installation of the 9:1 balun/unun:

The End-Fed is connected to one terminal of the "high" winding and the other terminal is connected to a good "EARTH" ground. One or more copper rods or pipes driven, at least, 4 feet into the earth near the dwelling entry point (2 or 3, is better, being spaced about 4 feet apart). The coax is connected to the SO-239 and fed to your radio. The best place for the balun for receive-only antennas, is mounting it directly to the primary ground rod and keeping the ground conductors as short as possible. Use a heavy copper wire (not steel or aluminum) or, better yet, low inductance conductors which have an *aspect ratio* that is other than "round." The higher the aspect ratio, the better, like flat copper braid or copper sheet metal strap. This, in effect, will give you an inverted "L" antenna (of sorts), depending on the length of the vertical element. For transmitting, it's best to place the transformer at the actual feed point, up, and away, from possible contact by humans and pets. Of course, extra care must be taken to properly ground the balun by running the ground conductor down the tree, house, etc. If your antenna is attached to your tower and ground-BONDED to the household grounding system, as mine is, then you are home free ... just be sure your tower itself is properly grounded ... *you'd be crazy if it wasn't suitably grounded the day you put it up!!!*

A word about grounds.

We are talking about RF (signal) ground on this page. These are the grounds that provide the antenna counterpoise (true ground plane), and afford static bleed to NOT allow lightning's near field (DC component) induction, or just general DC static electricity buildup on the wire, to pass along to your radio. *A balun will not stop the RF component of near-field strikes, although the inductive component of the windings and ferrite will lessen its amplitude.*

These grounds ARE NOT about electrical service safety. Smart people tie their radio grounds to a common point "service ground" ("BONDING") with heavy gage wire, I do - and this is fine if ALL the other ground measures discussed here have been met. Simply put: electrical service ground is NOT a substitute for a good RF Earth ground, which is required for a good antenna system. In fact, your service ground will probably be a very bad RF ground and a good source of (household / neighborhood) noise, if not outright dangerous to you and your equipment. *Remember, the "neutral" wire in your circuit breaker box travels outside of your home and all around the neighborhood ... it's a noise magnet and (going from pole-to-pole) a potential*

*lightning rod!!!* Best to consult with a licensed electrician about "bonding" the entire household, IE: electrical service, cable service, telephone lines, and RF grounds.

Technically speaking, that addition of outside antennas may modify or invalidate you home's fire insurance coverage. If in doubt, contact your insurance agent. Also, consult with a licensed electrician to be sure you conform to all NEC and local electrical codes for the proper BONDING of ALL service grounds, and ground systems, within and about your home.

#### RF Grounding With a Balun Feed

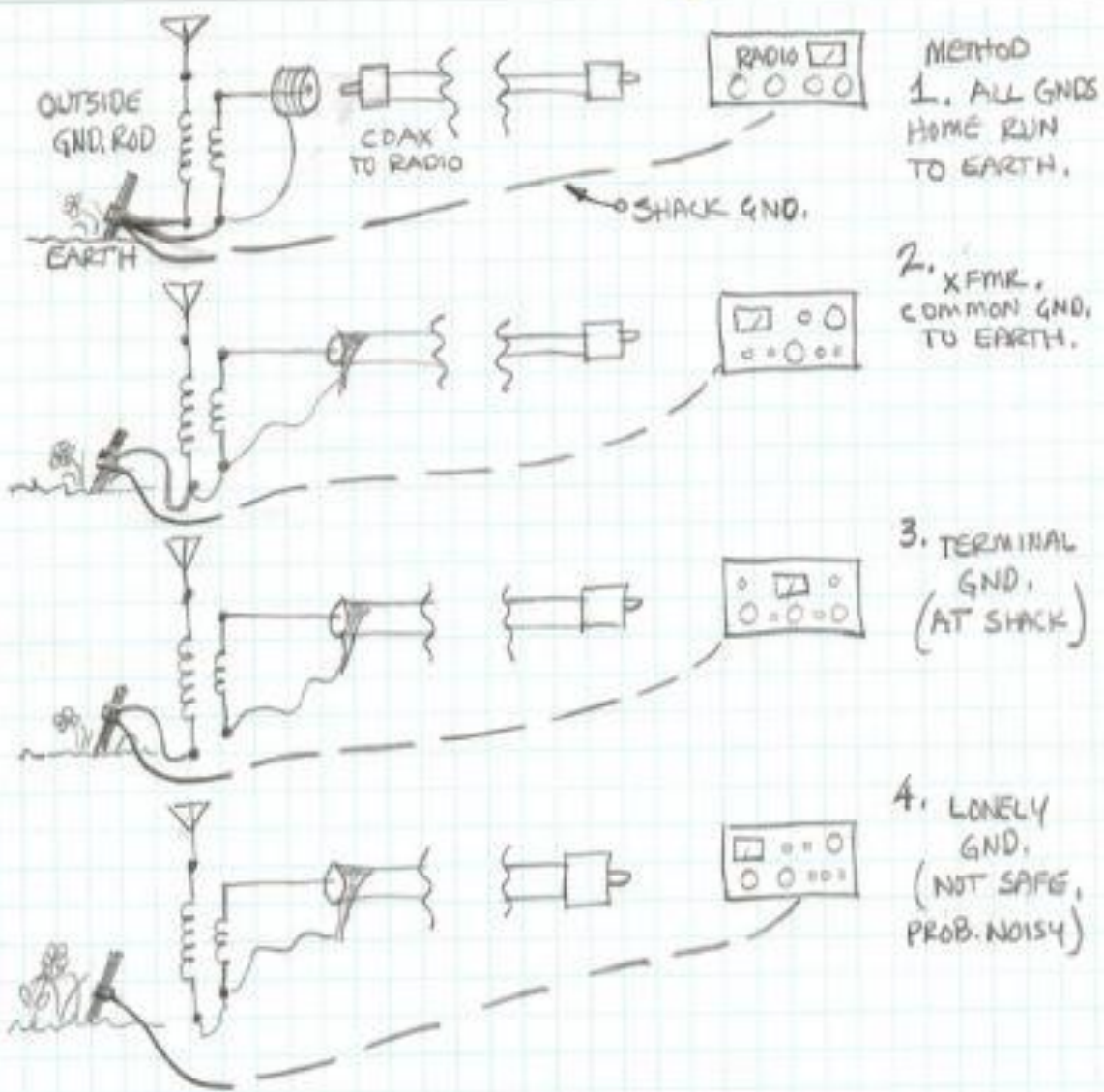
Transformer coupling and properly grounding your end-fed antenna will offer you four benefits: (1) Greater signal levels across a larger bandwidth (impedance smoothing), (2) Less electrical noise pickup from local sources (common mode rejection), (3) Greater protection to your equipment (constant static bleed and near-strike (DC only) shunting). Shown here are 4 possible ways to connect your transformer (balun wired as an unun) to the antenna and the radio. (Note that the first example uses a coax connector at the transformer and the subsequent figures show the coax as being hard wired - both are acceptable and are options for your particular requirements.) The sketches are pretty much self explanatory. Technically, they are shown in the order of functional preference.

If you have trouble reading these sketches, you may "right click" them to your clipboard and paste them to a .jpg viewer. Please give full credit if reused elsewhere.

Here is a graphical illustration of a typical installation. The details will be different, but the principles are the same. The primary point is to mount the xfmr as close to the system ground as possible. Mounting it directly to the first ground rod is text book-ideal. An alternate would be to eliminate the vertical component of the antenna and mount the xfmr to the insulator above it and run a heavy ground up to it. This will depend on how much the vertical wire is exposed to near-field electrical noise from your home.

Here is an example of good RF "ground farm" practice. As opposed to many socio-religious beliefs, in this case, more is better! There will be a point of diminishing returns, but generally speaking, one ground rod is not going to be optimal. Experimental and empirical testing is the only way to determine what will be best for you. You may get a relative ground conductivity test as shown below. Most electrical service entry points are grounded to the fresh water (cold water) feed pipe. Homes with plastic well pipes will have some other code-compliant grounding system. Either way, you should consider "bonding" your ground farm with the house/utility grounds. (And you'll need a licensed electrician to properly perform this kind of system upgrade.) Regarding RF grounding: some soils will indicate a few dozen ohms/foot and others will offer thousands of ohms. You'll have to do some measurements with an ohm meter to get a "feel" of what your ground farm will be like. But remember, this is only a "test indication" that will give you a "feel" of your soil quality. You will also learn how conditions change with seasons and weather.

Disclaimer: Remember, you are dealing with earth (signal) grounds only. Never tamper with, or intrude upon, or compromise your electrical service grounds in any way. If in doubt, consult your utility company and/or a licensed electrician for bonding information. Also, lightning is completely unpredictable. A direct strike or a close near-strike may damage your equipment, start fires, or cause personal injury, or death. Use common sense and be careful !

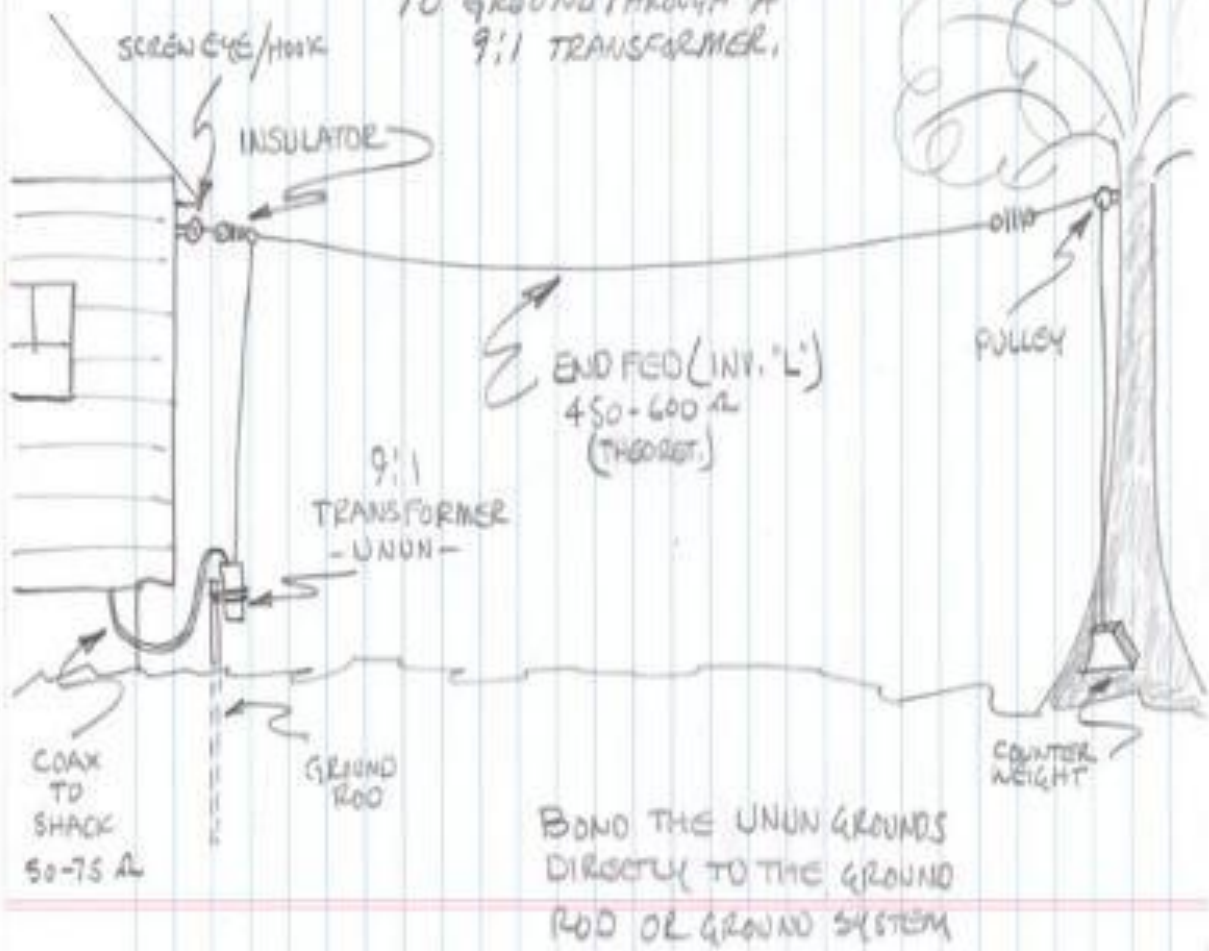


~ 9:1 UNUN TRANSFORMER ~  
CONNECTION PERMUTATIONS

NOTE THAT THESE ITERATIONS ARE LISTED BY THE SAFEST FIRST & LEAST SAFE LAST, (LIGHTNING ATTRACTION). (PERFORMANCE/NOISE REDUCTION IS PROBABLY IN THE SAME ORDER.) SHACK GND. SHOULD BE AS SHORT & DIRECT AS POSSIBLE - FLAT COPPER CONDUCTOR IS BEST (BRAID, STRIP) BUT HEAVY WIRE USUALLY SUITABLE. (12 GA COPPER SHOULD BE MIN. SIZE.)

4-18-05 NIKPR

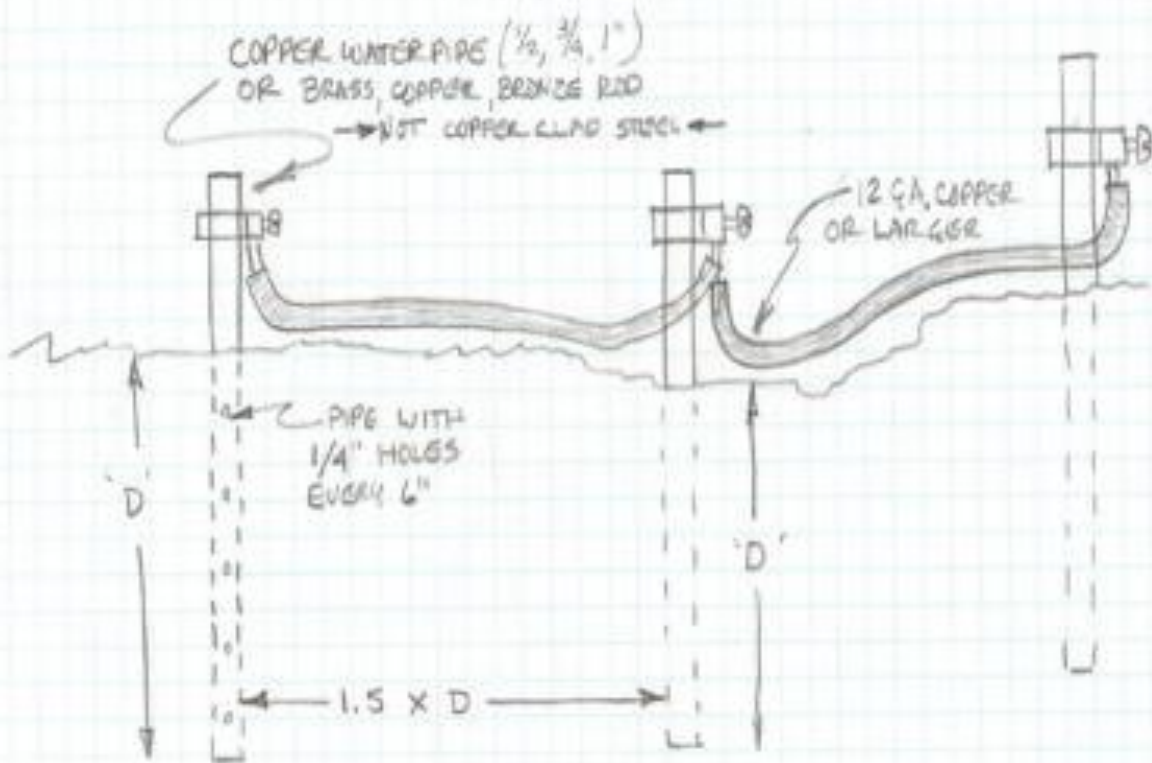
ELIMINATE "LIGHTNING-ATTRACTING" STATIC BUILD UP & REDUCE COMMON MODE ELECTRICAL NOISE BY PROVIDING A CONTINUOUS BLEED TO GROUND THROUGH A 9:1 TRANSFORMER.



N4XR 305



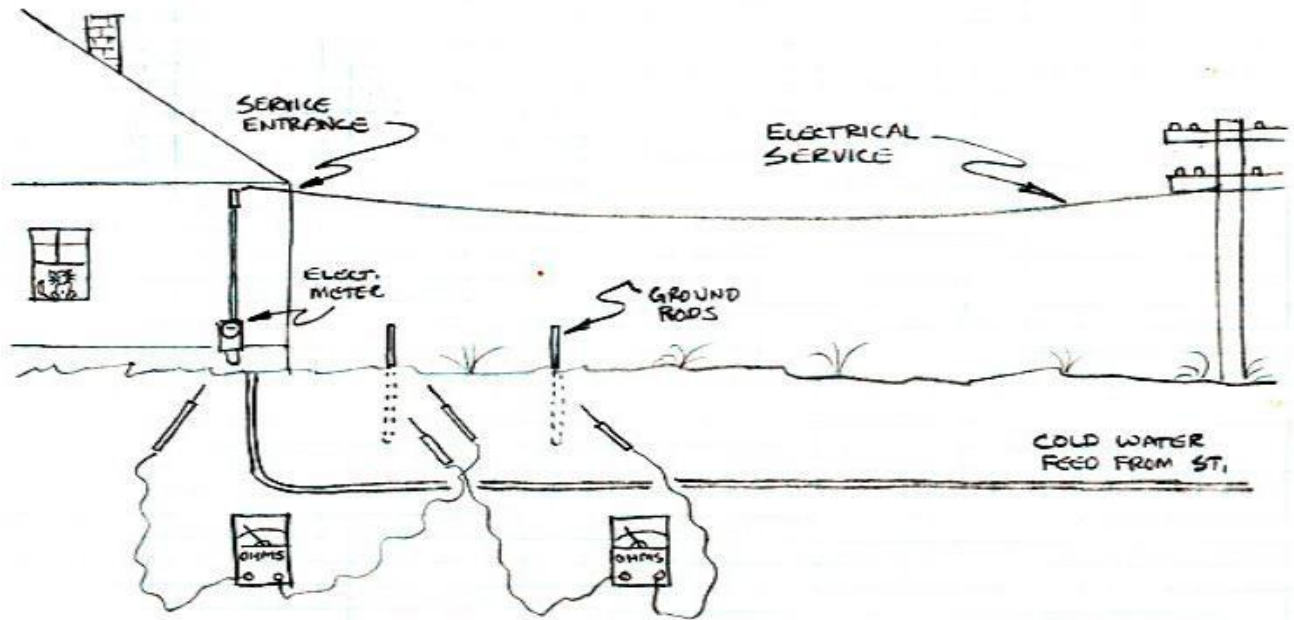
# TYPICAL "GROUND FARM" INSTALLATION



D = FROST LINE ++ (MIN: 36", TYP: 48"-60", BEST: 96")  
 DIMENSIONS ARE GUIDELINES ONLY  
 DEPENDING ON SOIL CONDITION, 2-3 MAY BE SUFFICIENT  
 SANDY & CLAY SOIL USUALLY CONTAIN LESS ELECTROLYTES.

NEKPR 5/65

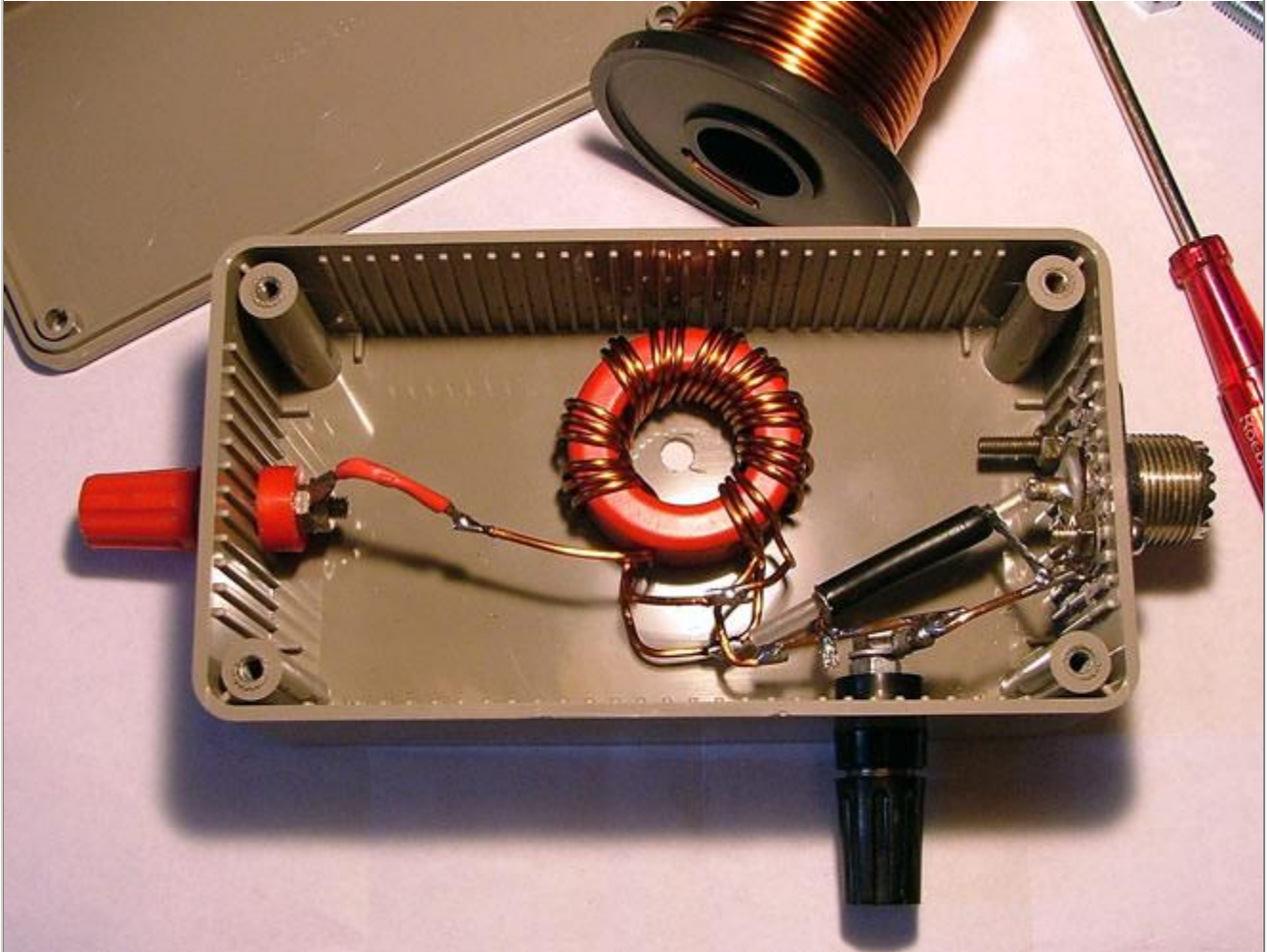
~ SOIL CONDUCTIVITY ~



NIKPR 6.05

The above sketch is just for illustrative purposes to point out that soil is not a very good conductor of electricity, no matter where you live, and no matter what kind of chemicals you "seed" the soil with. The above test will give a good indication of just how resistive soil can be and an interesting exercise to conduct during various seasons and/or weather conditions. Of course DC ohms measurements are pretty meaningless at RF frequencies where electrical current flow behaves much differently, but you will gain a "feeling" for what grounding is all about and why *Ground Bonding* is so important

## Magnetic Long Wire UnUn 9:1



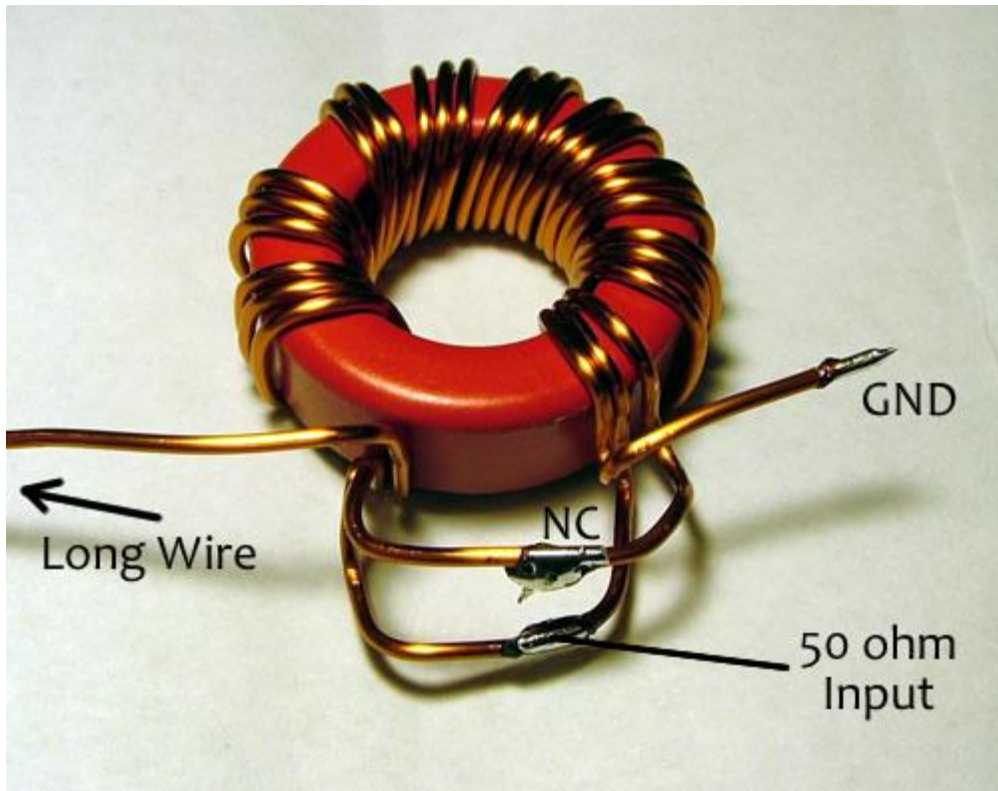
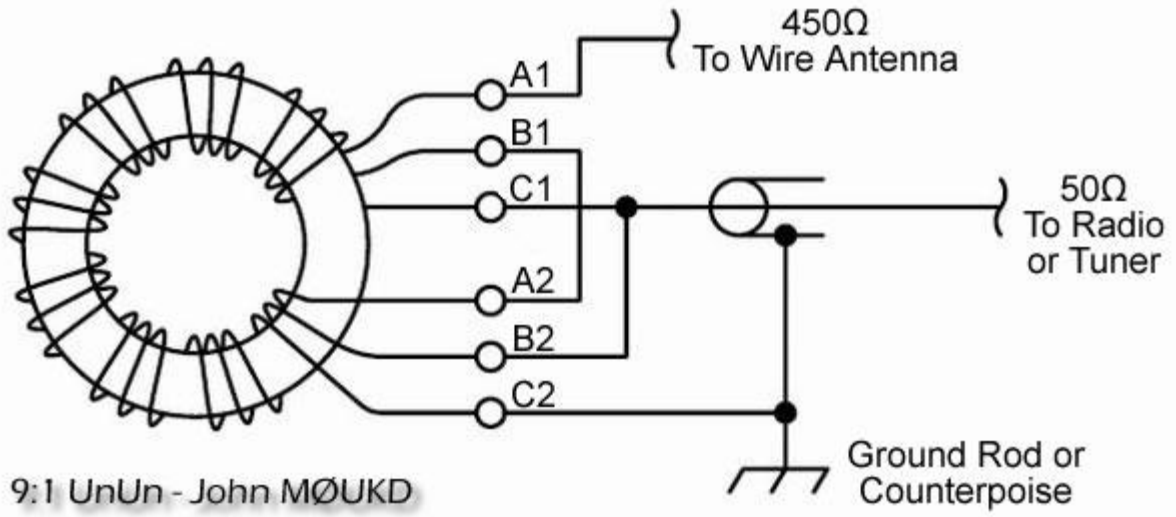
These are usually called a *Magnetic Longwire Balun*. Its really an impedance transformer (9:1) to feed a high impedance long wire (~450 ohm), down to a 50 ohm unbalanced coaxial input. I have heard them called an UnUn which seems more appropriate. I almost bought one of these for around £30, but then decided to make one. The toroid is a T130-2 Iron Powder core, with 3 x 9 turns of 18SWG enameled copper wire, and the connections can be seen below.

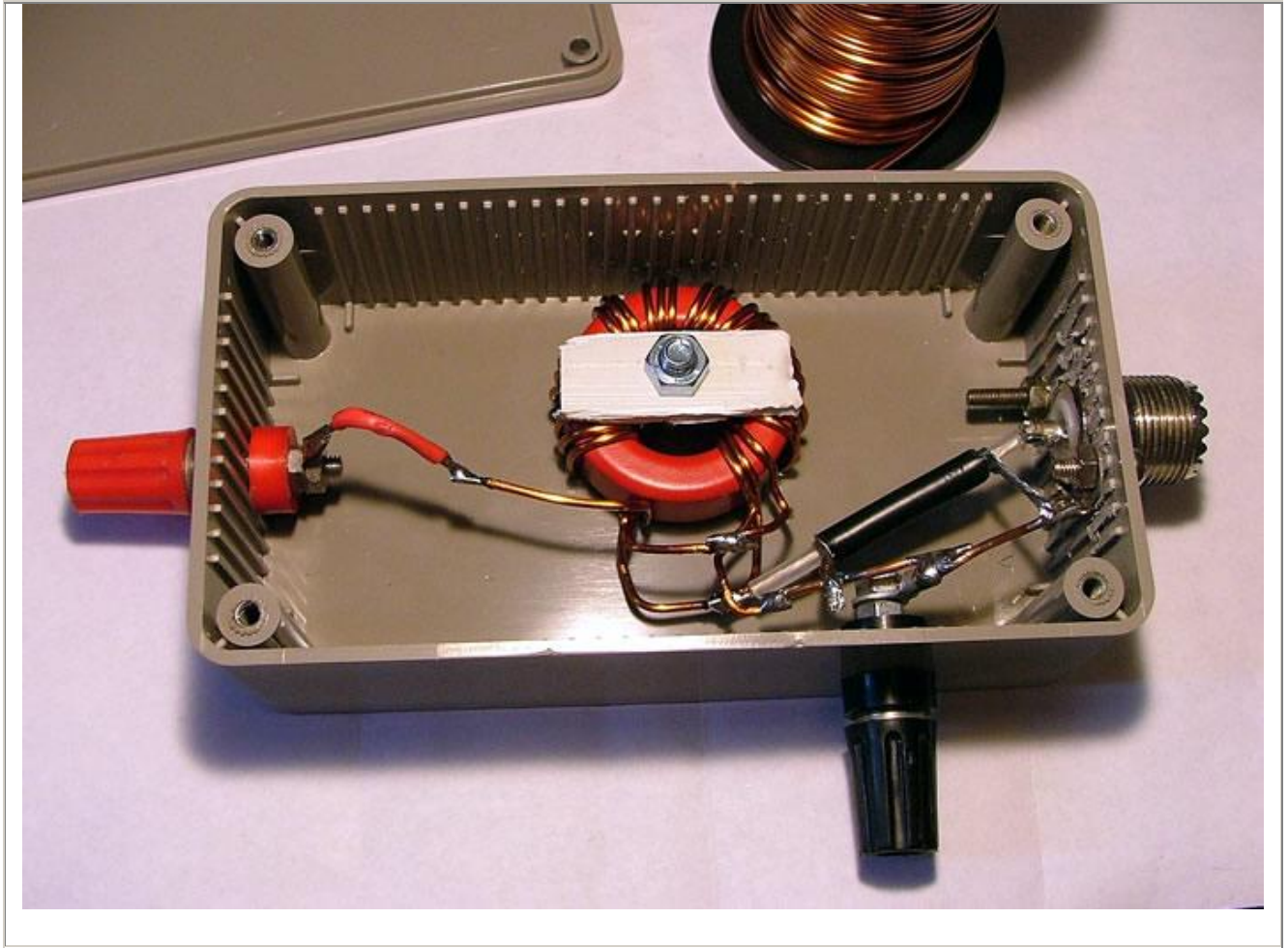


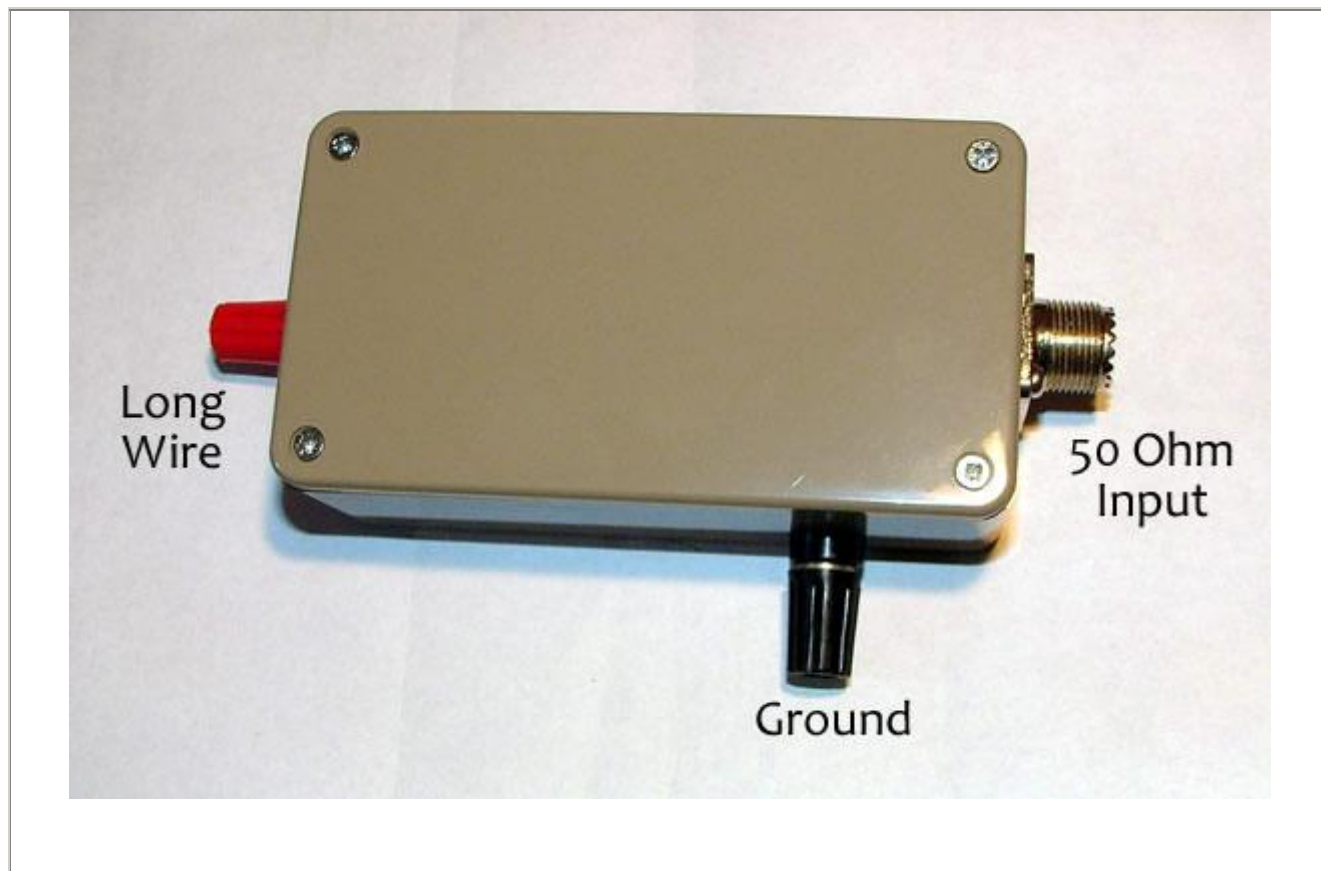
The T130-2 Torroid Core











### Long wire and Un-Un part 1

I have been playing with a 4:1 unbalanced-unbalanced transformer and a long wire. The theory is that the Un-Un reduces the impedance at the feed point to a point that your internal ATU can cope with.

My first tests were with my 85ft end fed and were not too encouraging. These are the SWR results I got using an MFJ analyser:

1.9MHz >30  
3.6MHz: 10  
7.1MHz: 3.0  
10.1Mhz: 5.7  
14.150MHz: 2.4  
18.1MHz: 2.9  
21MHz: 2.6  
24.93MHz: 2.0  
28MHz: 5.7

from these you can see that the rig would be able to match the long wire on five bands. On test it would not match on 80m, although when run as a W3EDP through my external ATU it works

well.

I then wound a 9:1 Un-Un (sometimes referred to as a magnetic long wire Balun) and tried again. Here are the results:

3.6MHz – SWR 28:1  
7.10MHz - SWR 1.9:1  
10.1MHz – SWR 3.6:1  
14.2MHz – SWR 1.9:1  
18.14MHz – SWR 3.8:1  
21.2MHz – SWR 2.5:1  
24.9MHz – SWR 3.5:1  
28.5MHz – SWR 8.6:1

While 40, 20 and 15 metres were quite good I can't really recommend this as a multiband solution.

In all then, it is too long and not really worth playing with.

## Long wire and Un-Un part 2



In the next round of tests I used the same 9:1 Un-Un wound using PVC covered cable and a T200-2 toroid. Note in the photograph that the PVC tape is only used to keep the turns neatly arranged.

If you want to build your own follow these instructions:



## **Building a 9:1 unun**

To understand how to construct an unun lets build a 9:1 version. You will need a T-200 (red) toroid and three pieces of wire, each 24 inches (60cm) long . It will also help if you a small plastic box with an SO239 socket mounted at one end and with two wing nuts or mounting posts at the other. In the UK you can buy a small plastic box from Maplin which is watertight with a rubber seal, yet inexpensive.

It will help if the wires are different colors, although that isn't critical if you have a multimeter available. It just makes it a lot easier to follow these instructions.

For the sake of this explanation I'll assume that you are using green, red and black pieces of wire.

Put the three pieces of wire together and wind them carefully onto the T130-2 toroid. Place the wires (left to right) green-black-red, and wrap nine turns on to the toroid.

Try not to let the wires overlap.

You should end up with a toroid with three wires extending from the left winding and three wires extending from the right.

Now twist and solder the left black wire with the right red wire. This can be covered with PVC tape once complete.

Now twist the left green wire with the right black wire. Strip the ends of the two wires, twist and solder them together leaving the length about 2" long from the toroid.

Finally trim and strip the remaining right green wire and solder another 5" piece of green solid wire to it.

Now take the left green wire and right black wires that you twisted together and connect them to the center pin of the SO239 socket – this is the input side and will connect to your radio via a length of coax.

One of the green wires is now soldered to the ground connection of the SO239 socket. The other end of the wire you soldered on (which is connected to it) becomes the earth connection for the unun and typically goes to a ground stake and ground radials.

This leaves the remaining red wire which connects to the other wingnut and will become the connection for the antenna.

If you are worried about the wires unraveling you can either use PVC tape to hold them in place or plastic cable ties.

So how do we use an unun? Let's look at a typical example.

This time I erected a 10m high fishing pole and attached a 65ft quarter wave antenna for 80m in an inverted L fashion. That is, 10m up and then 9.8m out to the nearby summerhouse.

This was arranged away from the house and fed with 12m of RG8 coax, a single earth stake and two 20ft radials at the feed point..

Here are the SWR readings at the end of the coax:

3.5MHz – SWR 3:1

3.65MHz – SWR 4.2

3.8MHz – SWR 5.9

7.10MHz - SWR 13.6:1

10.1MHz – SWR 2.5:1

14.2MHz – SWR 3.3:1

18.14MHz – SWR 1.8:1

21.2MHz – SWR 2.4:1

24.9MHz – SWR 1.9:1

28.5MHz – SWR 1.2:1

From this you can see that by shortening the wire to 65ft from the original 85ft you gain 80m, but lose 40m. The rig (FT2000) would quite happily tune seven bands with its internal ATU.

Here are the quick comparison results against my 80m Windom and parallel-dipoles in the loft for 40m, 20m, 17, and 10m.

### **80m**

Not as good around the UK as the Windom - probably due to the maximum current being in the vertical section. Modeling shows the antenna to be down about 10dB on a low dipole.

### **30m**

Lithuania similar. Other EU and Italy similar. Bulgaria down 2 S points

### **17m**

Similar – inverted L has slight edge at times. Slightly noisier

## 15m

Better than Windom by about 1 S point.

## 10m

Much better than Windom, dipole and mag loop around Europe via Es, by about 2 S points. Slightly more noise (+ 1 S point).

From this I can see that I need to do more tests, especially on 20m, but for an all-in cost for the antenna of about £15-£20 it shows promise. If you have a tree then the up and out idea with a 65ft wire looks quite good. A way to get 40m back would be to put a 40m trap in the wire at the 10m mark.



Type	Length	Power	Bandwidth /SWR
<b>MONOBAND</b>			
Monoband 40 meterband	20,0 mtr	300 Watt PEP	200 kHz / < 1:2.0
Monoband 30 meterband	14,1 mtr	300 Watt PEP	200 Khz / < 1:1.5
Monoband 30 meterband	14,1 mtr	300 Watt PEP	200 Khz / < 1:1.5
Monoband 20 meterband	10.0 mtr	300 Watt PEP	300 kHz / < 1:1.5
Monoband 17 meterband	7,87 mtr	300 Watt PEP	400 kHz / < 1:1.5

Monoband 10 meterband	5,0 mtr	300 Watt PEP	700 kHz / < 1:1.5
Monoband 11 meterband	5,25 mtr	300 Watt PEP	700 kHz / < 1:1,5
QRO monoband 40 mtr	20,0 mtr	800 Watt PEP	200 kHz / < 1:1.6
QRO monoband 20 mtr	10,0 mtr	800 Watt PEP	350 kHz / < 1:1.6
Super QRO mono 40mtr	20,0 mtr	2500 W PEP	250 kHz / < 1:2.0
Super QRO mono 20mtr	10,0 mtr	2500 W PEP	300 kHz / < 1:1.5
<b>M U L T I B A N D</b>			
Multiband <b>40, 20, 10 mtr</b>  <b>Tri Band</b>	11,85 mtr	200 Watt PEP	40m 100 kHz / < 1:2.0  20m 300 kHz / < 1:1.5  10m 500 kHz / < 1:1.5
Multiband <b>40, 20, (15), 10 mtr</b>  <b>Four Band</b>	20,0 mtr	200 Watt PEP	40m 200 kHz / < 1:1,5  20m 300 kHz / < 1:2,0  15m 450 kHz / < 1:3,0  10m 1000 kHz / < 1:2,0
Multiband <b>80,40,20,(15), 10 mtr</b>  <b>Five Band</b>	23,0 mtr	200 Watt PEP	80m 100 kHz / < 1:2,0  40m 200 kHz / < 1:1,5  20m 300 kHz / < 1:2,0  15m 450 kHz / < 1:3,0  10m 1000 kHz / < 1:2,0
<b>A L L B A N D</b>			
Allband  ( line Iso recommended )  <b>160mtr ~ 6mtr</b>	7m>52m	200 Watt PEP	160m~6m +/- /<1:3
Line Isolator			

The matchboxes for the 3, 4 and 5 HyEndFed Multibanders have the same size.

The difference is the length of the wire and the size of the coil. The 4 band HyEndFed multibander has no coil in the antenna wire.



**Monoband  
Matchbox**

**Multiband  
Matchbox**



# Monoband





