AD5X

The 43-Foot Vertical

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Outline

- Why a vertical?
- Ground Losses and Antenna Efficiency
- Why a 43-foot vertical?
- SWR-related coax and unun losses
- Matching Networks for 160- and 80-meters

Why Use a Vertical?

Advantages

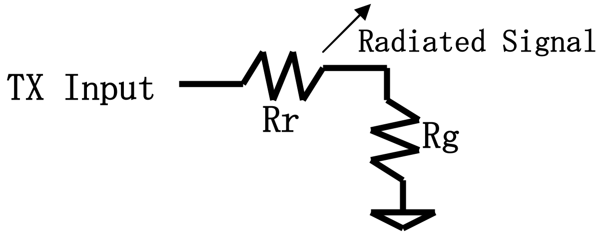
- Generally are inexpensive
- Relatively unobtrusive
- Self-Supporting
- Easy to ground mount
- Low angle of radiation
  - Good DX performance
- Omni-directional (no rotator needed!)

Disadvantages

- Omnidirectional (no gain or F/B)
- Needs a ***good*** radial system for best performance

AD5X Ground Loss & Antenna Efficiency

- ***Radiation Resistance*** (Rr) is the "resistance" of the antenna such that the antenna will radiate all power delivered into this resistance.
- ***Ground loss*** (Rg) is antenna efficiency-robbing loss resistance that looks like a voltage-divider to your transmitter output.



- ***Antenna Efficiency*** (%) = 100 x Rr/(Rg + Rr)

Efficiency Calculation

- A ¼-wave vertical has a radiation resistance of 36 ohms.
- Assume 10 ohms of ground loss
  - This is a ***much*** better ground than most hams have
- Your SWR = 1.09:1
  - Rr + Rg = 36 + 10 = 46 ohms
  - SWR = 50/46 = 1.09
- Your antenna efficiency is 78%
  - If you have a 100 watt transmitter, you will radiate 78 watts

How about an electrically short antenna?

- A Hustler 6BTV 80/40/30/20/15/10 meter vertical is 24 feet tall.
- On 80 meters, it is only 0.092 wavelength long.
- Rr decreases as 1/length^2.
- So Rr is approximately 5 ohms.
- With 10 ohms ground loss, the efficiency is 33%
  - Assumes no inductor losses
- Now your 100 watt transmit signal results in only 33 watts being radiated.

AD5X Electrically short antenna (Cont)?

- A Butternut HF-9VX with TBR-160 160M loading coil is 26 feet tall.
- On 160 meters, it is only 0.051 wavelength long.
- Rr decreases as 1/length^2.
- So Rr is approximately 1.5 ohms.
- With 10 ohms ground loss, the efficiency is 13%
  - Assumes no inductor/loading coil/matching losses
- Now your 100 watt transmit signal results in only 13 watts being radiated.

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The 43-foot Vertical Antenna

Advantages

- Still can be self-supporting
- Still moderately unobtrusive
- 3X higher radiation resistance than the typical trap or loaded vertical.
- And no trap or loading coil losses to worry about
- Modest compromise SWR from 60-10 meters when fed with a 1:4 unun.
  - My worst case SWR is 5:1 on 20 meters
  - Results in negligible SWR-related cable and unun losses.

43-Foot Antenna Efficiency

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- **The Hustler 6BTV on 40 meters**
  - The 24-foot Hustler is 0.188 wavelengths long
  - Hustler Rr = 20 ohms
  - Efficiency = 67% (assumes Rg = 10Ω & _no_ coil losses)
- **The 43-foot vertical on 40 meters**
  - Antenna is 0.34 wavelengths long
  - Rr = 65 ohms
  - Efficiency = 87% (with Rg = 10Ω & ***there are no coils***)

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43-foot Antenna Disadvantages?

- Can be moderately expensive
  - But you can build your own (remember - we live close to Texas Towers!)
- Really doesn't work well on 160- and 80-meters without base matching
  - Regardless of what the 43-foot antenna vendors say
- With Rg = 10Ω,
  - 160 Meter SWR = 324:1
  - 80 Meter SWR = 41:1

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Matching & Coax Losses

- 43-foot antenna vendors say the antennas can be matched from 160-10 meters with your in-shack tuner. However, there can be a problem using the antenna on 160- and 80-meters.
- One vendor says to use 150 feet of RG-213 for best all-band operation of their 43-foot antenna (so you can tune from the tuner in your shack). Another says to ***ADD*** 150 feet to your cable run.
  - On 160 meters, SWR-related coax cable loss is 10.7 dB, plus 6.4dB ground loss. Total loss ~17dB.
    - TX = 100W results in ***2-watts radiated***
  - On 80 meters, SWR-related coax cable loss is 4.7 dB, plus 3 dB ground loss. Total loss ~8 dB.
    - TX = 100 watts results in ***16-watts radiated***
- Added to this will be additional excess unun loss due to the severe mismatch, plus losses in your antenna tuner.

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Minimize Coax Losses

- Use LMR-400 (I use ½-inch Andrew Heliax)
- Length should be that necessary for your antenna system
- Assume 60-feet of LMR-400 (the length from my shack to my 43-foot vertical).
- Worst-case SWR on 60-10 meters is on 20 meters where SWR = 5:1.
  - SWR-related cable loss is only 0.39 dB, plus 0.27 dB matched cable loss = 0.66 dB total cable loss.
- With 150 feet of RG-213, the SWR-related cable loss would be 1 dB, plus 0.8 dB matched cable loss = 1.8 dB total cable loss.

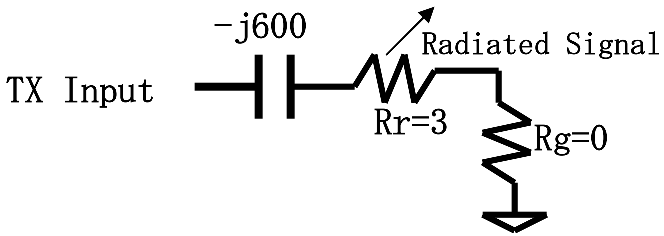
Matching & Coax Losses

- But it is very difficult to match the 43-foot vertical on 160- and 80-meters from your shack if you use low-loss LMR-400 (or 1/2-inch Heliax)!! The mismatch is too great for most manual- or auto-antenna tuners.
- The right thing to do is to properly match the antenna directly at the base on 160- and 80-meters.
- This virtually eliminates SWR-related coax and unun losses, reduces antenna tuner losses, and makes matching from the shack very easy.

AD5X First A Word About RF Voltages

- An electrically short antenna has high capacitive reactance. This ***WILL*** cause high RF voltages across a matching network.
- Example: Assume 1500 watts and a perfect inductor ground system (Rg = 0) on 160 meters. In this case all power is delivered to Rr. From Ohm's Law:

$I = \sqrt{(1500/3)} = 22.4$ amps rms
$|Z| = \sqrt{(3^2 + 600^2)} = 600$
So, $V_{rms} = 22.4 \times 600 = 13{,}440$
and $V_{pk} = 19{,}007$ volts



RF Voltages (Cont.)

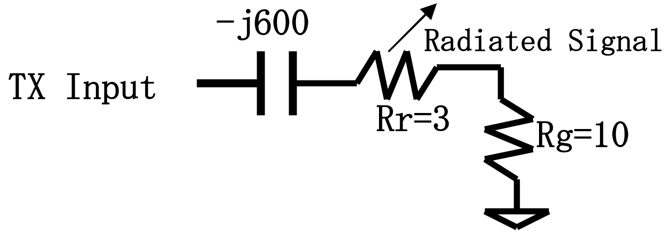
- Example: Assume 1500 watts and Rg = 10 ohms on 160 meters. So all power is delivered into Rr+Rg. From Ohm's Law:

I = √(1500/13) = 10.74 amps rms

|Z| = √(13^2 + 600^2) = 600.1

So, Vrms = 10.74 x 600.1 = 6,445

And Vpk = 9,115 volts



- My Case: 600 watt amplifier (ALS-600).

I = √(600/13) = 6.8 amps rms

So, Vrms = 6.8 x 600.1 = 4,081

Vpk = 5,770 volts

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RF Voltages (Cont.)

- Use relays with high breakdown voltage
  - Contact-to-contact
  - Contact-to-coil
- Put contacts in series to increase breakdown voltage
- Two relays:
  - Array Solutions RF-10 DPDT Relay good for about 500 watts
    - 1.7KV peak contact-to-contact breakdown voltage
    - 3.1KV peak contact-to-coil breakdown voltage
  - Array Solutions RF-3PDT-15 3PDT Relay good for full legal limit if properly applied.
    - 3.1KV peak contact-to-contact breakdown voltage
    - 5.3KV peak contact-to-coil breakdown voltage

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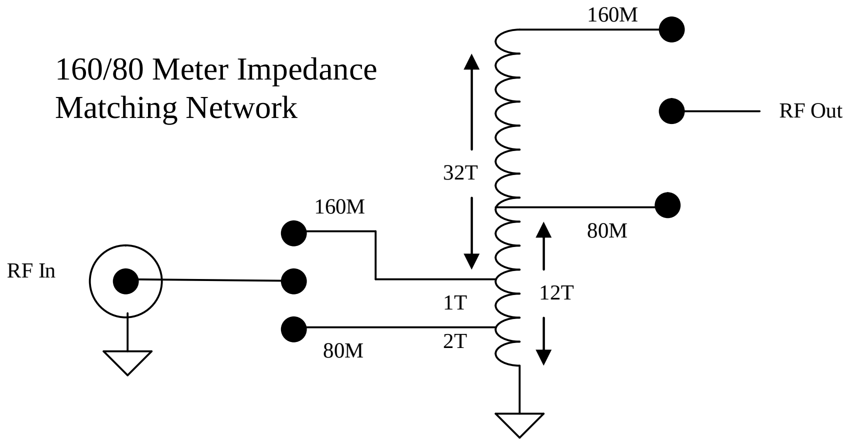
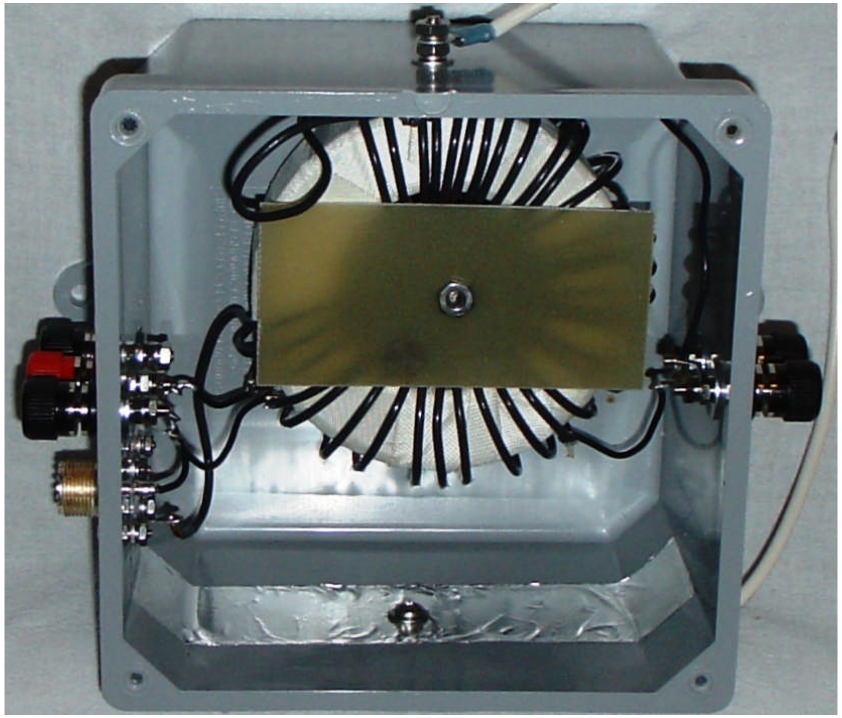
160- & 80-Meter Matching

- Three matching units were built
- The first uses a large T400A-2 toroid
  - Must be manually inserted and 160/80 Meters selected with straps
- The second uses the T400A-2 toroid with relays for remote switching
  - Remotely switchable for 160-, 80-, or 60-10 Meters
- The third uses an air-core inductor and relays
  - OK OK – so I like to keep tinkering!!
  - But this is the best solution (lower inductor losses)

Toroid Matching Solution

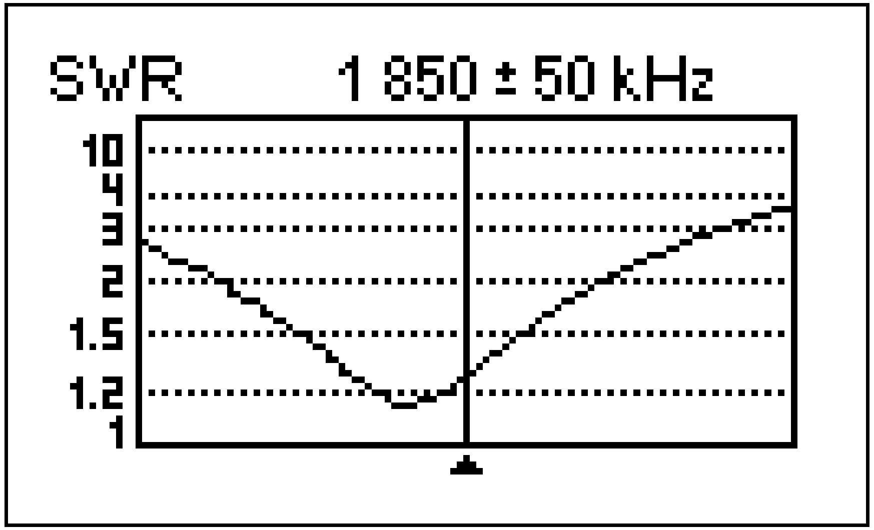
- Fits into a 6x6x4” electrical box from Lowes

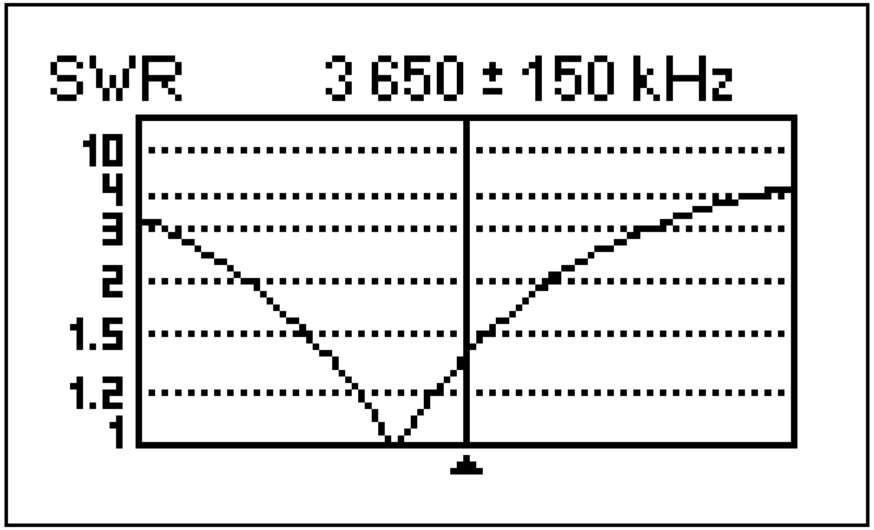




AD5X #1: Toroid Matching Solution

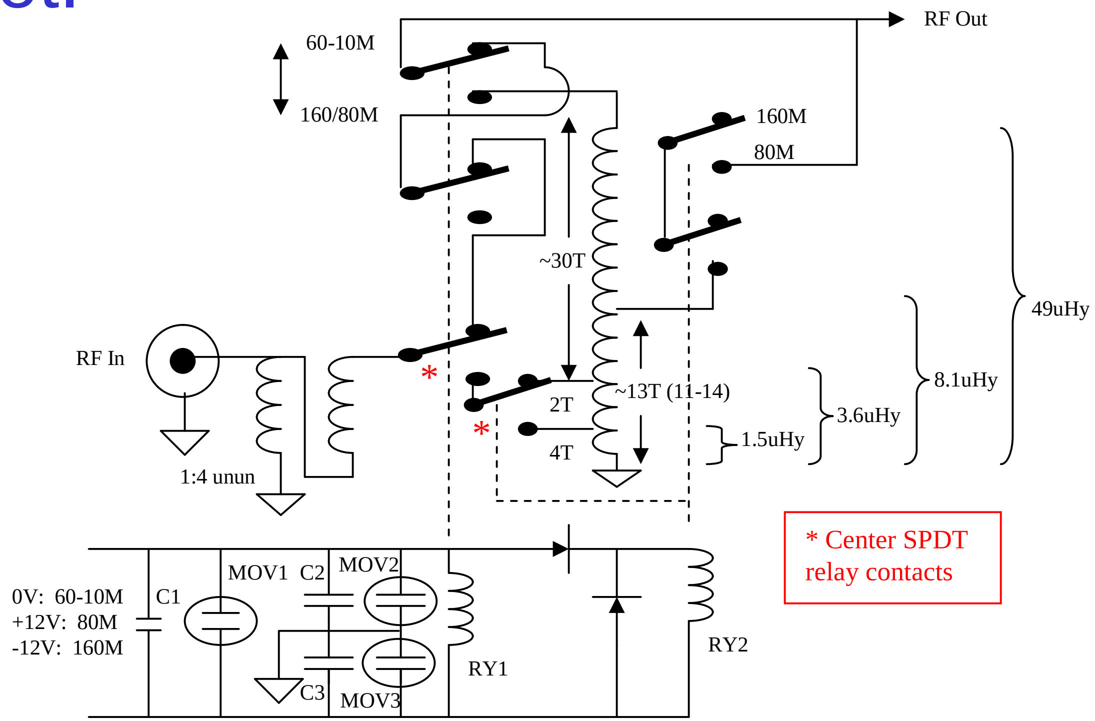
- How well does it work?





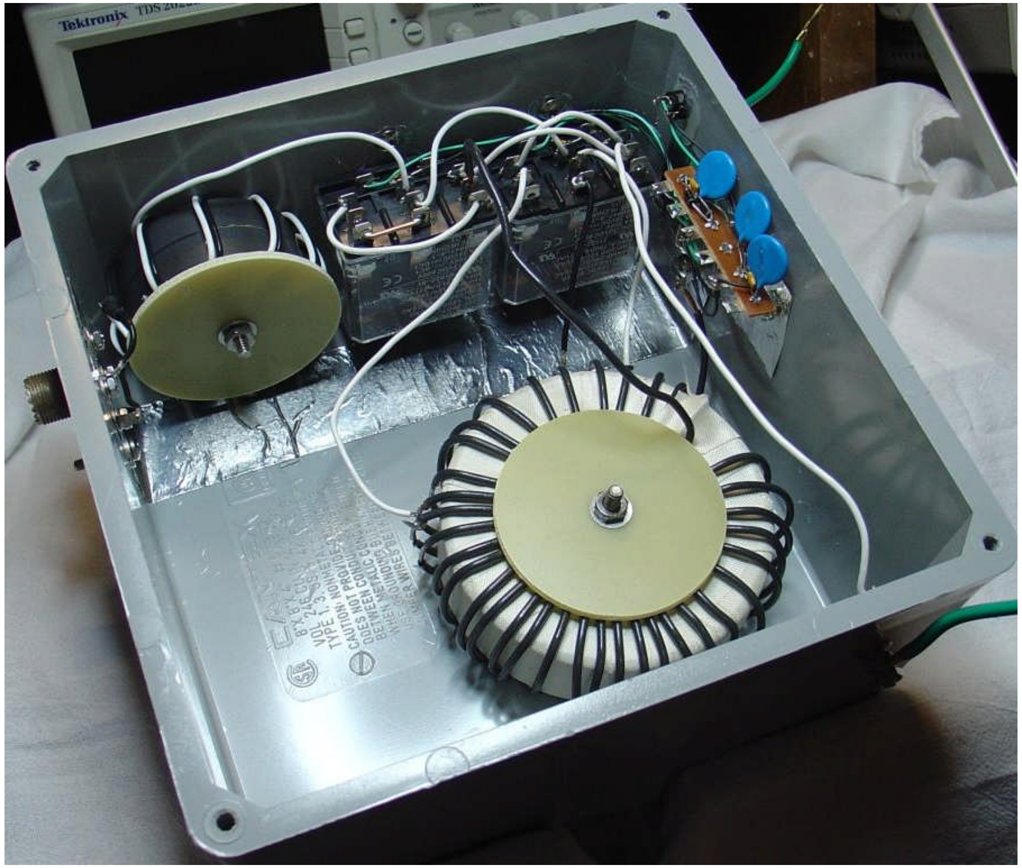
AD5X #2: Switchable Matching Solution

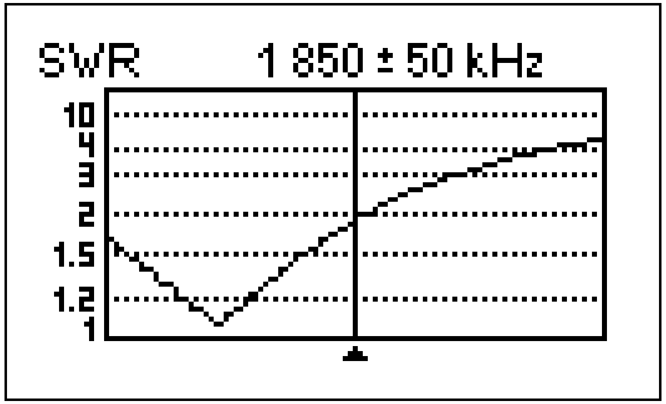
- Fits in 8x8x4” electrical box from Lowes/Home Depot.

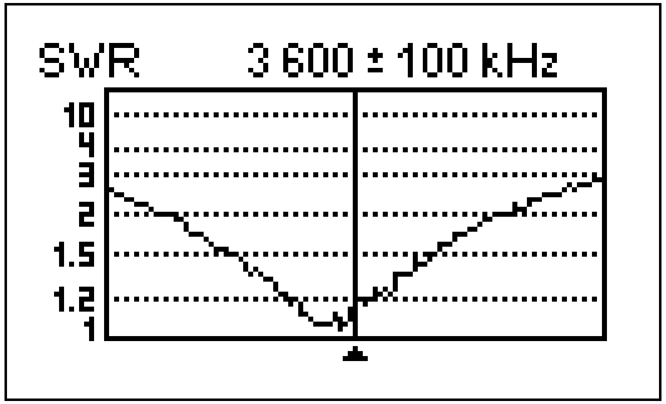


Toroid-based 160/80 Meter Impedance Matching Network

AD5X #2: Switchable Matching Solution







#3: Switchable Matching Solution

- Fits in 8x8x4" electrical box from Lowes/Home Depot.

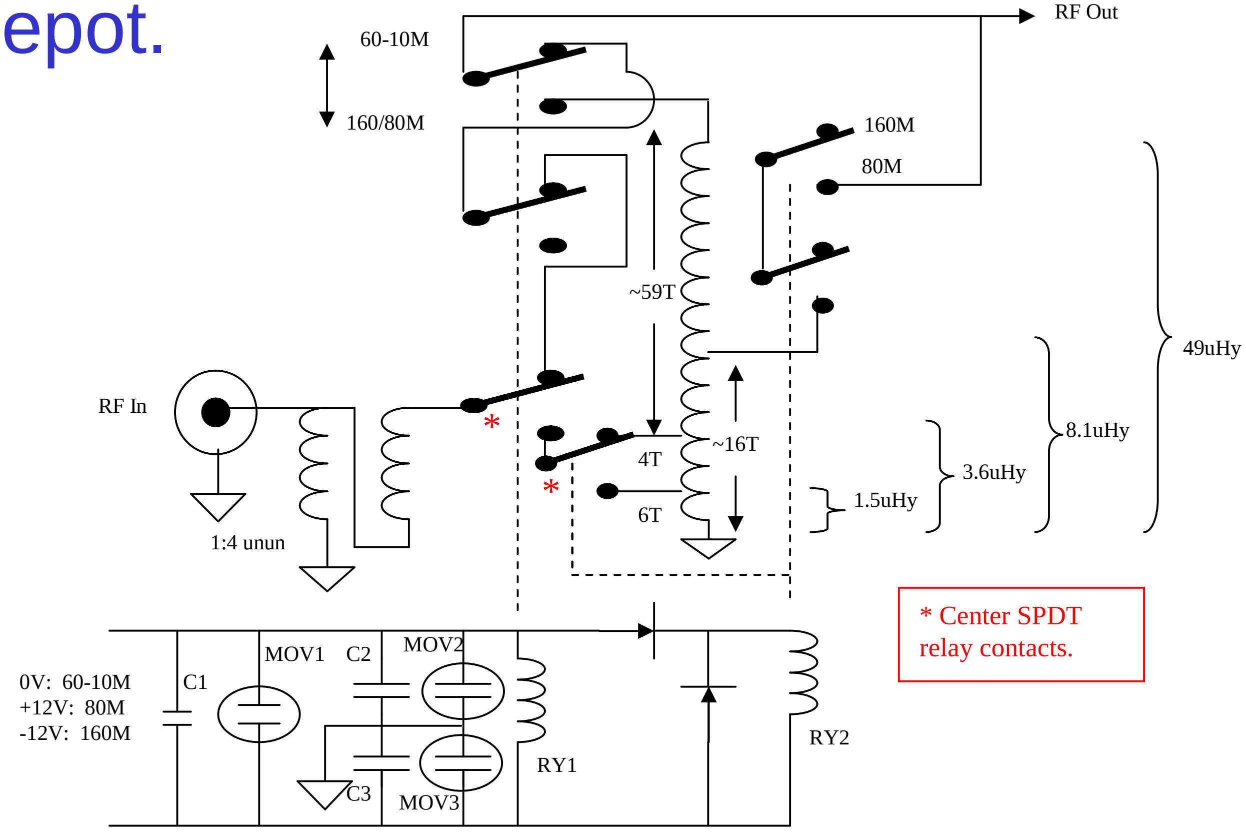
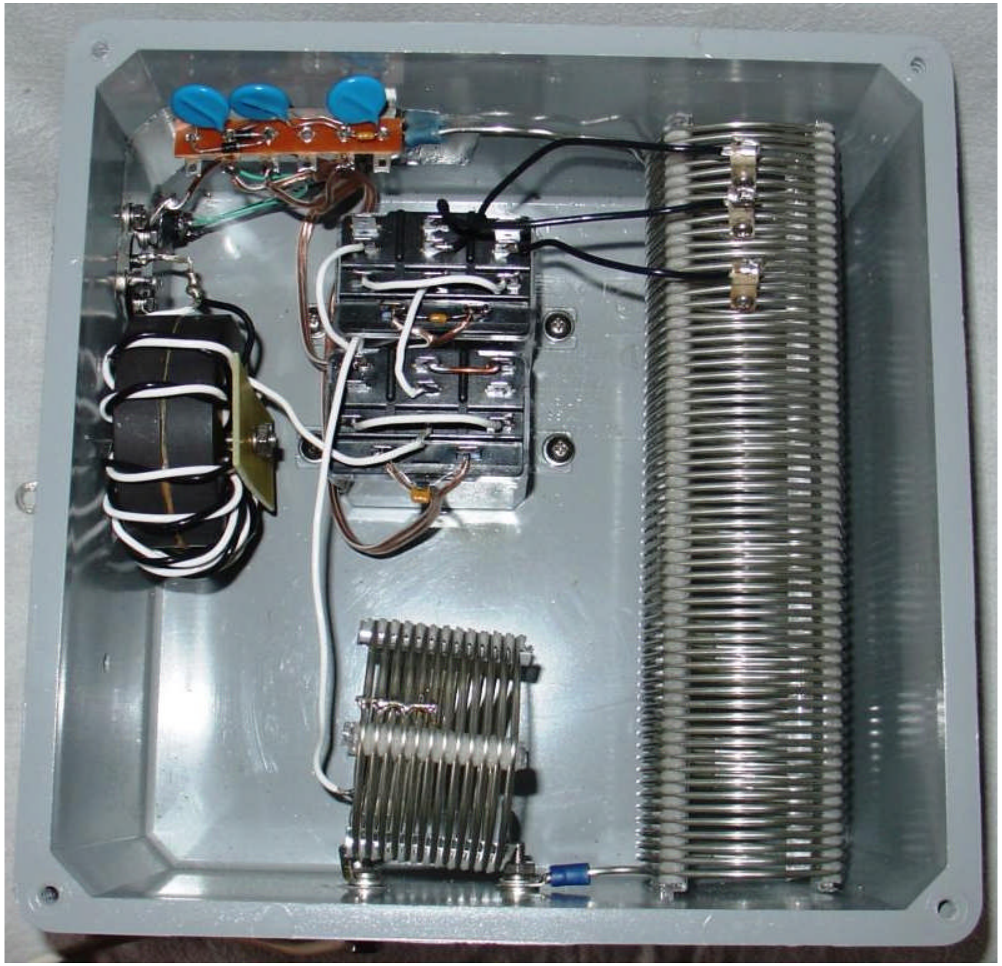
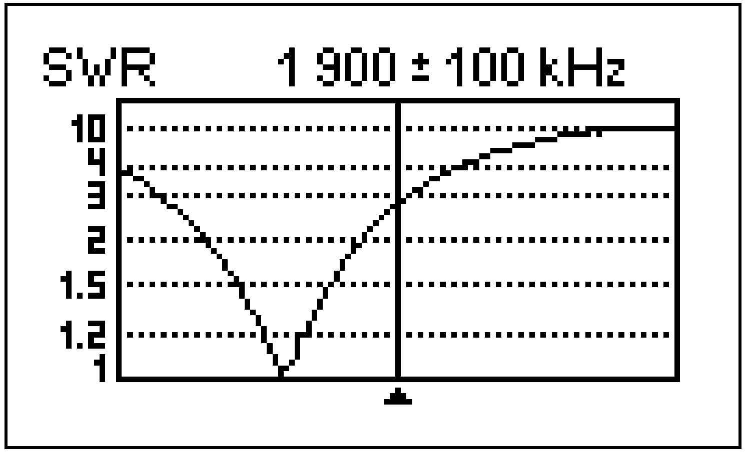
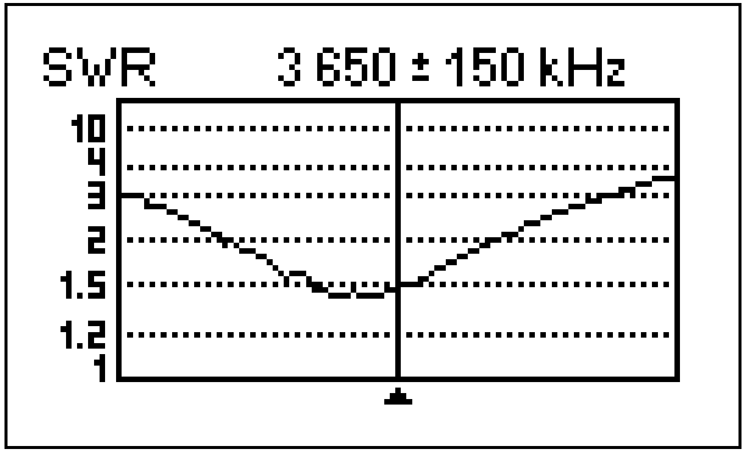


Figure 6: 160/80 Meter Impedance Matching Network

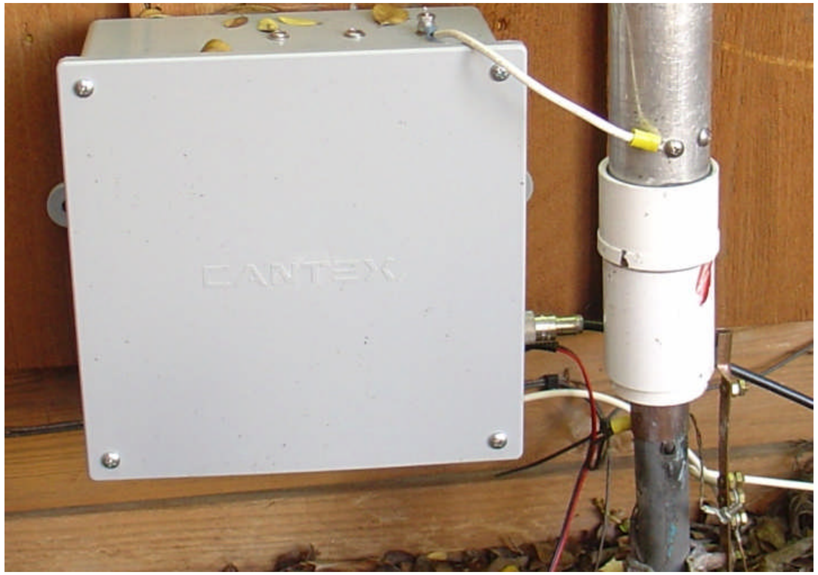
#3 Switchable Matching Solution







Which Solution Is For You?



If you run high power, the air-core inductor solution gives the lowest losses (Inductor Q>400). However, toroid dissipation is not an issue at lower powers as toroid heating increases as I^2. Example:

1500 watts: Toroid dissipates ~500 watts
750 watts: Toroid dissipates ~120 watts.

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Build your own 43-Foot Vertical

Aluminum Tubing from Texas Towers:

- 2”ODx0.12”x6’ = $33.00
- 1.750”ODx0.062x6’ = $16.80
- 1.625”ODx0.062x6” = $15.30
- 1.500”ODx0.062x6’ = $13.50
- 1.375”ODx0.062x6’ = $12.30
- 1.250”ODx0.062x6’ = $11.10
- 1.000”ODx0.062x6’ = $9.00
- 0.875”ODx0.062x6’ = $8.40
- 0.750”ODx0.062x6’ = $7.80
- 0.625”ODx0.062x6’ = $7.20

Total = $127.40 + Tax
+ 9 SS hose clamps.

Probably around $160 total

Build Your Own Base Mount

2”OD Antenna

1-1/2”x1/2” PVC Bushing

1”x1/2” Copper Reducer

1” Copper pipe

Base mount (Cont.)

- Base mount doesn’t need to be tilt-over
- And it doesn’t need to support the antenna if you can use your house or a fence for support.
- My solution:

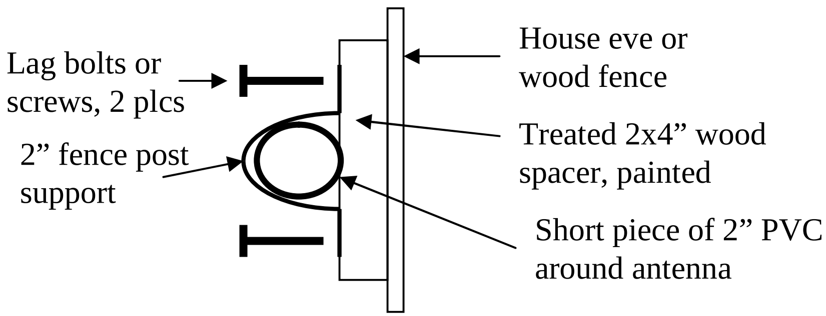
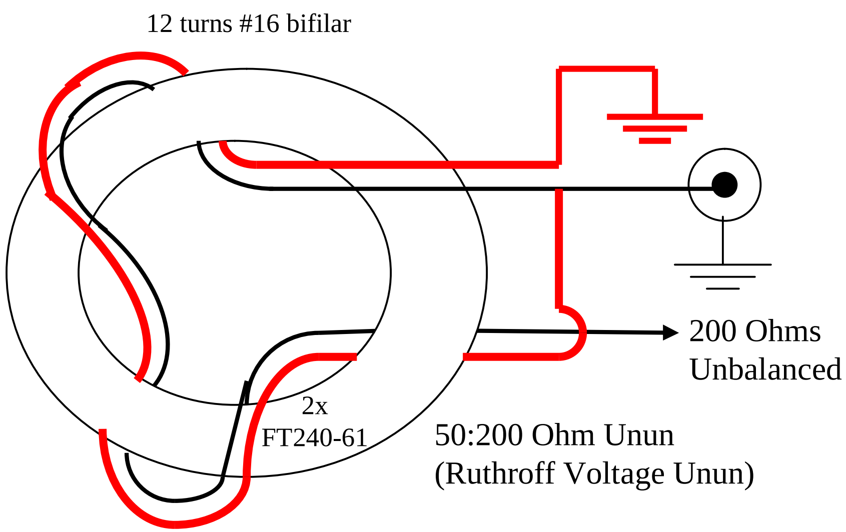
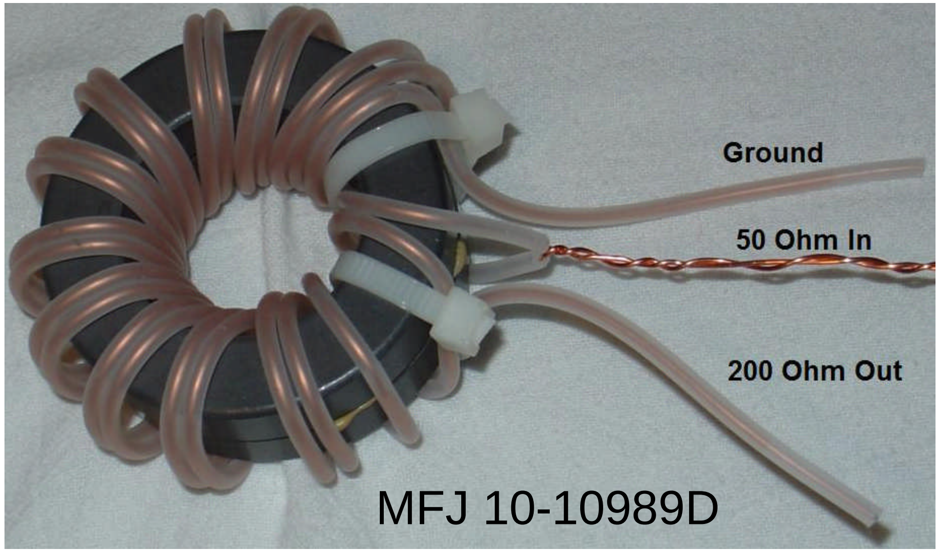


Figure 1: Alternative House or Fence Support

Build Your Own Unun

- 12 bi-filar turns #16 teflon insulated wire on two FT240-61 toroids
  - Excellent wire substitute: McMaster 9634T701 2-cond HV wire ($3/ft). This is 20KV-rated wire.





Build Your Own Antenna - Alternative

- Purchase MFJ-1965 ($200)
  - 64-ft telescoping aluminum mast with slotted tubing and hose clamps
  - Telescope down to 43-ft. Good tubing overlap = very robust antenna.
- Purchase MFJ-1900 Base Mount ($70)
- Purchase MFJ-10989D Balun ($30)
  - Mount in Lowe's electrical junction box.
- Of course, now you're approaching the cost of a ready-to-go 43-foot commercially-available vertical
- Or consider a mix of purchases and home build assemblies

Summary

- The more metal in the air, the better the antenna
  - Radiation resistance increases as the square of the length change.
  - Increased radiation resistance improves antenna efficiency over real ground.
- A 43-foot antenna is very good for 60-10 meters
- A 43-foot antenna needs base matching to provide good results on 160- and 80-meters.
  - Detailed matching network details at www.ad5x.com

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Parts Sources

- MFJ Enterprises
  - 404-0669 coil, 10-10989D unun
- Array Solutions
  - RF-10, RF-3PDT-15 relays
- Texas Towers
  - Aluminum tubing
- AutoZone
  - Stainless-steel muffler/hose clamps
- Lowes/Home Depot
  - Junction boxes, wire, hardware, Teflon™ or glass tape, fence-post clamps, copper pipe, PVC adapters
- CWS Bytemark
  - FT240-61, FT400A-2 toroids