



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
- ◆ RF Voltages
- ◆ Matching Networks for 160- and 80-meters
- ◆ Building your own 43-foot vertical



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!)

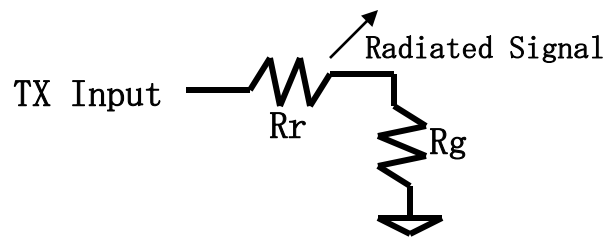
◆ Disadvantages

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



Ground Loss & Antenna Efficiency

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



- ◆ **Antenna Efficiency (%)** = $100 \times R_r / (R_g + R_r)$

- ◆ You can get very close to actual short antenna impedances using simple calculations.
 - $R_r = (\text{Actual length} \div \frac{1}{4} \text{ wave length})^2 \times 36 \text{ ohms}$
 - $C_{pf} = 3.5 \text{ pf/ft} \times \text{Actual length}$
- ◆ 43-foot 160 meter examples
 - $R_r = 43/128 \times 36 = 4 \text{ ohms}$
 - EZNEC = 3 ohms
 - $C = 3.5 \times 43 = 150.5 \text{ pf} = -j580$
 - EZNEC = -j640 **BUT** VNA actually measured -j580
 - Nearby objects add some stray capacitance



Efficiency Calculation

- ◆ A $\frac{1}{4}$ -wave vertical has a radiation resistance of 36 ohms.
- ◆ Assume 10 ohms of ground loss
 - Probably a *much* better ground than most hams have
- ◆ Your SWR = 1.09:1
 - $R_r + R_g = 36 + 10 = 46$ ohms
 - $SWR = 50/46 = 1.09$
- ◆ Your antenna efficiency is 78%
 - If you have a 100 watt transmitter, you will radiate 78 watts



Electrically Short Antennas have Low Radiation Resistance

- ◆ 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.
- ◆ R_r decreases approximately as $1/\text{length}^2$.
- ◆ So R_r is approximately 5 ohms.
- ◆ With 10 ohms ground loss, the efficiency is 33%
 - Assumes no trap/inductor losses
- ◆ Now your 100 watt transmit signal results in only 33 watts being radiated.



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.
- ◆ R_r decreases as $1/\text{length}^2$.
- ◆ So R_r 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.



The 43-foot Vertical Antenna

◆ Advantages

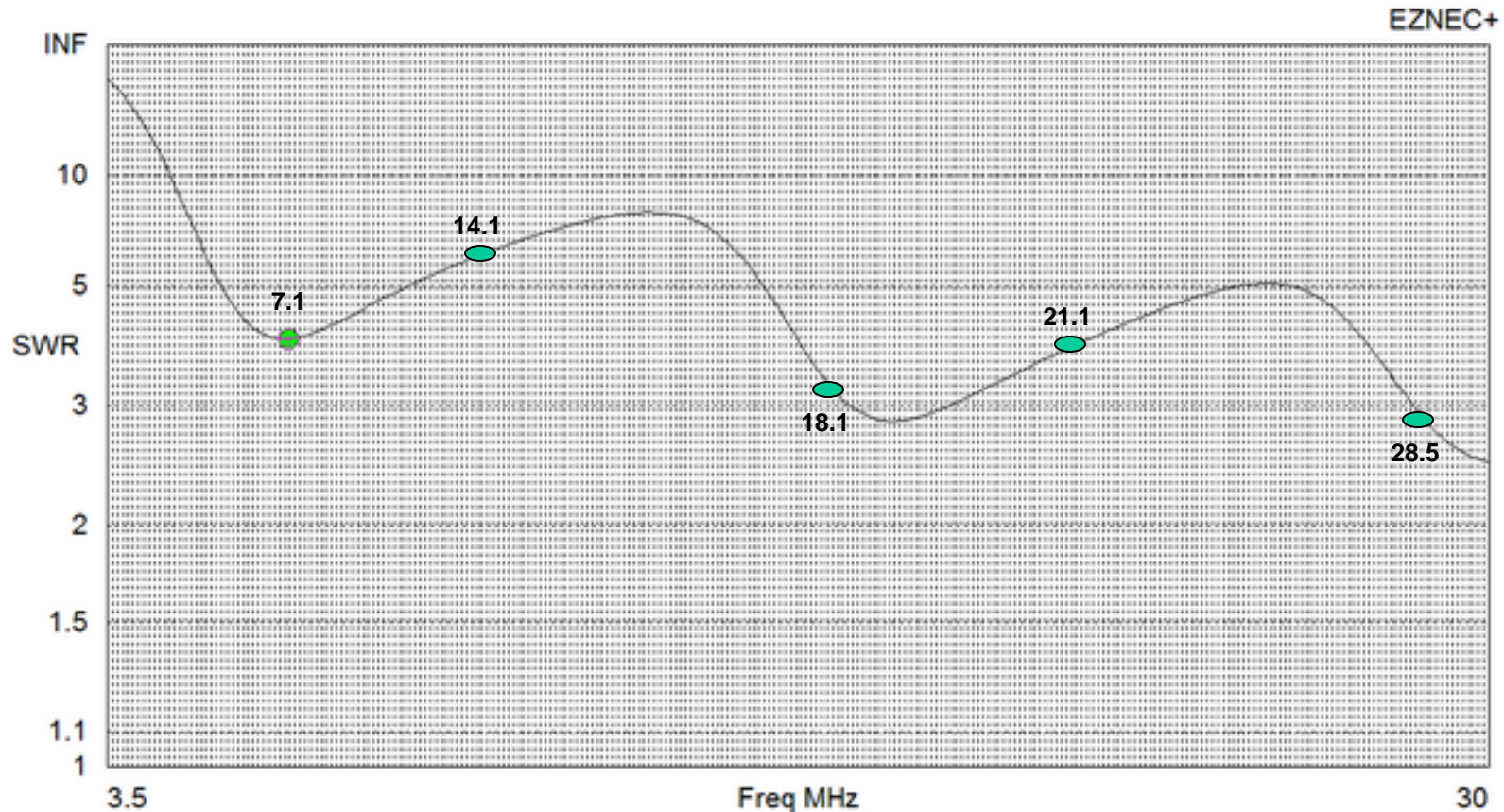
- Still can be self-supporting & moderately unobtrusive
- Approximately 3X higher radiation resistance than the typical trap or loaded vertical.
- No trap or loading coil losses to worry about
- Modest compromise SWR from 60-10 meters when fed with a 1:4 unun.

◆ Disadvantages

- Take-off angle is not optimum on 12/10 meters
 - More on this later)
- You need an in-shack tuner



43-foot SWR over Perfect Ground with 1:4 Unun at the Antenna



EZNEC Generated SWR Curve: 43-foot vertical over perfect ground with 1:4 unun
Thanks to Dave Cuthbert WX7G



43-Foot Vertical SWR (Cont.)

- SWR-related cable losses are fairly minimal.
 - Refer to SWR-related cable loss curves in the ARRL Handbook & ARRL Antenna Book
- SWR over real ground is better
 - My worst case SWR is 5:1 on 20 meters
 - ↓ vs EZNEC calculated 6.5:1 over perfect ground
 - ↓ 60 feet LMR-400 SWR-related coax losses: 0.4dB on 20 meters

A couple of references

- Dave Cuthbert WX7G: “The 43' Vertical -- a Theoretical Analysis”, www.eham.net/articles/21272.
- W. Griffith W5CSU "The Truth About the Vertical Antenna“, May 1952 QST
 - This antenna has been around a long time!



43-Foot Antenna Efficiency

◆ The Hustler 6BTV on 40 meters

- The 24-foot Hustler is 0.188 wavelengths long
- Hustler $R_r = 20$ ohms
- Efficiency = 67% (assumes $R_g = 10\Omega$ & no coil losses)
 - **Note:** There are multiple inductors (traps) in-line on 40 meters

◆ The 43-foot vertical on 40 meters

- Antenna is 0.34 wavelengths long
- $R_r = 65$ ohms
- Efficiency = 87% (with $R_g = 10\Omega$ with no coils/traps)



43-foot Antenna Disadvantages?

- ◆ Can be moderately expensive
 - But you can build your own (we live close to Texas Towers!)
- ◆ High take-off angle above 15 meters
 - DX performance \geq 1/4-wave vertical 60-15 meters, but 5dB down from 10 meter 1/4-wave vertical at 10 degree take off angle (but higher Rr compensates some)
- ◆ Really needs base matching on 160/80-meters
 - Regardless of what the 43-foot antenna vendors say
- ◆ Example: With $R_g = 10\Omega$,
 - 160 Meter SWR = 324:1, 80 Meter SWR = 41:1



Matching & Coax Losses

- ◆ Some 43-foot antenna vendors claim the antenna can be matched from 160-10 meters with your in-shack tuner.
- ◆ One vendor says to use 150 feet of RG-213 for best all-band operation of the 43-foot antenna (so you can tune from the tuner in your shack). Another vendor says to **ADD** 150 feet of RG-213 to your cable run.
- ◆ The typical 160 meter base impedance of a 43-foot antenna with the 1:4 UNUN is $2 - j183$. 150 feet of coax transforms this to a matchable $38 + j180$ at the shack.
- ◆ But the antenna SWR is $\sim 150:1$ resulting in 12dB (two S-units) of **coax losses** due to the SWR at the antenna. Plus about ≥ 6 dB ground loss. Total loss ~ 18 dB.
 - TX = 100W results in **2-watts radiated**



Matching & Coax Losses (Cont.)

- ◆ Add to this additional unun losses due to the severe mismatch, plus internal losses in your antenna tuner.
- ◆ On 80 meters, SWR-related coax cable loss (150 feet) is 4.7 dB, plus 3 dB ground loss. Total loss ~8 dB.
 - TX = 100 watts results in **16-watts radiated**
 - Again, don't forget to add in unun and tuner losses
- ◆ Will shack matching work? Sure – because QRP works. But sometimes you want more than QRP power on 160 & 80 meters!



First: 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.
- ◆ FYI - With 150 feet of RG-213, the 20 meter SWR-related cable loss would be 1 dB, plus 0.8 dB matched cable loss
 - Total cable loss = 1.8 dB



160/80 Meter Matching

- ◆ Difficult to match the 43-foot vertical on 160/80-meters from your shack when low-loss coax is used! The mismatch may be too great for most manual- or auto-antenna tuners (though adding coax can help the match as discussed earlier).
 - But don't forget about the significant SWR-related losses also discussed earlier!
- ◆ The right thing to do is to 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 final matching from the shack very easy.



Two Ways to Match

◆ Autotuner at antenna base

- Autotuner needs $> 50\mu\text{H}$ for 160 meter matching.
- Most autotuners will match 80-10 meters.
- Evaluated CG-3000, CG-5000, MFJ-927 and SG-230
 - Only SG-230 has enough inductance to tune 160 meters, but you're limited to 200 watts PEP
 - MFJ-927 will tune 160 meters with external coil (see my website), but again you're limited to 200 watts PEP.
 - CG-3000/5000 claim enough inductance to tune 160 meters, but they don't!

◆ Relay-switched or manual tuner at antenna base

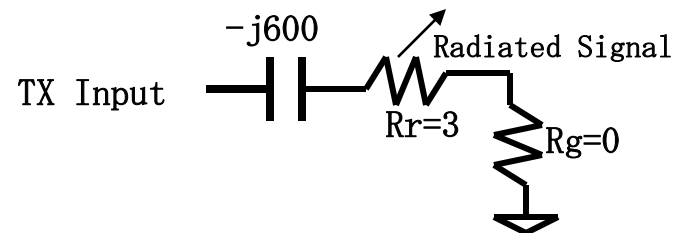
- My preference is the relay-switched matching unit



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 ground system ($R_g = 0$) on 160 meters. In this case all power is delivered to R_r .

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



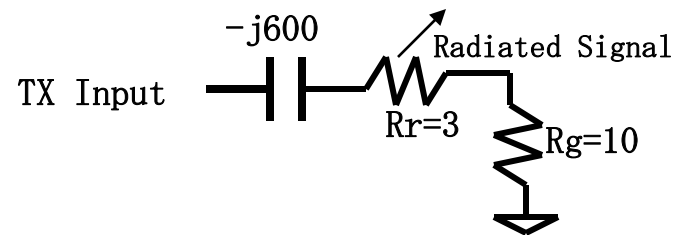
- ◆ Example: Assume 1500 watts and $R_g = 10$ ohms on 160 meters. Now all power is delivered into $R_r + R_g$:

$$I = \sqrt{(1500/13)} = 10.74 \text{ amps rms}$$

$$|Z| = \sqrt{(13^2 + 600^2)} = 600.1$$

$$\text{So, } V_{\text{rms}} = 10.74 \times 600.1 = 6,445$$

$$\text{And } V_{\text{pk}} = 9,115 \text{ volts}$$



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

$$I = \sqrt{(600/13)} = 6.8 \text{ amps rms}$$

$$\text{So, } V_{\text{rms}} = 6.8 \times 600.1 = 4,081$$

$$V_{\text{pk}} = 5,770 \text{ volts}$$



RF Voltages (Cont.)

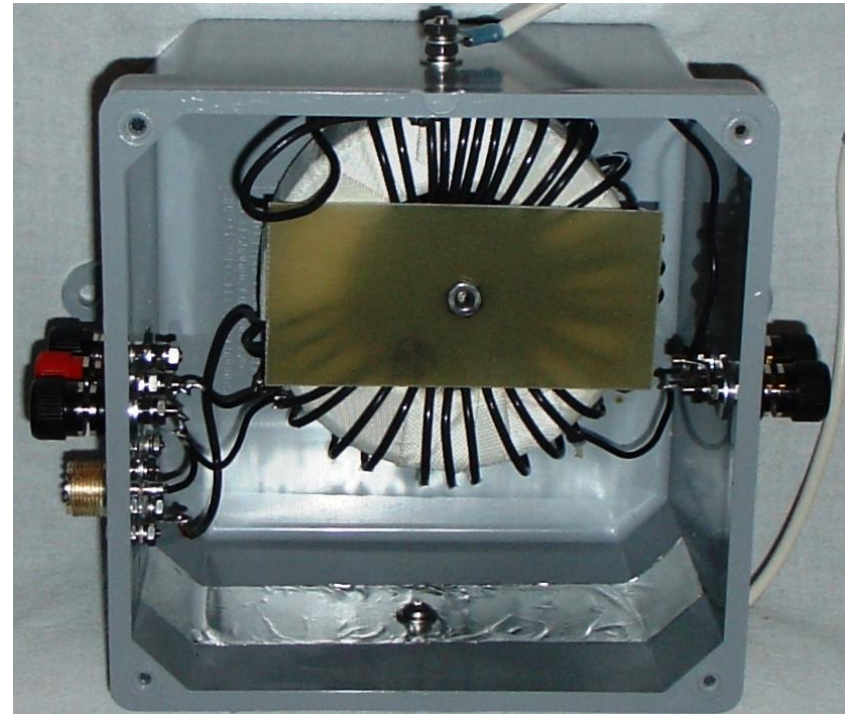
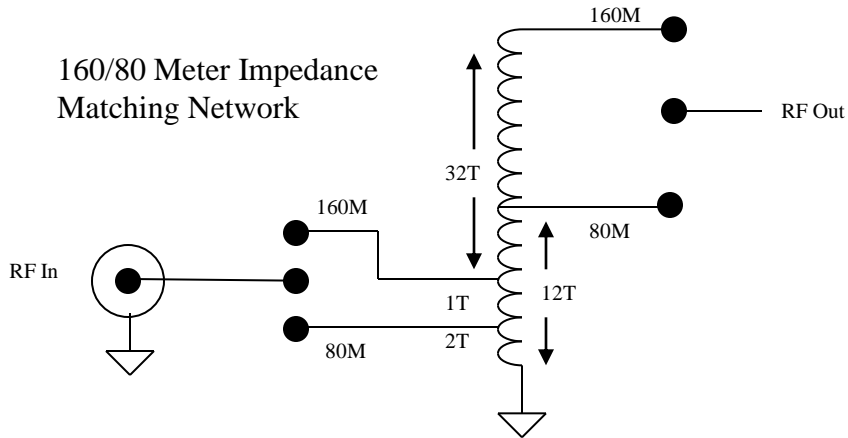
- ◆ For switched matching networks, switches or relays must have high breakdown voltage ratings.
 - For relays:
 - Contact-to-contact (Put contacts in series to increase breakdown voltage)
 - Contact-to-coil
- ◆ Two relays:
 - Array Solutions RF-10 DPDT Relay good for about 500 watts
 - 1.7KV peak contact-to-contact breakdown voltage
 - 3.1KV peak contact-to-coil breakdown voltage
 - Array Solutions RF-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



160- & 80-Meter Matching

- ◆ Three matching units were built
 - See www.ad5x.com for more details
- ◆ The first uses a large T400A-2 toroid
 - Must be manually inserted and 160/80 Meters selected with straps
- ◆ The second adds 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 (lowest inductor losses)

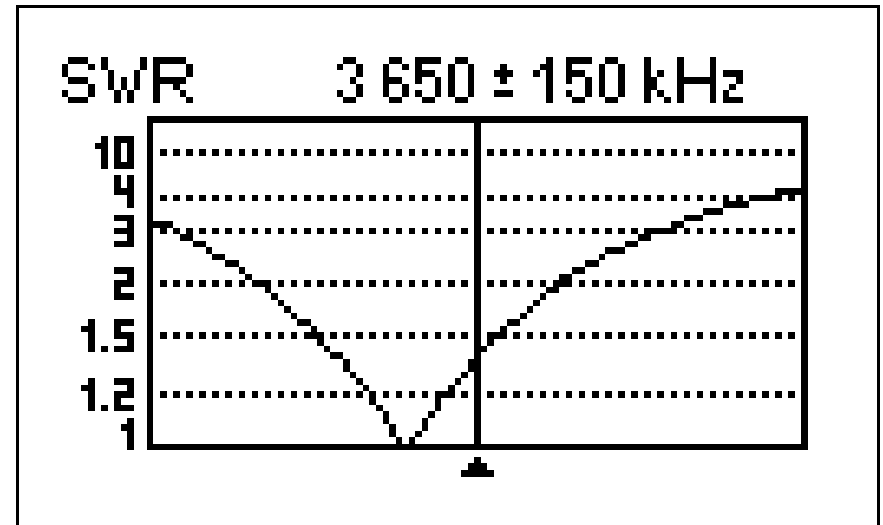
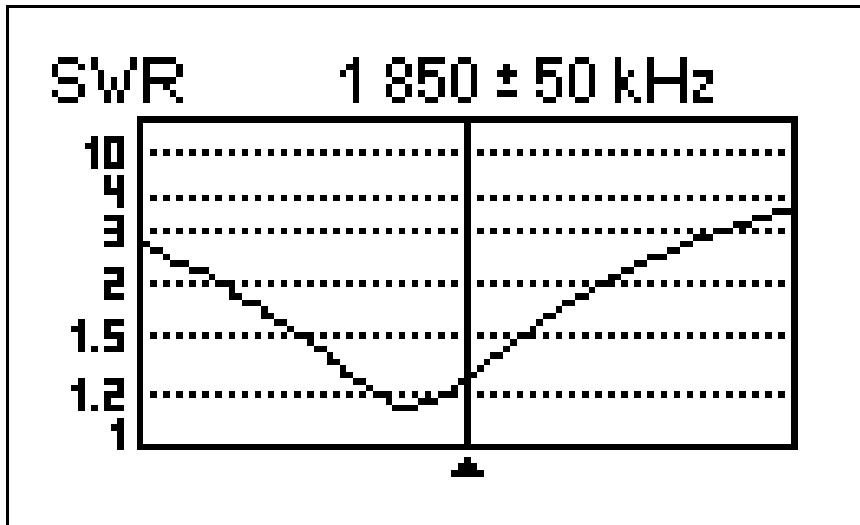
◆ Fits into a 6x6x4" electrical box from Lowes



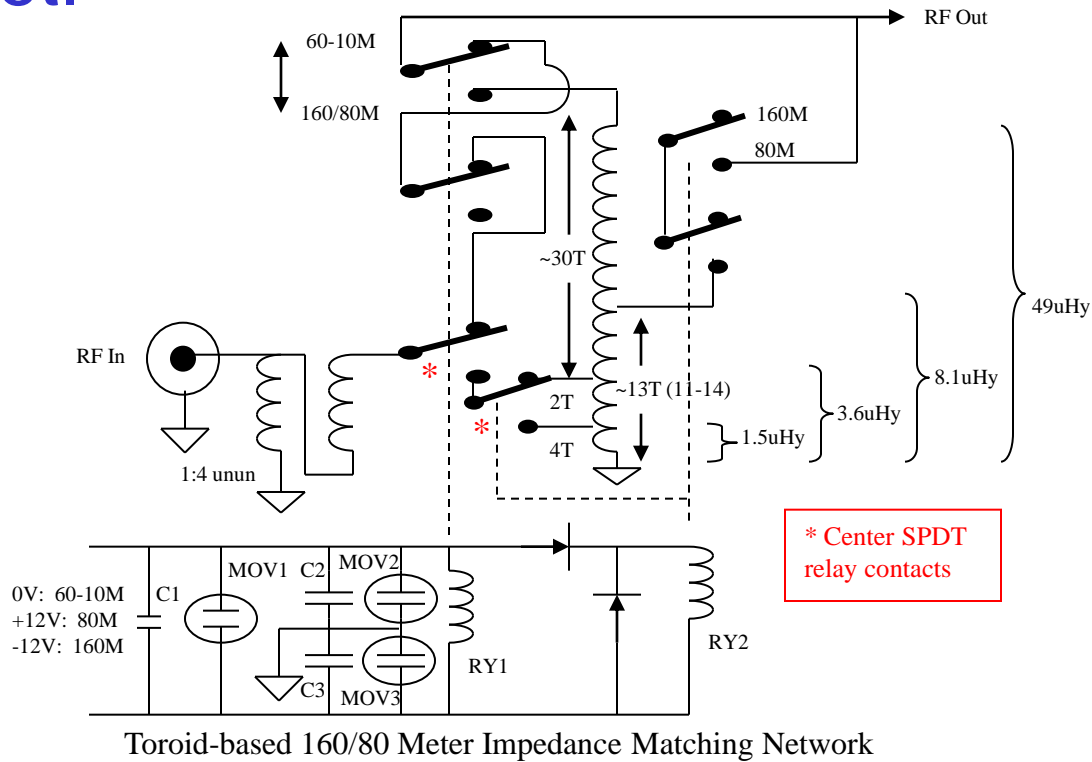


#1: Toroid Matching Solution

◆ How well does it work?

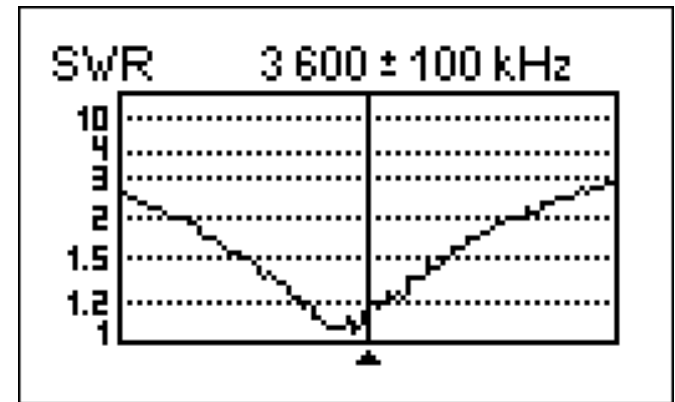
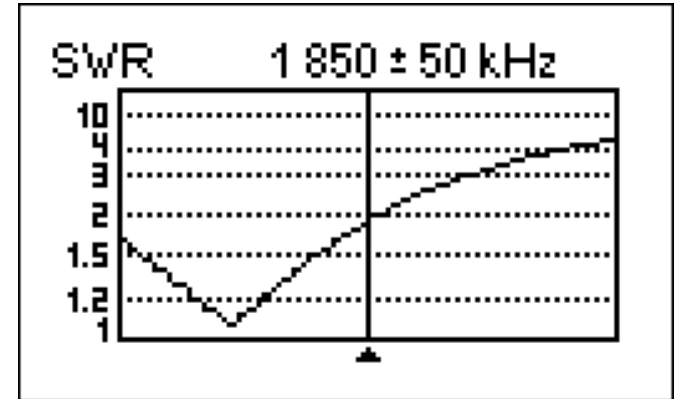
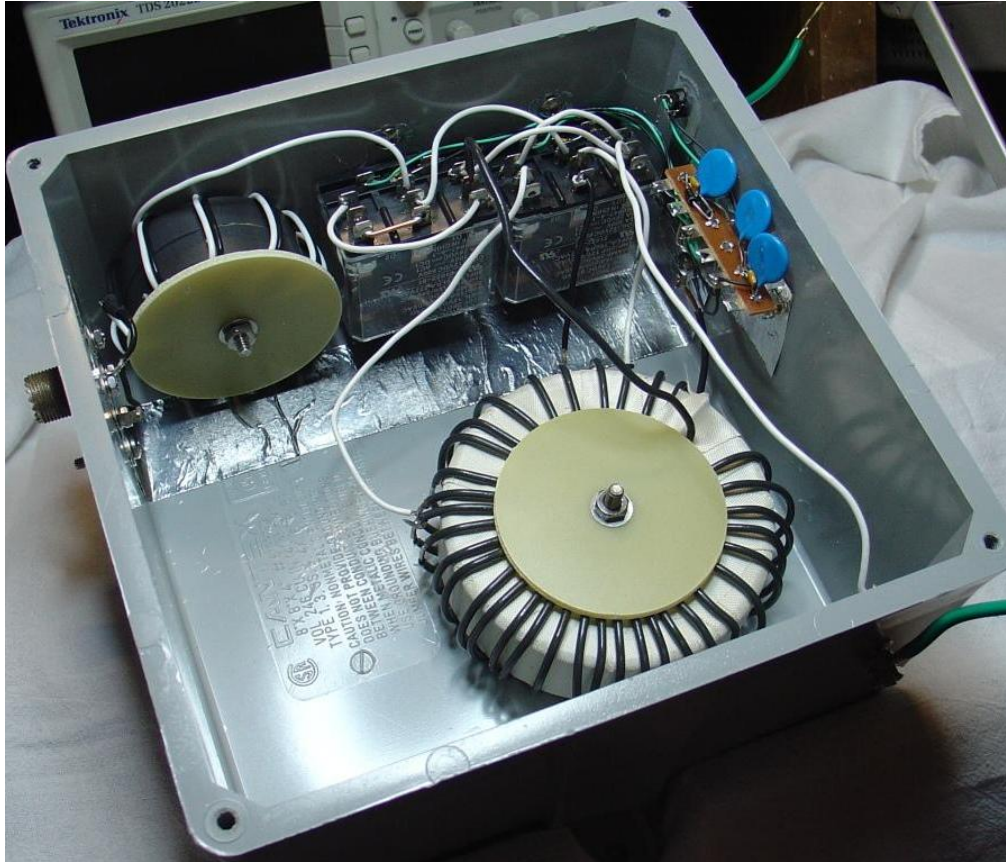


- ◆ Fits in 8x8x4" electrical box from Lowes/Home Depot.





#2: Switchable Matching Solution



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

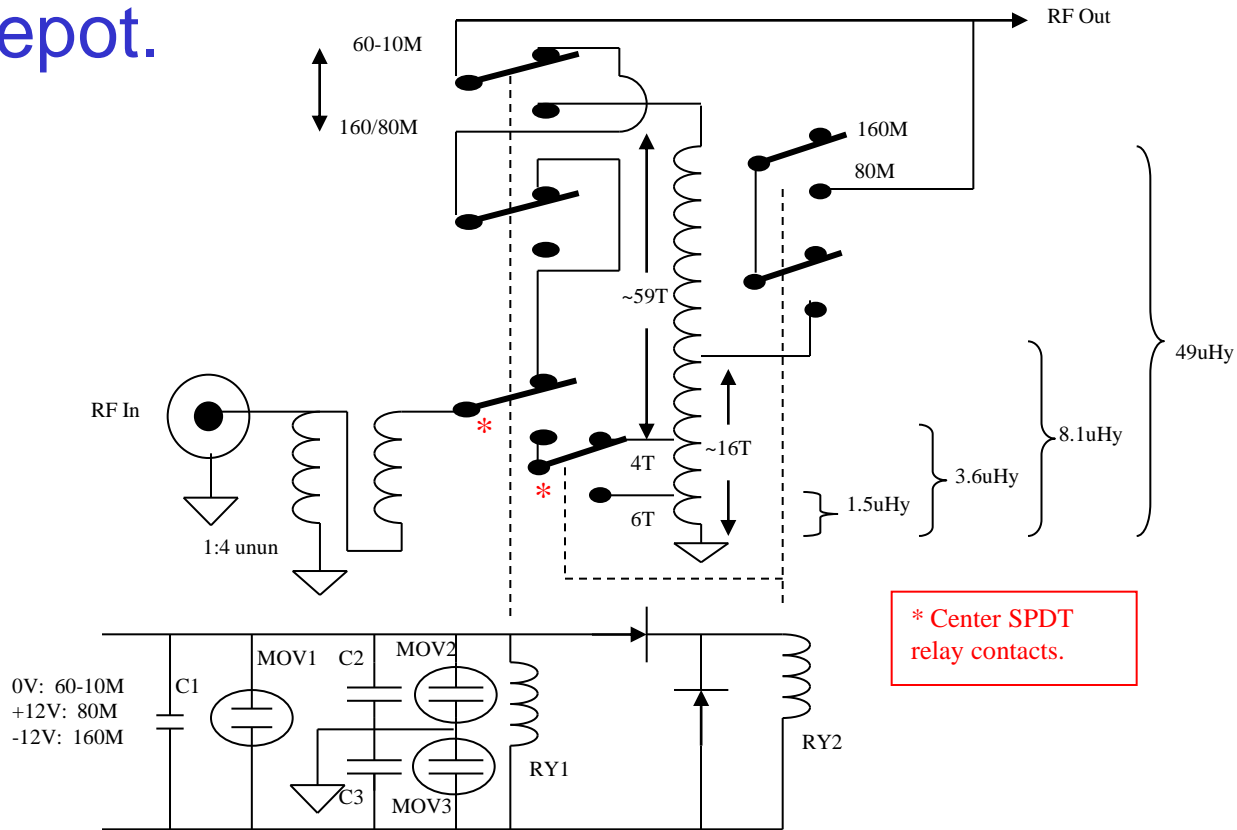
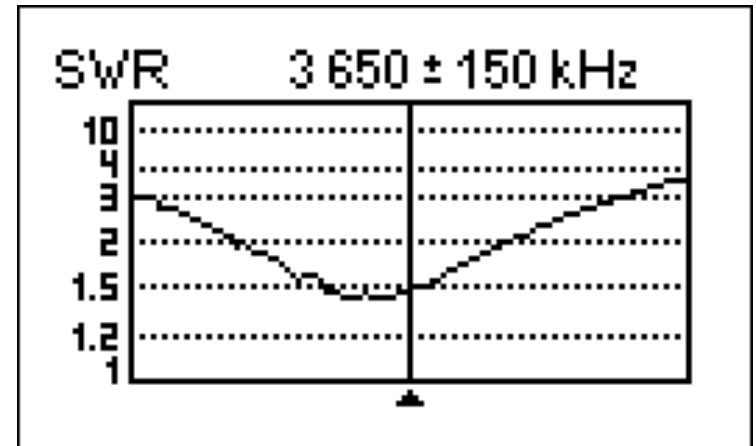
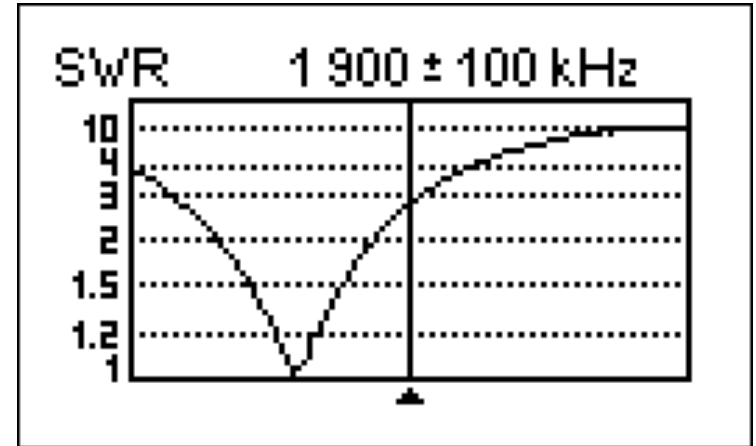
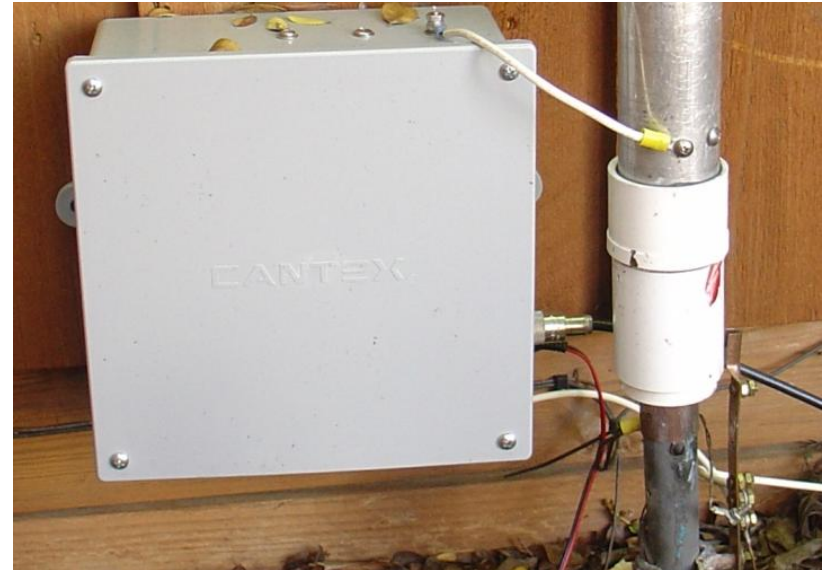


Figure 6: 160/80 Meter Impedance Matching Network

#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 linearly with power. Example:

1500 watts: Toroid dissipates ~240 watts

750 watts: Toroid dissipates ~120 watts.



Build your own 43-Foot Vertical

◆ Aluminum Tubing from Texas Towers:

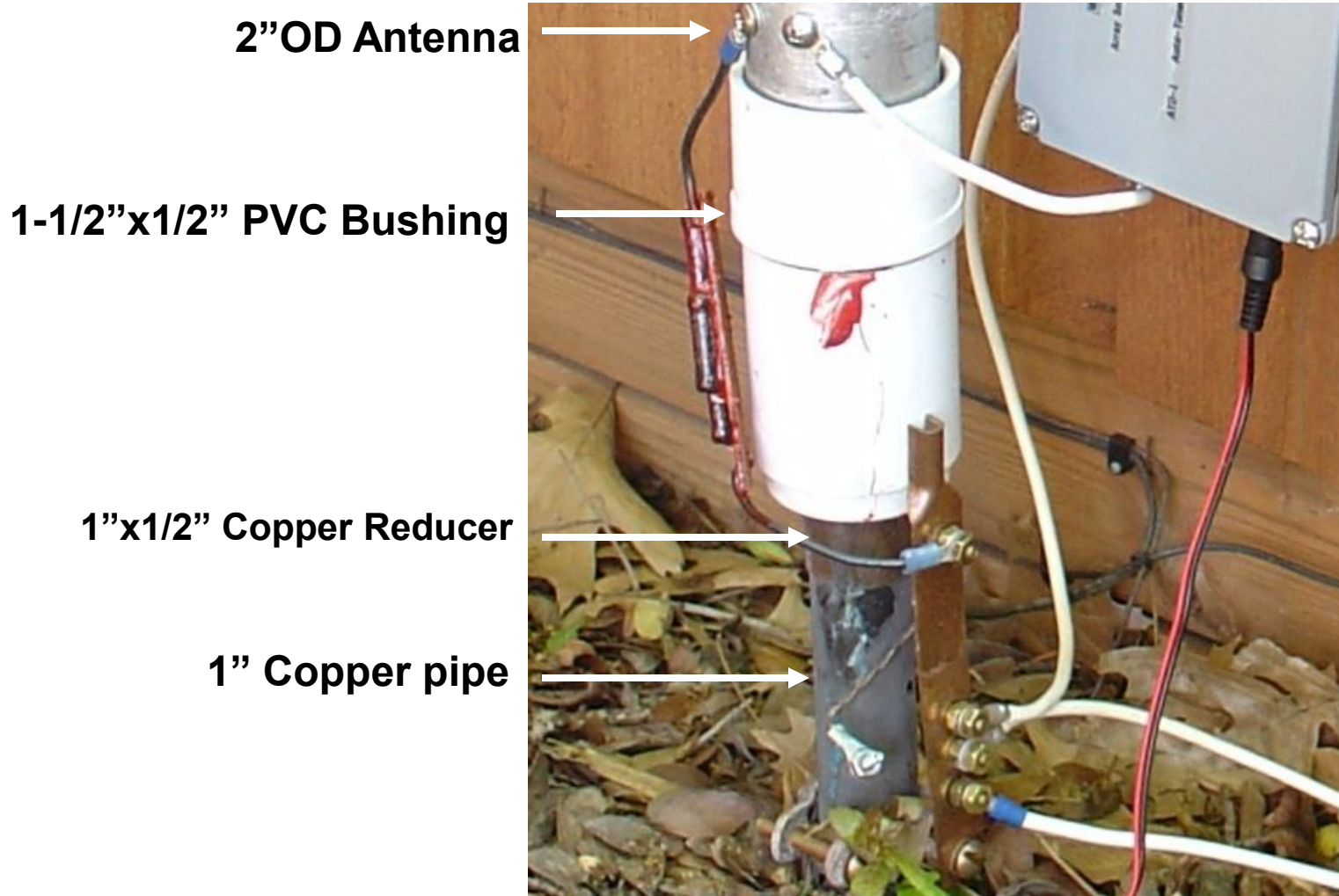
- 2"ODx0.120"x6' = \$33.00
- 1.750"ODx0.058x6' = \$16.80
- 1.625"ODx0.058x6' = \$15.30
- 1.500"ODx0.058x6' = \$13.50
- 1.375"ODx0.058x6' = \$12.30
- 1.250"ODx0.058x6' = \$11.10
- 1.125"ODx0.058x6' = \$ 9.90
- 1.000"ODx0.058x6' = \$9.00
- 0.875"ODx0.058x6' = \$8.40
- 0.750"ODx0.058x6' = \$7.80

**Total ~ \$130.00 + Tax
+ 9 SS hose clamps.**

Probably around \$140 total

Note: Prices will change with time!

Build Your Own Base Mount



- ◆ 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:

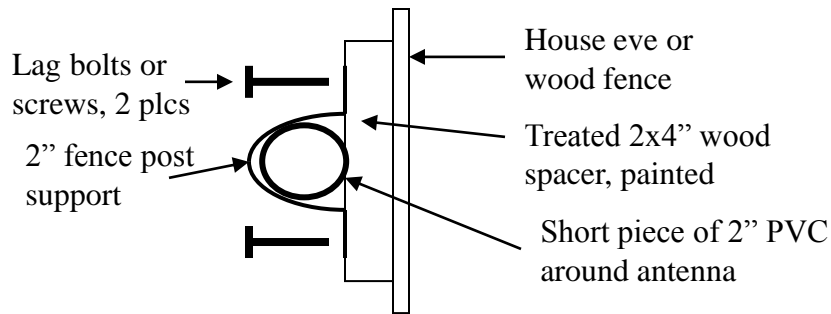
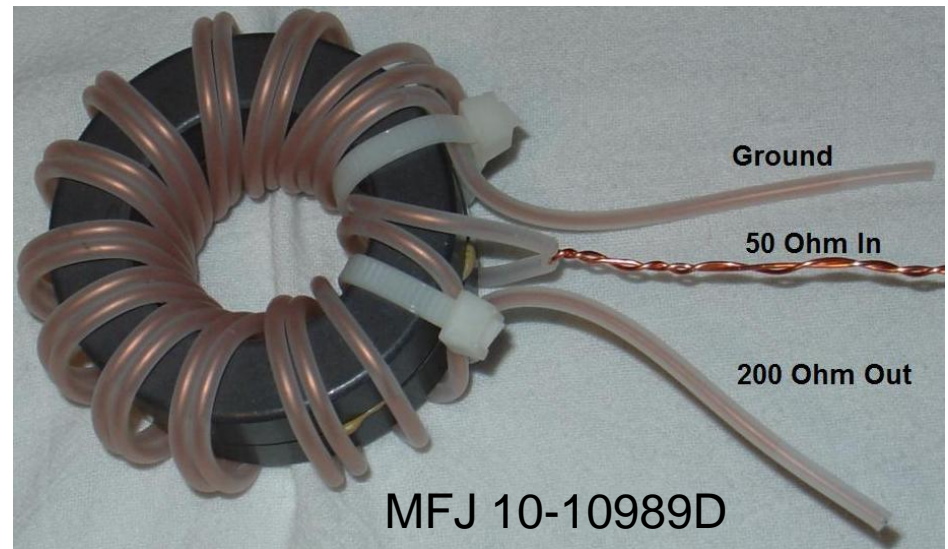
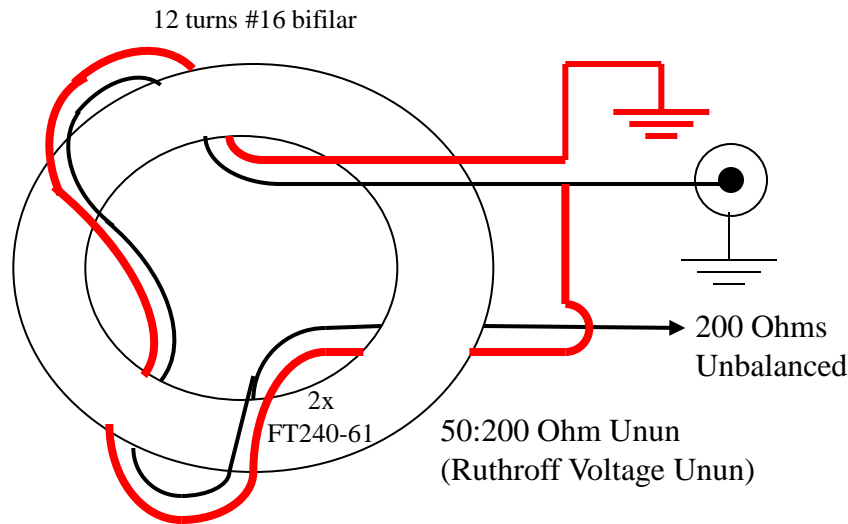


Figure 1: Alternative House or Fence Support



Build Your Own Unun

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





Build Your Own Antenna - Alternatives

◆ Purchase MFJ-1965 (\$200)

- 64-ft telescoping aluminum mast w/ slotted tubing & hose clamps
- Telescope down to 43-ft. Good tubing overlap = robust antenna.

OR

◆ Purchase a self-supporting fiberglass 43-foot vertical from LDG (www.ldgelectronics.com) <http://www.ldgelectronics.com/http://www.ldgelectronics.com/>

- At \$200 (including 1:4 unun), this is very attractive

THEN

◆ Build your own base mount and unun.



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



Parts Sources

◆ MFJ Enterprises

- 404-0669 coil, 10-10989D unun

◆ Array Solutions

- RF-10, RF-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 (CWS F-240-61), FT400A-2 (CWS T400-2D)