Integrated Tuning for 160 and 80 meter Dipoles and Verticals

Hamcation 2024

Nelson Sollenberger
KA2C

Slides at www.KA2C.com/antennas

Challenges with 160/80 Meter Antennas

- Everything is big
  - Tall towers and long wires
  - Large inductors for loading/tuning
  - Large radial ground systems
- Antenna bandwidth
  - Most antennas only cover a fraction of the 160/80m bands which are wide as a percentage of frequency
  - Some form of tuning is common
  - High SWR operation is common
    - Does not necessarily mean poor efficiency but efficiency may be poor
    - Does require matching somewhere
    - May result in very high voltages/currents in parts of the system

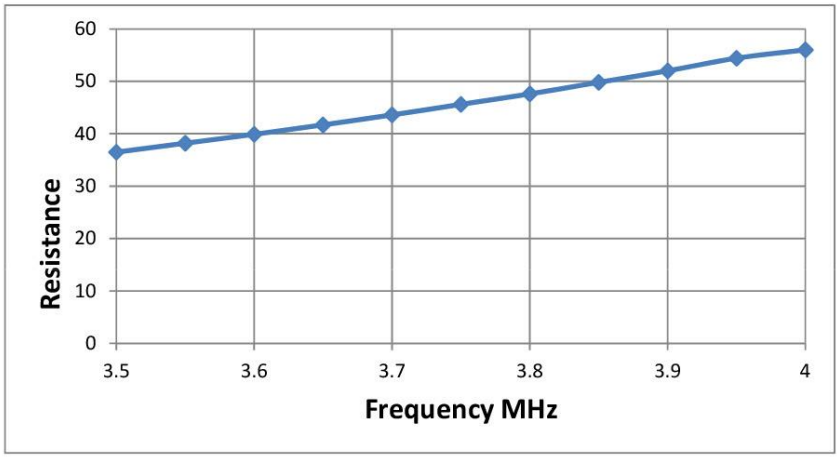
Solutions for Bandwidth

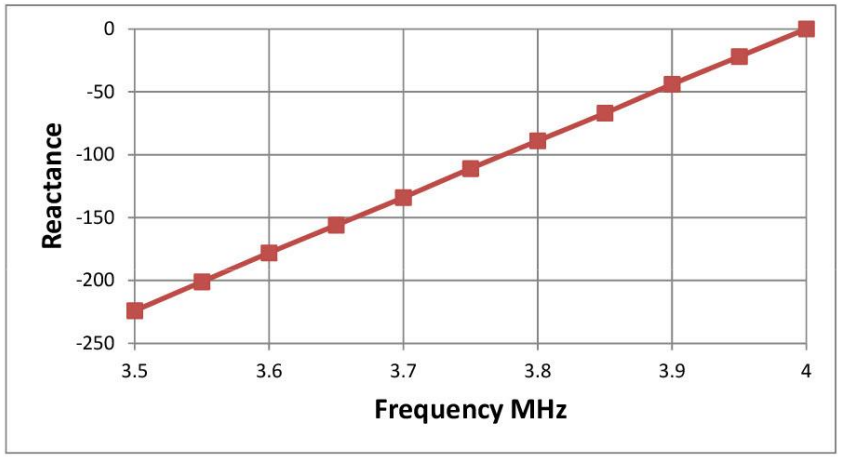
- Direct antenna broad-banding without any form of tuning
  - Generally makes the antenna/system even larger
  - Cage dipoles, added resonant elements, transmission line impedance transformers,…
- Some form of tuning
  - General purpose manual or automatic tuners – desktop or remote
  - Physically changing element length or loading coil taps
  - Special purpose or integrated tuning
    - Antenna elements resonant in the band
    - Tuning/loading components attached directly/closely on antenna elements – for example, Baluns/Ununs, coaxes, chokes…. are NOT placed between antenna elements and loading or tuning components
    - Multi-segment or binary stepped - with several to many steps

Advantages of Specialized/Integrated Antenna Tuning

- Full band coverage on 160/80 meters with that expensive and/or large antenna
- Antenna is tuned directly – good matching or low SWR throughout the system – coaxes, Baluns/Ununs, switches… not subject to high RF voltages and/or currents – losses are minimized
- Low cost with a handful of inexpensive components
- Easily implemented for full legal limit power
- Loading requirements are small/modest starting with a full-sized resonant antenna to tune across the band
- No need for a general purpose ATU
- Tuning is simple and robust to antenna installation

80 Meters Inverted Vee Resonant at 4 MHz at 40 feet Center EZNEC Results



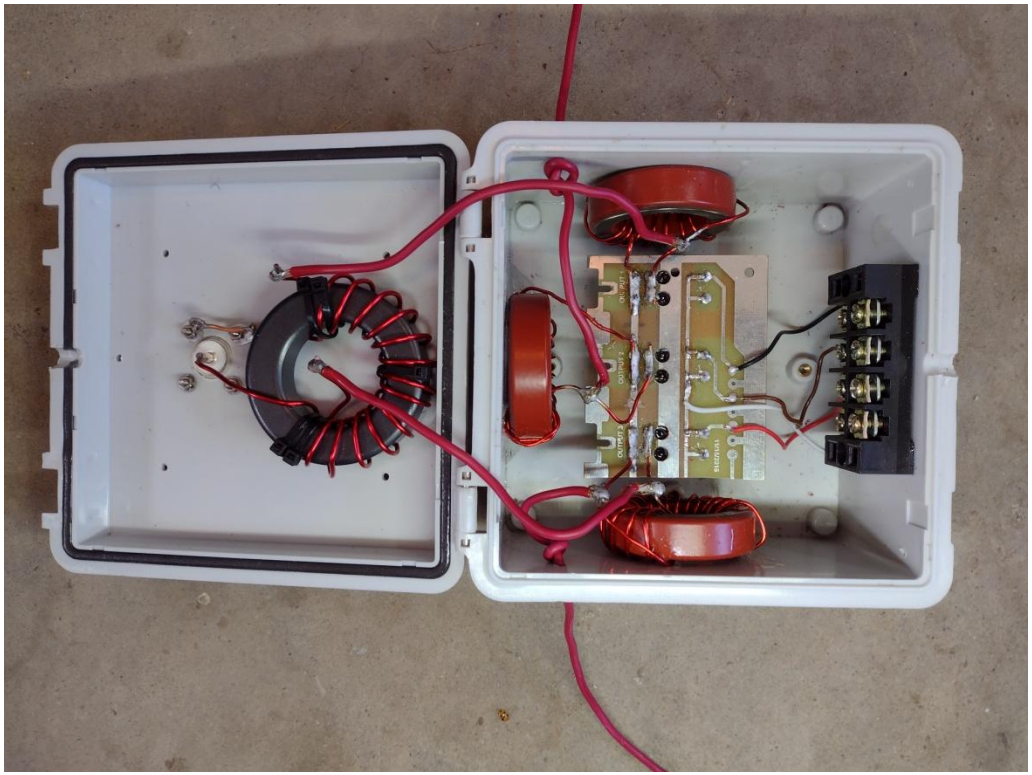


Antenna resistance varies from 36 to 56 Ohms - compromise match to 46 Ohms
Results in worst case SWR of only 1.28 assuming the reactance is 100% matched

Antenna reactance varies from 0 to -220 Ohms (capacitive) - varies about 10x the rate of change in the resistance but it is almost linear over the band

Match with 8 binary inductive loading steps
with 3 inductors to limit worst case mismatch to about 220/16 or 14 Ohms
Results in a combined worst case SWR of about 1.5

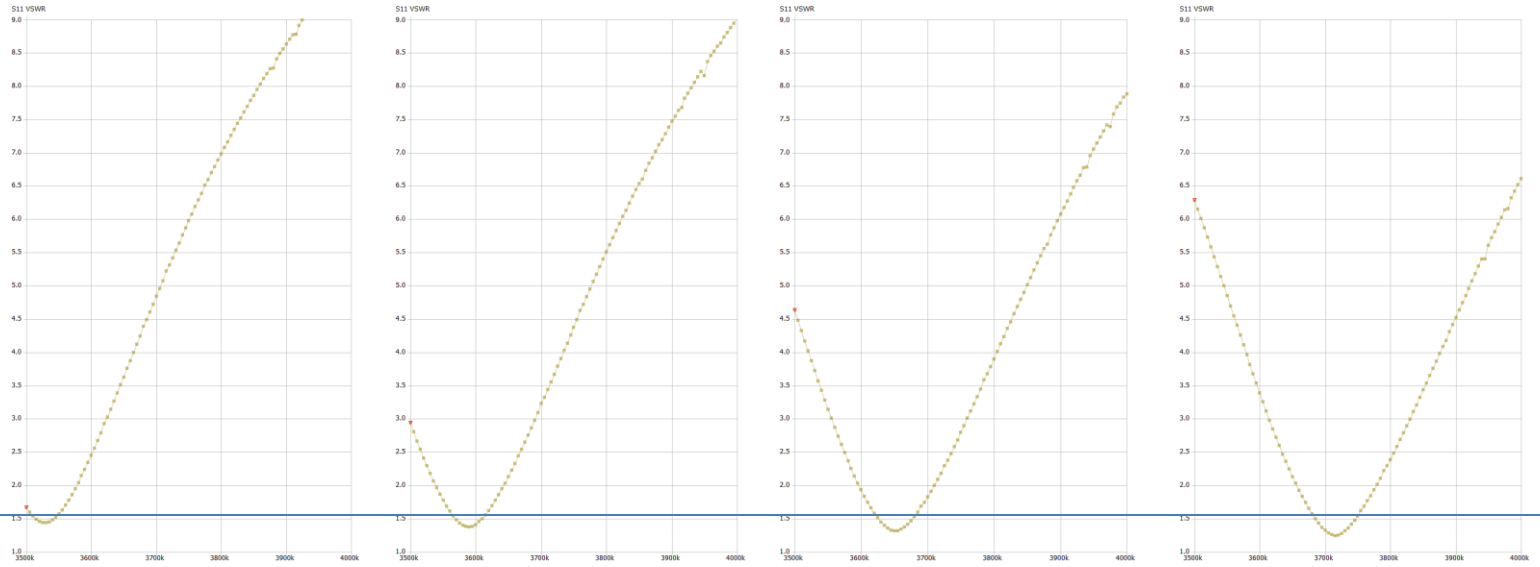
An Inverted Vee for 80 Meters with Integrated Tuning



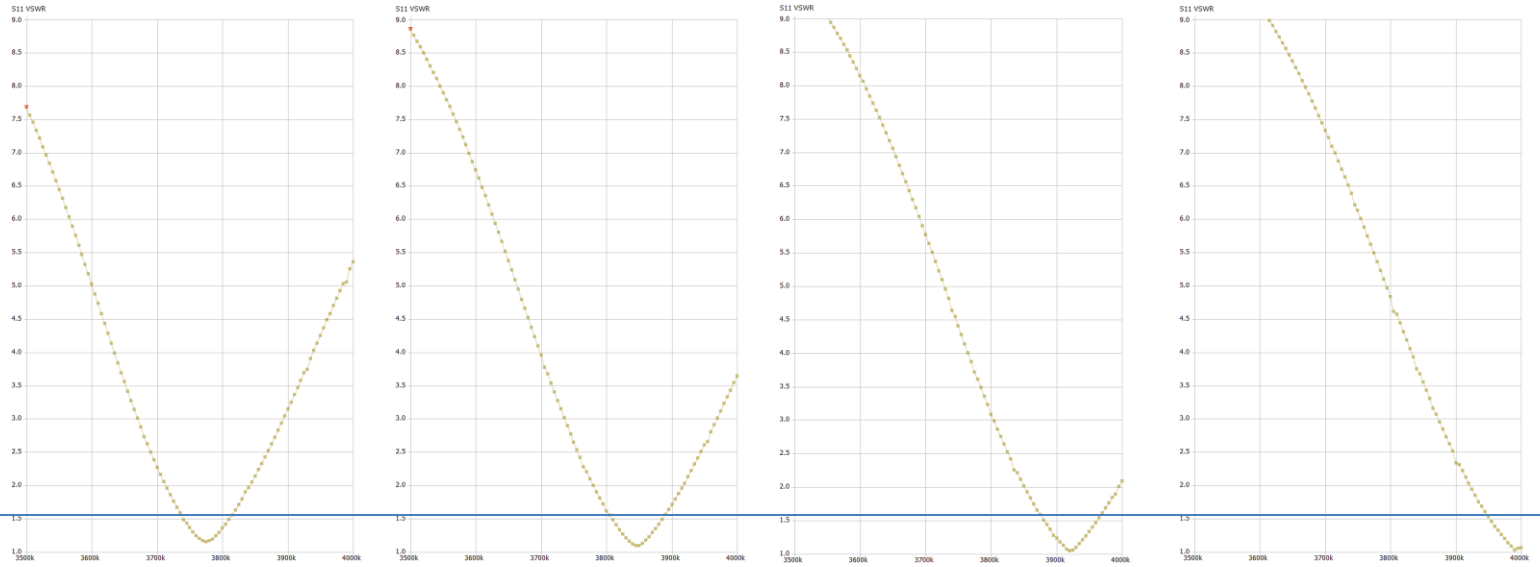
Antenna center unit
- 3 binary step loading inductors for 8 steps across 80 meters
- 3 relays mounted on a small PCB – taken from a QST antenna switch project
- Balun with 8:7 ratio
- Terminal strip for ground + 3 relay control wires for control

Reprinted with permission CQ Magazine – Aug 2023

SWR Results with 8 Frequency Steps



1.5

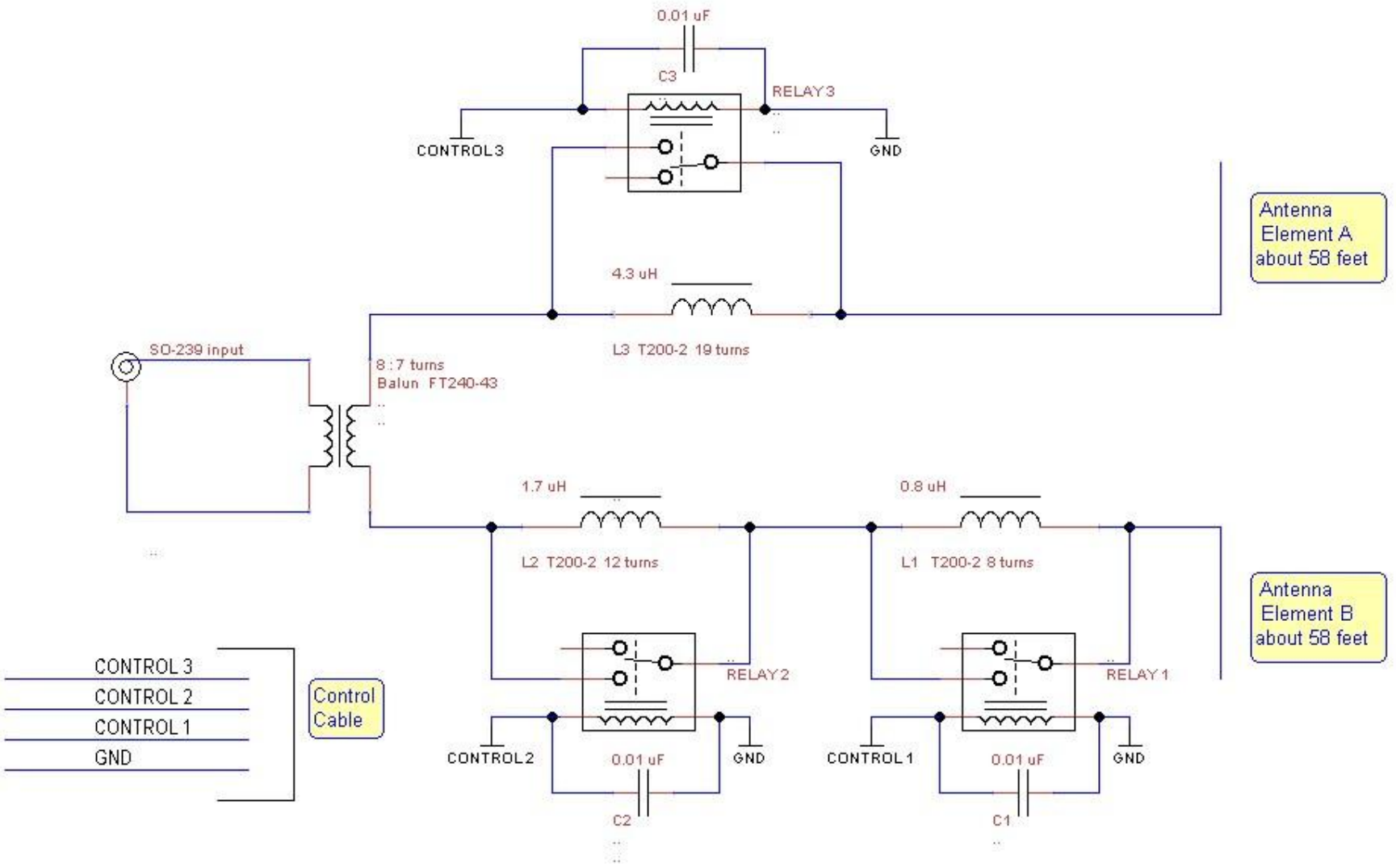


1.5

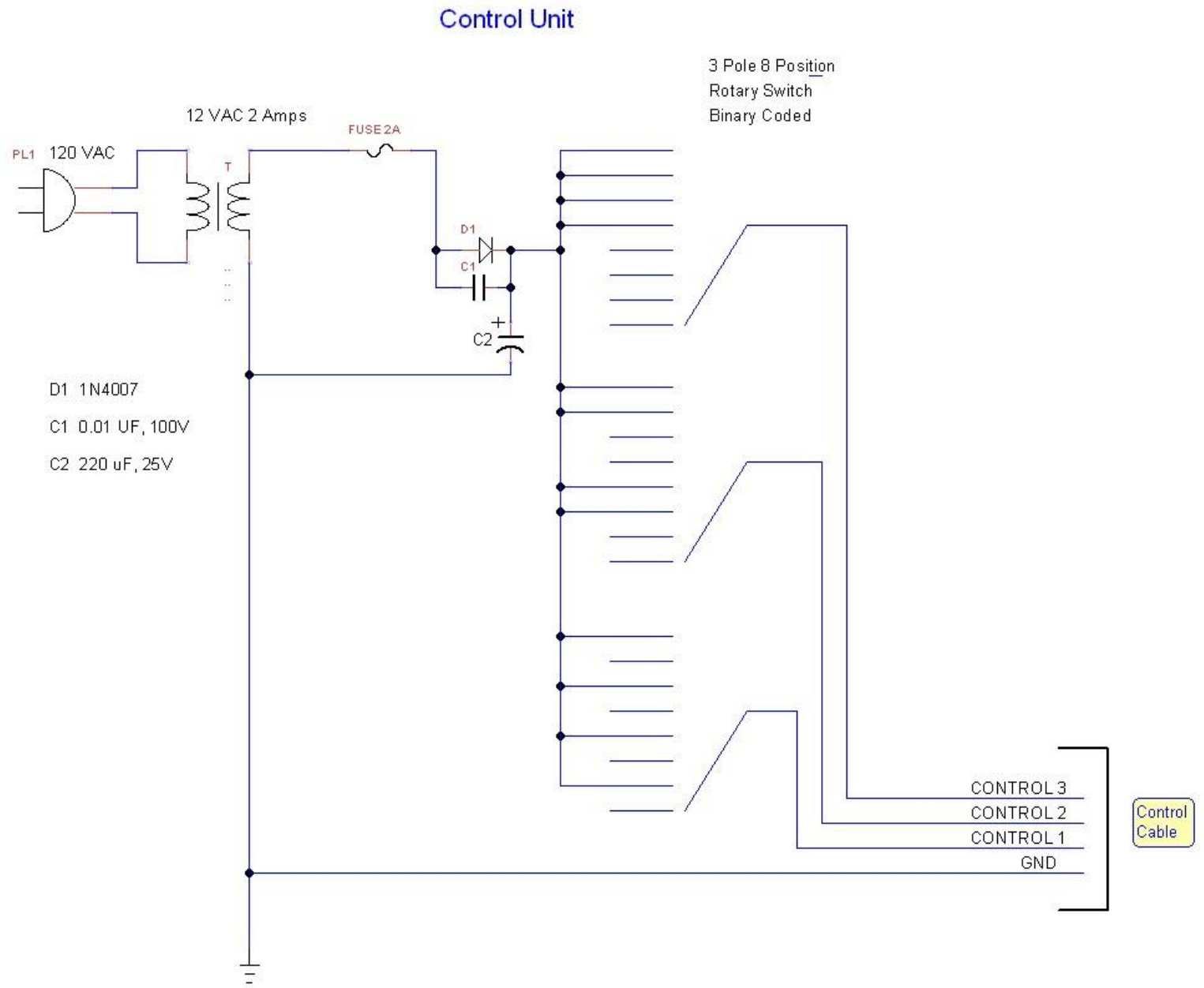
80 Meters Inverted Vee

- Center at about 40 feet height
- End points at about 15 to 20 feet height
- Cut to the top of the band without loading - about 58 feet per leg
- 2:1 SWR bandwidth about 120 KHz
- Impedance about 35 Ohms at mid-band
- SWR mostly below 1.5 across the band
  - with selection of best 1 of 8 frequency step
  - A few points at 1.6 to 1.7 at lower end of the band

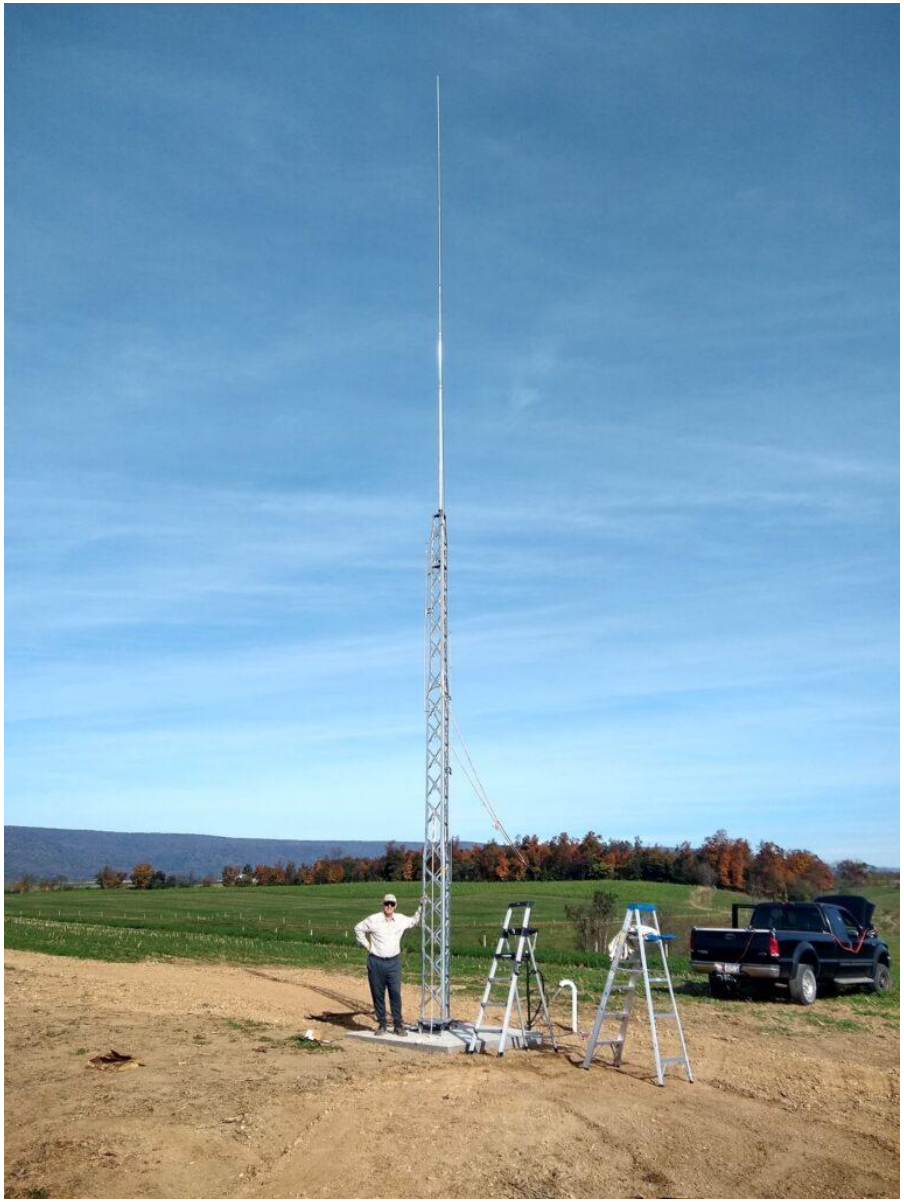
Center Unit Schematic



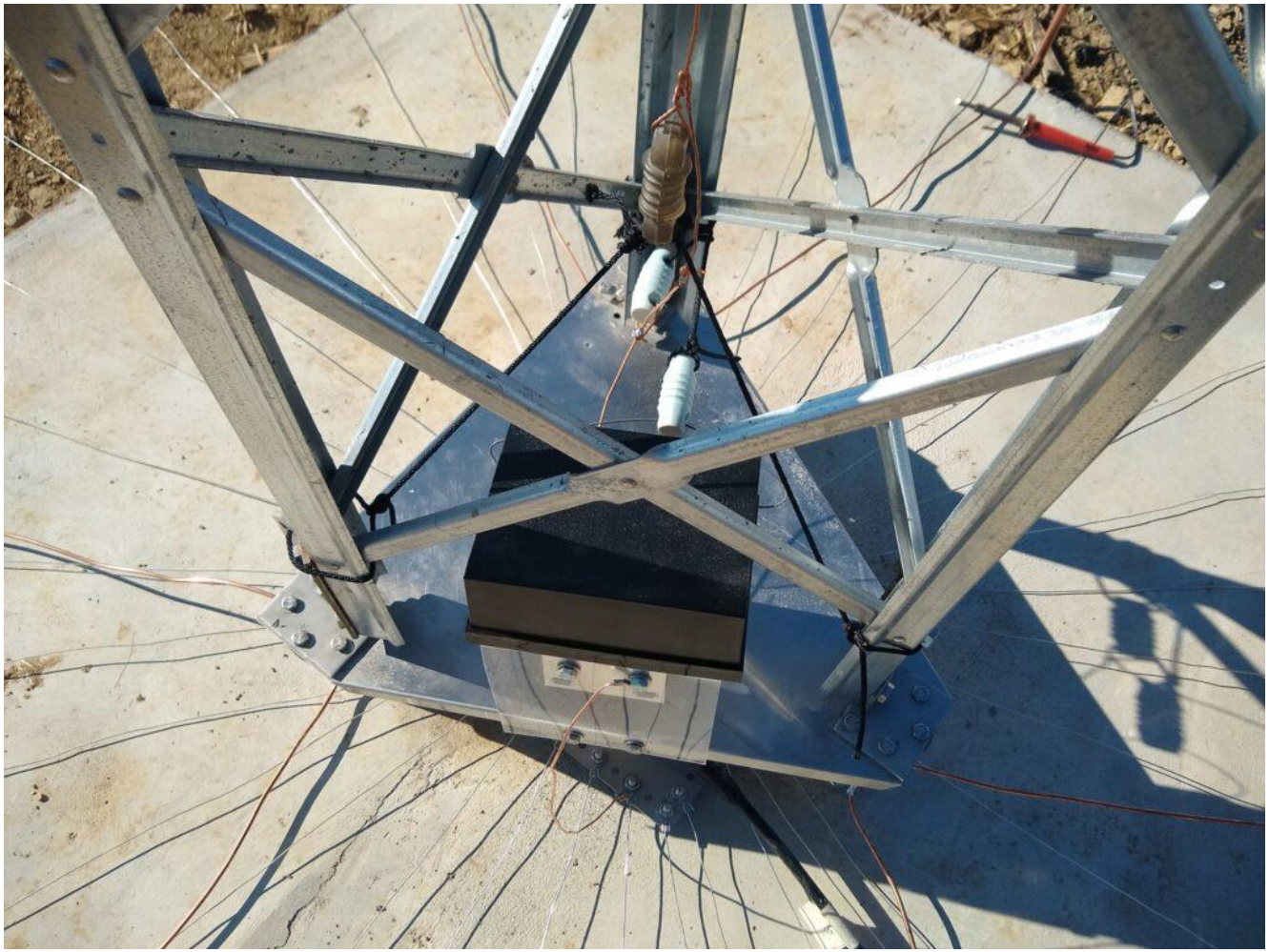
Controller Schematic



Hy-Tower **AV-18HT** with 80 Meters Step Tuning

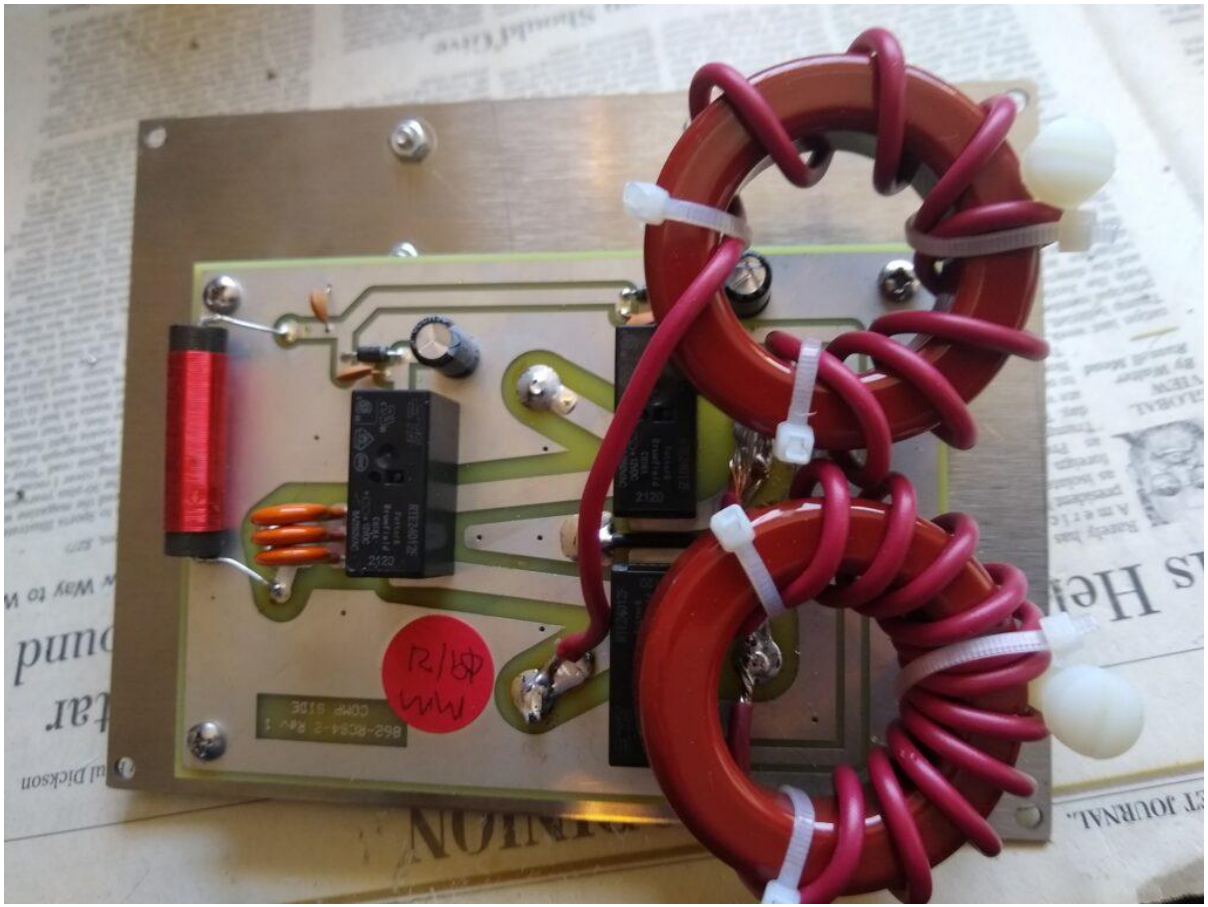


Hy-Tower base



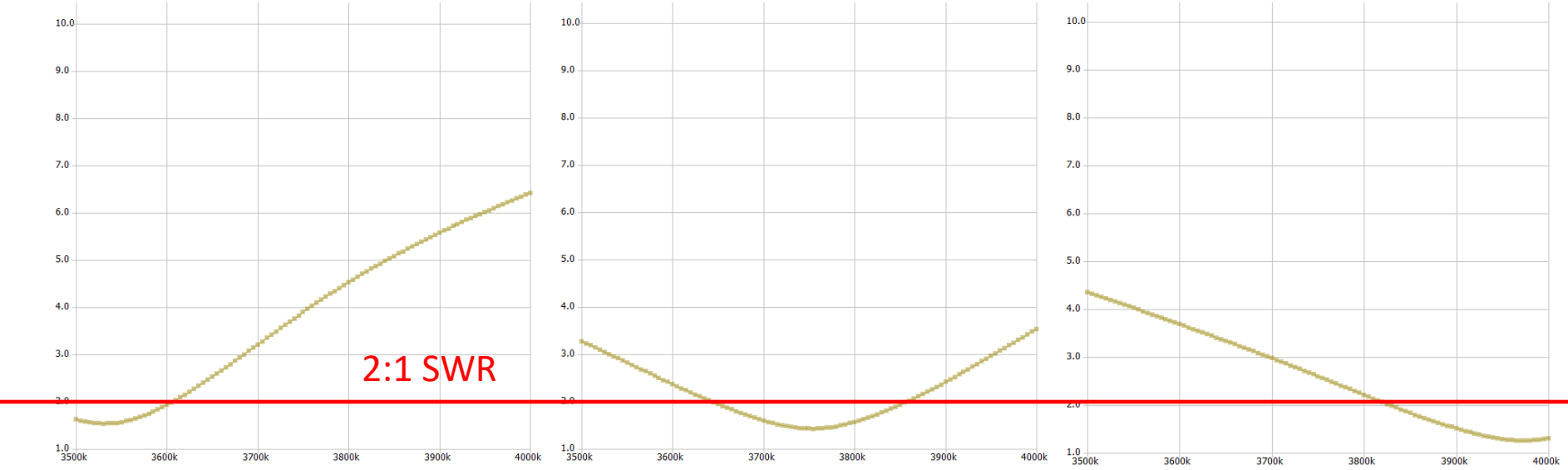
- 32 buried radials length 45 feet each + 6 ground rods
- Modified Ameritron RCS4 antenna switch provides 3 frequency steps across 80 meters
- 250 feet of buryflex coax to the radio shack

RCS4 Remote Switch Modifications



- Add 2 toroid inductors above the PCB in the remote unit – 8T and 11T on T200-2 cores
- No changes to the control unit
- Power and control is over the 250 feet coax shared with the high power TX RF
- More details – www.KA2C.com/antennas

SWR Results



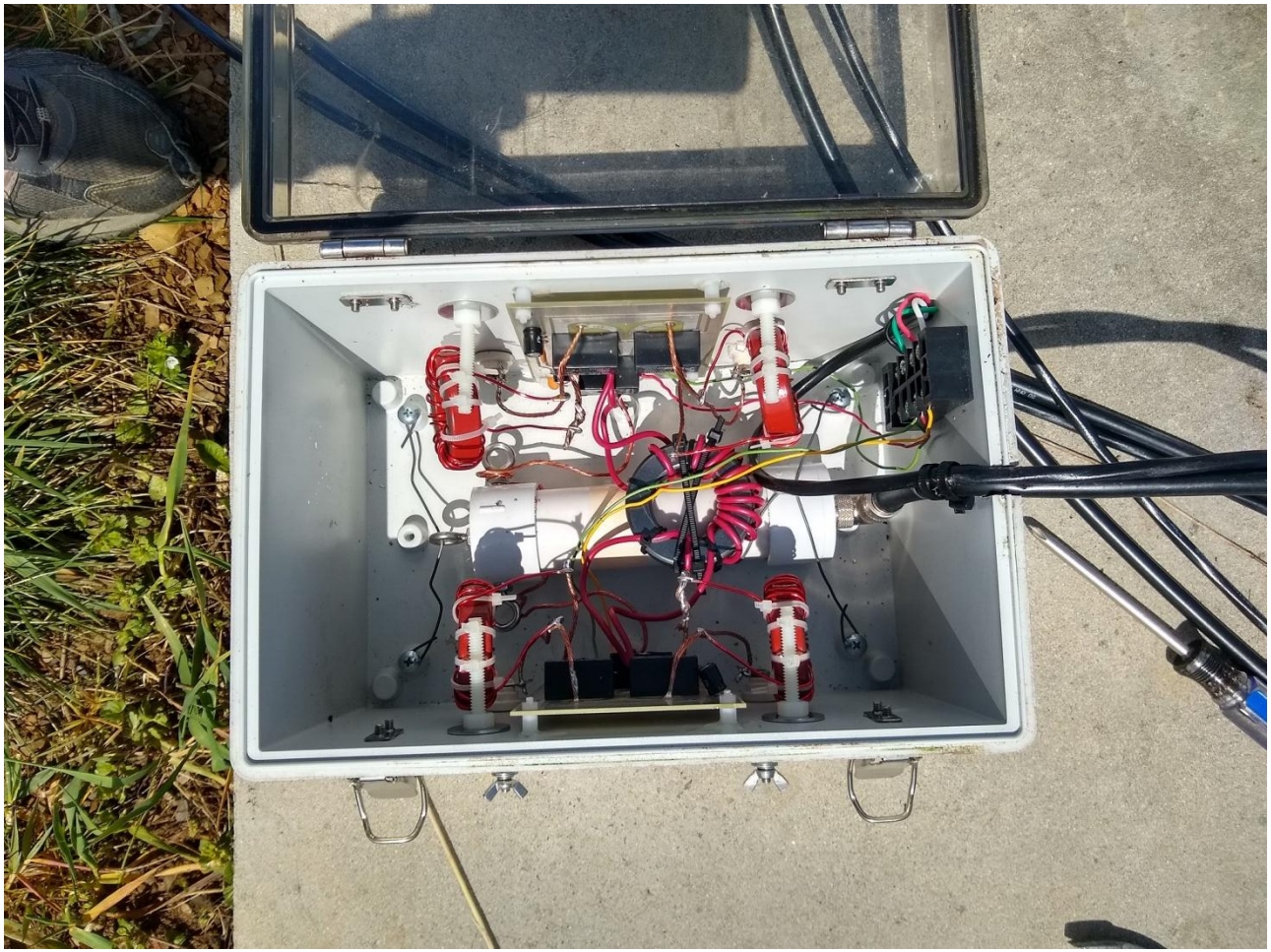
- Almost all points below 2:1 SWR with best selection of freq segment
- CW segment covered in 1 step and phone segment covered in 2 segments

-An RCS4 remote switch can also be used to remotely step tune a dipole or inverted vee - place the remote switch with loading inductors in the center unit for the antenna & connect the output directly to the antenna legs (hot to 1 leg and grnd to the other leg) - place a current balun immediately before the remote switch connecting to a coax to the shack (it must NOT short ground and hot wires due to the relay voltages on the coax) – in this case the “ground” of the remote RCS4 PCB has an RF voltage potential of one leg of the antenna at the center unit. Loading is applied only to 1 leg of the antenna.

KA2C 160/80 Meters Inverted Vee

- Center Unit box for 160/80 meters inverted vee near the tower top
-4 wire antenna elements forming 2 inverted vees at near 90 degrees
+ 2 for a separate 40 meters inverted vee

160/80 Meters Center Unit

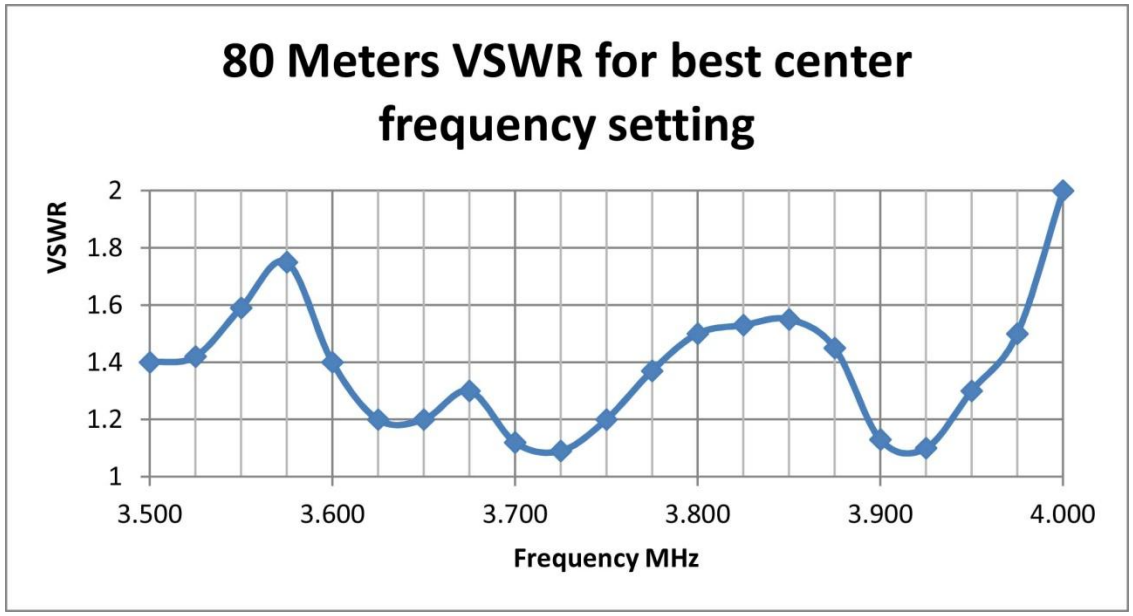


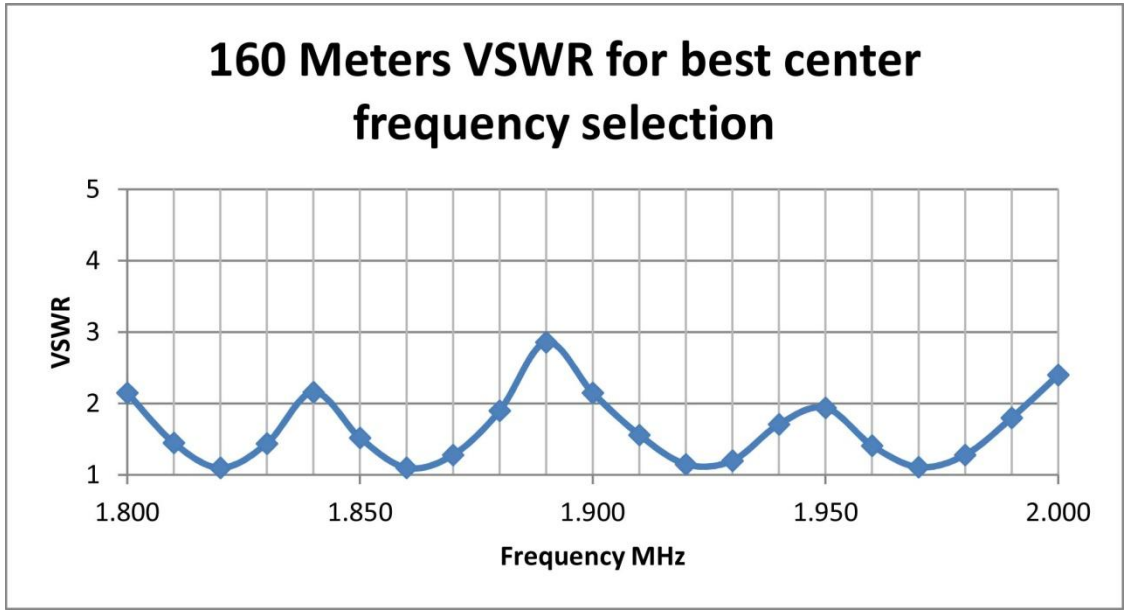
- Balun at input from coax
- RF transformer on 160 meters 50 to 20 Ohms
- 2 binary step tuned toroids for each band – 4 steps per band

Control Unit

- 4 positions per band with a rotary switch
- 2 Pole 8 Position rotary switch
- 4 wire control cable – grnd, band, 2-wires for segment selection

SWR Results


80 Meters VSWR for best center frequency setting
VSWR
2
1.8
1.6
1.4
1.2
1
3.500
3.600
3.700
3.800
3.900
4.000
Frequency MHz


160 Meters VSWR for best center frequency selection
VSWR
5
4
3
2
1
1.800
1.850
1.900
1.950
2.000
Frequency MHz

Antenna Integrated Tuning Comments

- Works best with full size or near full size antennas
- Works best with center-fed dipoles and inverted vees or conventional verticals or Yagi's
  - Antenna impedance changes slowly versus feedpoint offset or loading offsets at center or base
  - Impedances are "friendly"
- Works best with "friendly" impedances not too far from 50 Ohms
  - Current and voltages are not difficult
  - Low-cost relays are suitable for even 1.5 kW power

Antenna Integrated Tuning System Design

- Use EZNEC to determine
  - loading requirements
  - Number of required steps and SWR BW
- Inductor and/or capacitor selection/design
  - Suitable for RF
  - Power
  - Breakdown voltage
  - Current capacity
  - Toroid core saturation & heating
- Relay selection
  - Suitable for RF
  - Current capability
  - Open contact dielectric strength or breakdown voltage
  - Contact to coil dielectric strength
- Remote control
  - Adapt a remote antenna switch
  - Use a control cable and rotary switches to step remote relays

Relays for RF

- Vacuum relays are usually expensive - now usually not necessary for ham radio RF switching, but
  - Advantages for very high voltages
  - May have size advantages
- Very inexpensive relays have been developed for AC power control and the solar power industry
  - 16 to 20 Amps for 60 Hz is very common corresponding to standard power circuits
  - 1000 VAC for 60 Hz open contact dielectric strength ratings are very common
  - Unfortunately no ratings for HF RF in almost all cases but
    - Derate voltage by 0.8 x for HF – based on experimental studies
    - Derate current by about 0.5 x for 160/80m and about 0.25 x for 10m – rule of thumb based on behavior of known vacuum relays and skin effect
  - Remote antenna switches and antenna tuners now typically use these relays which are available for $2 -$4 or so each.

Power Relays – 12 Volt coils

Zettler AZ7555-1A-12DSKEF SPST - about $2 - $3
Rated - contacts 20A 1000VAC open contacts breakdown
Measured 2 to 2.5 kV – OK up to about 1.5 kV HF RF
SPDT should probably be limited to about 0.8 to 1 kV HF RF
Similar relays usually in RF switches and antenna tuners

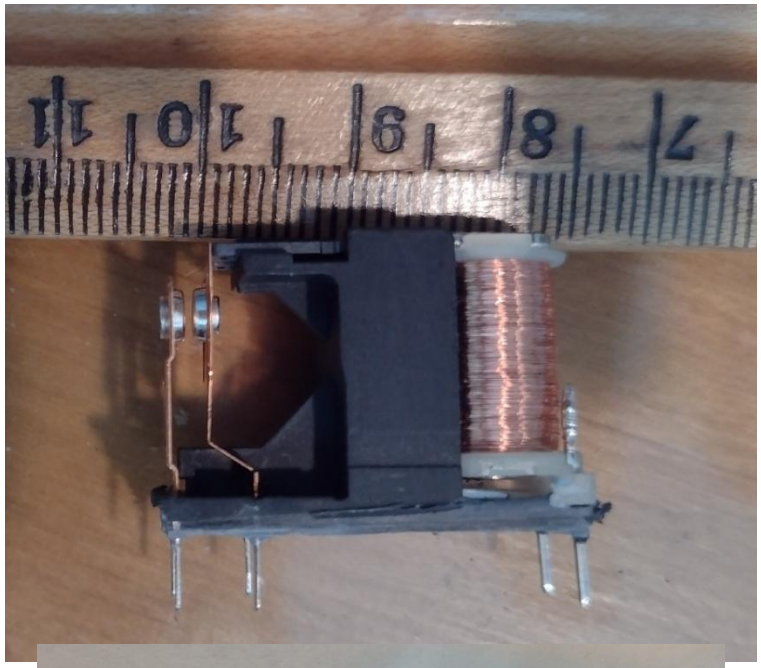
Panasonic ALFG2PF121 SPST - about $4 - $5
Rated - contacts 33A 2500VAC open contacts breakdown
Measured 3.8 to 4 kV – OK up to about 2.5 kV RF

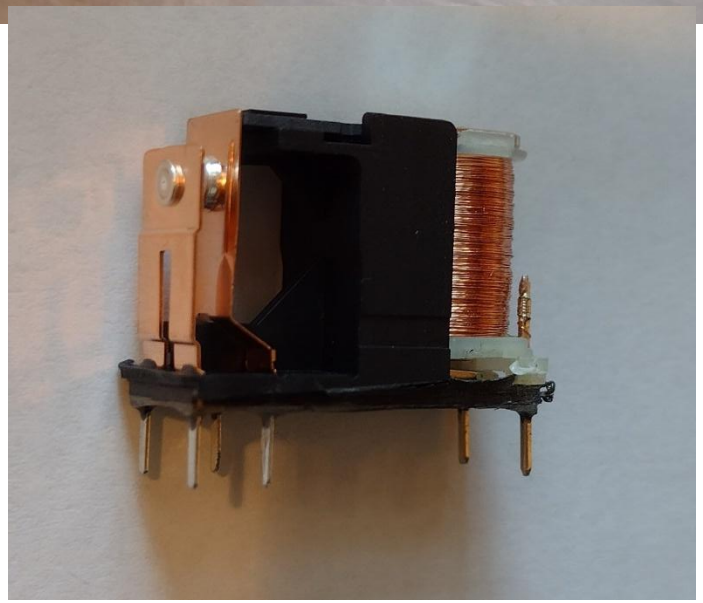
Panasonic HE1aN-W-DC12V-Y6 SPST - about $20 - $40
Rated - contacts 90A 2000VAC open contacts breakdown
Double break relay - May be OK up to about 4 kV HF RF

relays have 50% or more margin at sea-level - but they must work at 2000m altitude by spec where the break down of air is reduced by Paschen's curve by about 0.8 x

Other issues – contact to coil breakdown, Silver compound contacts, PCB pins

Zettler AZ7555-1A-12DSKEF SPST



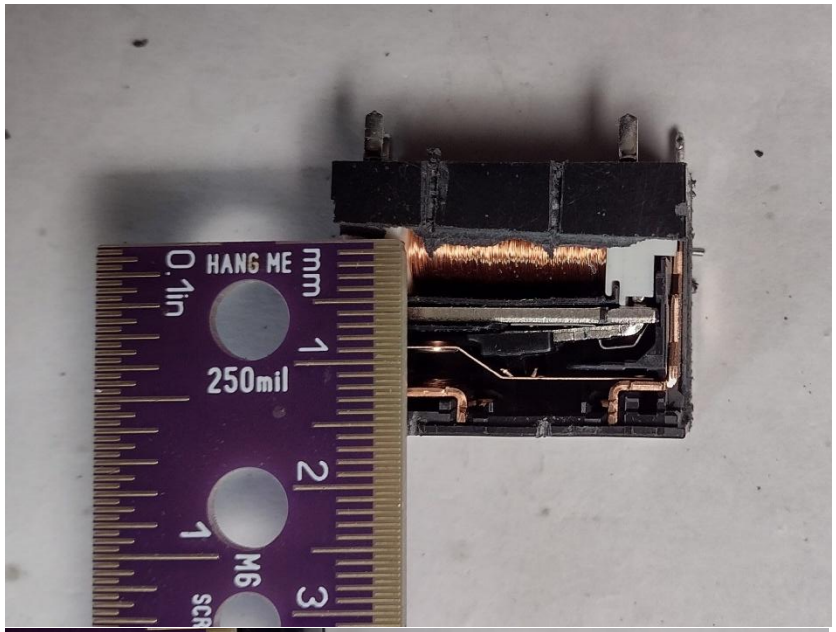


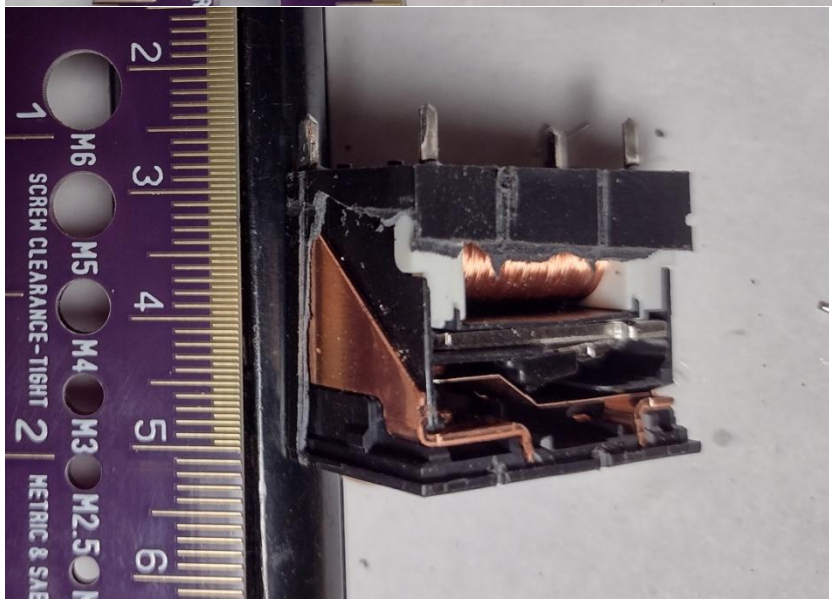
Similar relays from
- Omron G2RL series
-TE Connectivity Potter & Brumfield RZ series
-Finder 41 series

-Open contact gap about 0.7 mm
-At 30 kV/cm dielectric strength for air this is about 2.1 kV peak by calculation
-About 1.5 kV rms 60 Hz by calculation
-Measurements were over 2.0 kV rms 60 Hz, but were about 1.5 kV rms 60 Hz on the SPDT version - OK for 1.5 kV RF and 0.8 to 1.0 kV RF
- Open contact spacing and dielectric strength appears reduced for SPDT versions with the pressure on the NC contact reducing the contact gap in the SPST version

-Moving contacts appear to be steel spring strips with copper coating
-Appear to be low inductance and good for low parasitic inductance for HF RF

Panasonic ALFG2PF121 SPST





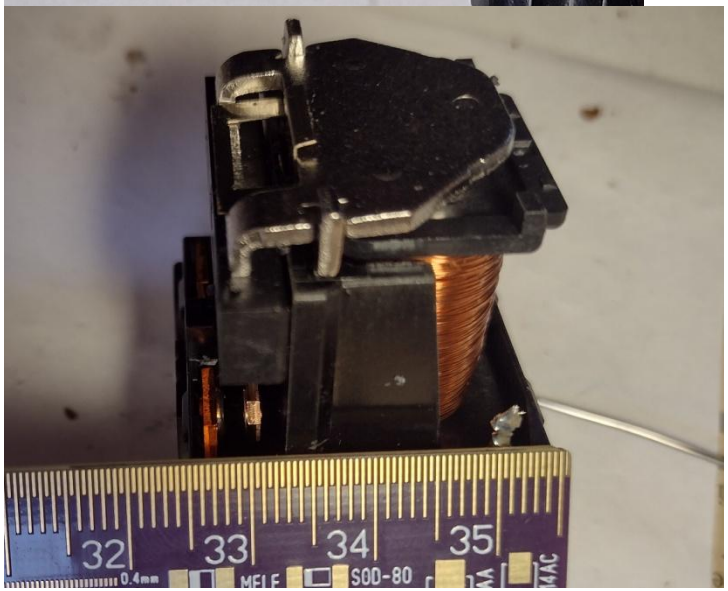
Capable of higher currents and voltages

About 1.8 mm contact air gap or about 5.4 kV peak and 3.8 kV rms 60 Hz AC but rated at 2500 V 60 Hz AC - measured at 3.8 to 4.0 kV rms 60 Hz AC - calculation and measurement are very close with the larger gap - good for 2.5 kV rms HF RF

Wide spacing between all pins

Conductor spreads out like a triangle to minimize resistance and inductance

Panasonic HE1aN-W-DCF SPST



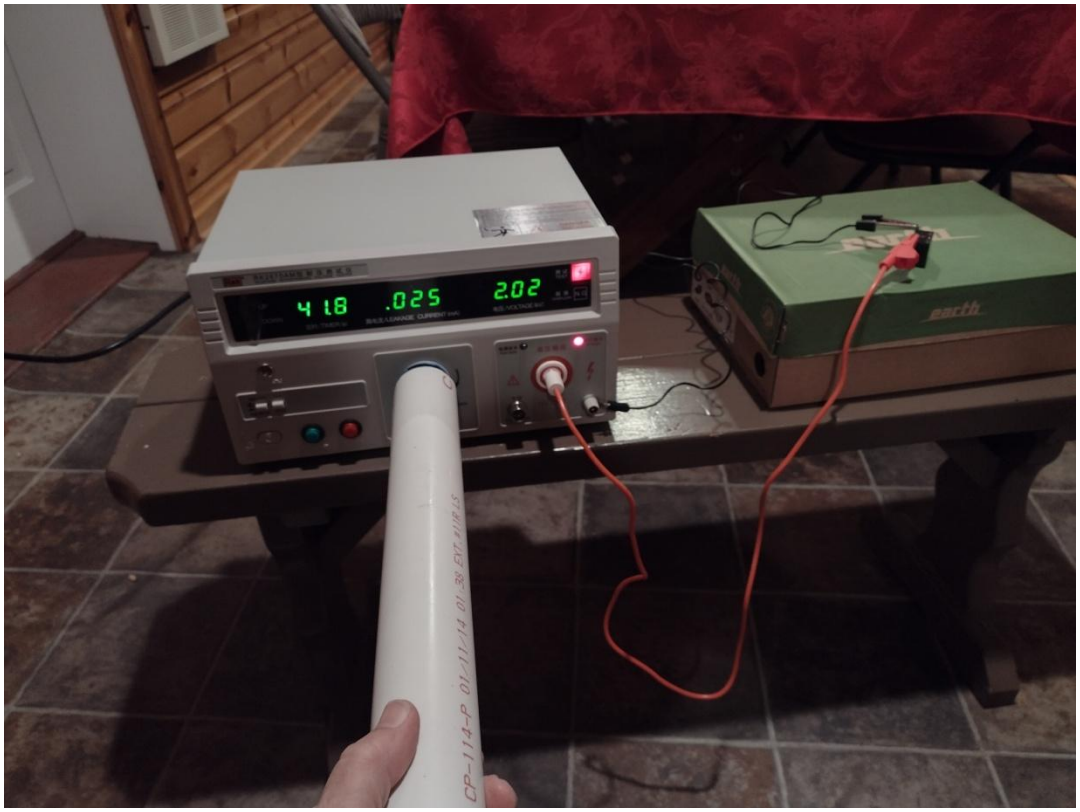
Double break high current relay

A moving arm closes 2 sets of contacts

Does dielectric strength of 2 relay open contacts add? Apparently yes for open contacts, but maybe NOT for RF breaking strength!

Measured 1 set of contacts at 3.8 to 3.9 kV rms 60 Hz AC and the 2 sets in series did not fail at 6 kV 60 Hz AC - may be good for 4 kV HF RF

Dielectric Strength Testing of Relay Open Contacts



- commercial test unit capable of up to 6 kV 60 Hz AC (rated at 5 kV)
- leakage thresholds of 2 ma or 20 ma
- **test procedure involves significant safety protocol**
  - **Test setup isolated on non-conductive platform**
  - **Adjustments during active power performed only with 18” PVC pipe**
  - **Shorting stick used after power down and 1 minute wait**

Loading Inductors

- Very High Q is not critical for low/modest loading - Loading here is small compared to typical ATU situations
- Toroid coils with compact form factor and contained fields work well – 14 gauge enameled wire OK
- T200-2 cores Ok for small/modest loading inductors for antenna integrated tuners at full legal power
- Info including inductance calculations available for different cores: https://kitsandparts.com/
- Core heating and saturation: https://www.amidoncorp.com/specs/

Previous and Related Work

-Broadbanding a 160 m Vertical Antenna, Grant Saviers, KZ1W, QEX May/June 2019 – 4 frequency steps on a 160 meters full size vertical with capacitive loading

-Some large Yagi's such as Optibeam, Ultra-Beam & Array-Com's 80 meters Yagi tune the Yagi driven and passive elements in 4 frequency steps with 2 inductors/relays per element

- 80/40 meters 2-element Yagi VE6WZ - https://www.qsl.net/ve6wz/switch.htm over 16 tuning segments on 80m with loading coils and vacuum switches on the antenna elements' centers

-80m 3500W Inverted "V" dipole antenna CW/SSB with relay switches, by Antennas-Amplifiers, inductive loading in the dipole center unit – 2 freqs

- Examples exist of hams using remote relays to switch taps on loading coils

Conclusions

- Specialized or Integrated tuning for 160/80 meter dipoles, inverted vees and verticals is attractive for full bandwidth operation and well matched antenna systems
- The dipole center unit or vertical base units are simple and low cost for full legal power operation using a few toroid inductors and common relays
- Remote antenna switches can be modified by adding several toroid inductors to provide remote operation over the coax for 3 or 4 frequency segments