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Broad-banding a 160 m Vertical Antenna

Cover the band in four switchable band segments.

Vertical antennas are by far the most popular and cost effective antennas for Top Band operation. A usual problem is a limited bandwidth for SWR less than 2:1, whether they are coil loaded or shortened "T" or "L" top loaded designs. For my western red cedar supported 160 m #13 AWG Copperweld® insulated wire "T" the 2:1 SWR bandwidth is about 80 kHz. It has eight 125 ft long radials elevated 10 ft at the feed point . The top is at about 87 ft and there are 37 ft of "T" arms on each side. The wire is held off the tree trunk at about 6 ft to minimize coupling and losses. My antenna resonates at 1820 kHz at 25 Ω and is fed with a 50 Ω το 25 Ω transmission line transformer, often also called a balun or choke.

I host multi-single teams for CW, SSB, and RTTY contests and use FT8 for DX (Japan stations are at 1908 kHz), so I wanted to be able to cover most of the band with my vertical antenna. The target was less than 1.5:1 SWR across the band since my amplifier was happier with that maximum. I thought a switched capacitor bank to neutralize the inductive reactance at frequencies above the native 1820 kHz resonance would work. My starting design was a series-switched set of parallel binary-weighted values at the feed point, but a suggestion on the Top Band reflector caused me to consider series-switched equal values.

A little work with *EZNEC* showed that three series connected 4000 pF capacitors, each with a shorting relay, would move the feed point 25 Ω SWR minimum in almost equal 40 kHz upward steps. That is, with the four values of 'short', 4000 pF, 2000 pF, and 1333 pF as series 3, 2, 1 capacitors shorted, and then no relay shorting any of them. My *EZNEC* analysis showed that the SWR was now switchable at a maximum 1.5:1 from 1800 to 1970 kHz. Just the last 20 kHz of the band was above 2:1. See the vector network analyzer (VNA) plot of Figure 1 showing measured SWR curves of the four band segments.

Capacitors

Now the question was which capacitors and relays could handle the RF currents and voltages, and the what relays have sufficient coil-to-contact voltage isolation. I used *EZNEC* to find the voltages and currents at high RF power across the capacitors and relay contacts at 25 Ω. As the mismatch reactance increases so does the voltage across the capacitors. Since they all are the same value – 4000 pF – they act as a capacitive equal voltage divider. Thus the voltage at high RF power (total voltage divided by the number of capacitors) per capacitor is about the same, under 250 V in the matching frequency band regardless of the number in series. Of course, with the capacitors in series, the current is always the same in each capacitor, about 8 A at 1500 W into the 25 Ω antenna.

Silver mica capacitors are the best capacitor choice (lowest ESR) if the current ratings are sufficient. CDE rates their CD/CDV16 series for RF current. The more common CD versions have lower current capability. For example, the CDV16 2000 pF 1000 V capacitor is rated 5.3 A continuous at 2.5 MHz and 85 °C. So two in parallel will handle high power level current at 25 Ω. However, I decided to gamble on some eBay Ukraine surplus "transmitting" 1000 V mica capacitors, which looked beefy enough and had screw tabs for mounting. A quick check with my VNA confirmed ESR below what can be accurately measured with its standard bridge and about the same as CDV units, so I had confidence in their power handling

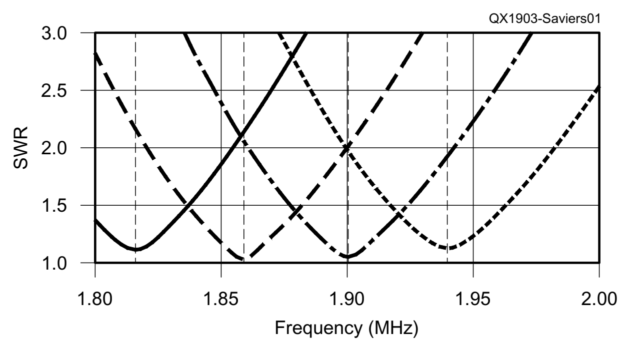

Figure 1 — Measured SWR curves at 1816 kHz, 1859 kHz, 1900 kHz and 1940 kHz center frequencies.

capability. To be extra sure, I paralleled two 2000 pF on standoff spacers for each 4000 pF value. With capacitors in hand the next step was to find a suitable relay.

Relays

My biggest concern was enough coil-to-contact voltage isolation so there was minimal chance of high RF power coming back into the shack via the relay driver wires. In case an operator transmitted outside the frequency range of the selected capacitor value, that could be more than 1000 V. Another consideration was short and direct leads to the relay contacts. I never expected hot switching, so 10 A or better contact ratings seemed sufficient. I found a 12 V dc PCB relay by Schrack (RZ01-1A4-D012) with a plastic arm from the coil armature to the contacts that is rated 5000 V coil to contact isolation, 12 A at 250 V ac switching, and has redundant leads to the Ag/Ni (90/10) contacts through flat alloy copper leads. This was an ideal and inexpensive ($2.59 at Digikey 12/2016) solution. While the 250 V ac load rating is about the maximum expected capacitor voltage, the open contact isolation voltage is 1000 V rms, more than sufficient if not hot switched. Although these relays are not hermetically sealed, the case is sufficiently tight to prevent dirt or insect ingress (Figure 2). Nearly sealed, very small size, very low cost, and an extra-short RF path are all a big plus over open frame relay alternatives. A couple of years of operation at high RF power levels and the usual mistakes of moving outside the tuning range enough to trip the amplifier protection circuits have not caused observed relay damage.

I added 39 kΩ 2 W Allen Bradley carbon composition resistors across each capacitor to drain and equalize any static charge since all relays are open when power is off. At high RF power the dissipation in any resistor is about 1.5 W at 100% duty cycle. The three capacitors, resistors, and relays were mounted in a 3.5” by 6” by 3” watertight plastic box and connected between the transmission line transformer output and vertical wire (Figure 3). The transformer is a dc short between the vertical wire and radials.

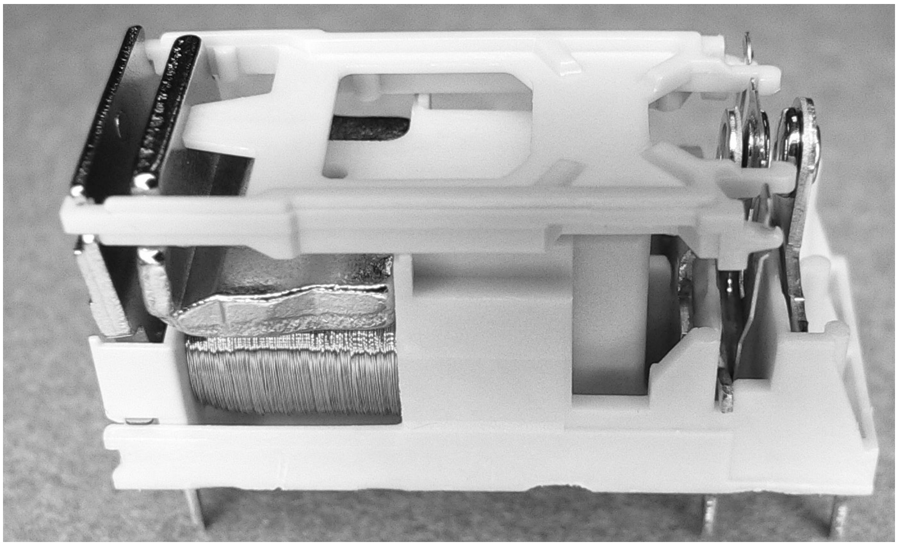

Figure 2 — The Schrack relay.

The Control Head

A 4-conductor cable carries the 12 V dc relay signals from the relay box to the shack. The wires are wound through a small ferrite toroid inside the relay box and each relay coil is bypassed with a 0.01 μF ceramic capacitor, see Figure 4 and Figure 5.

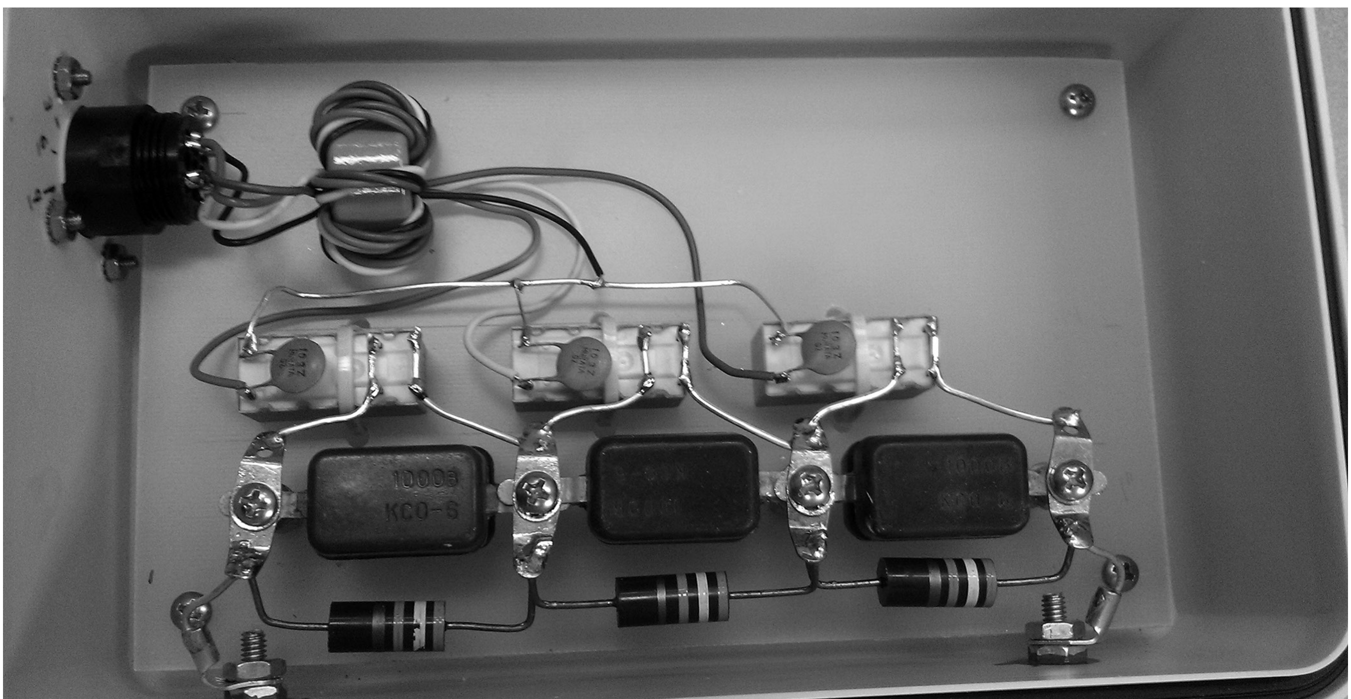

Figure 3 — Inside of the remote switch box after 3 years of operation.

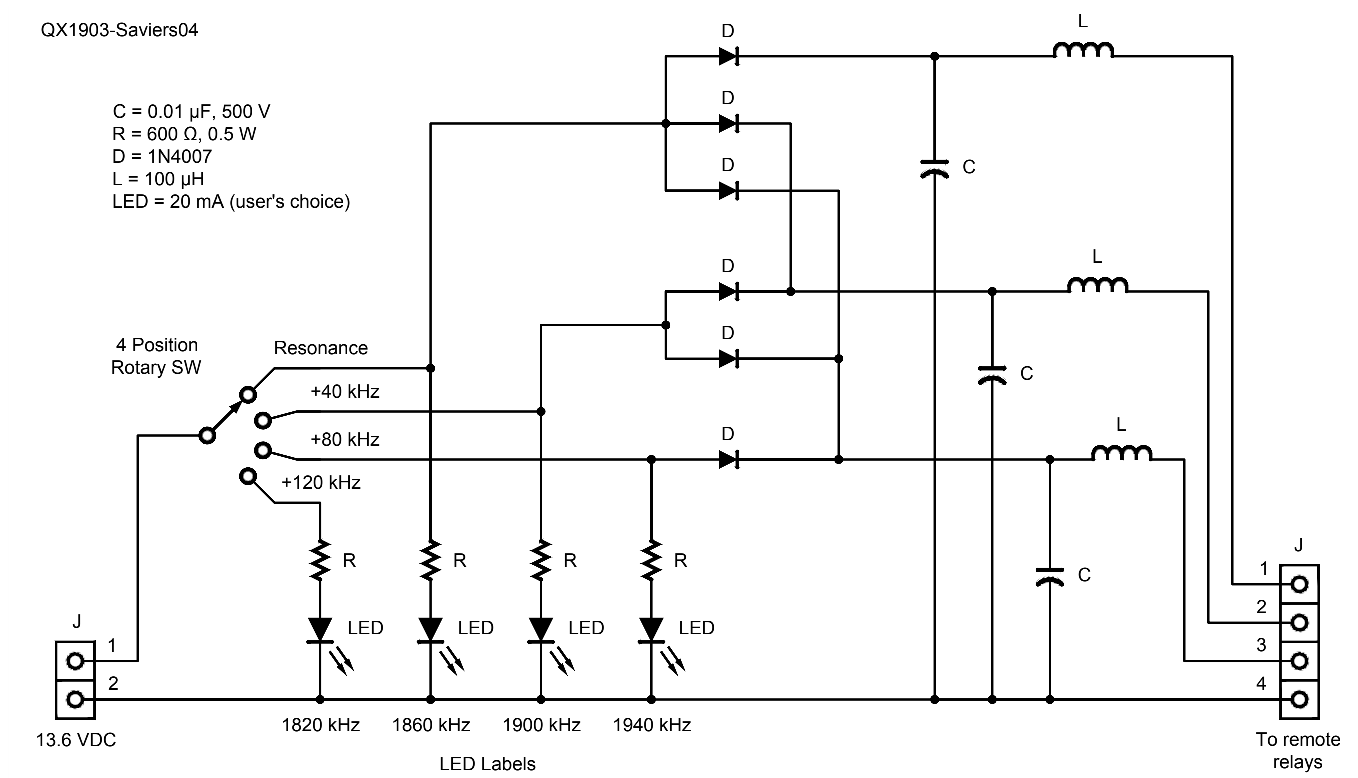

Figure 4 — Schematic of 160 m controller.

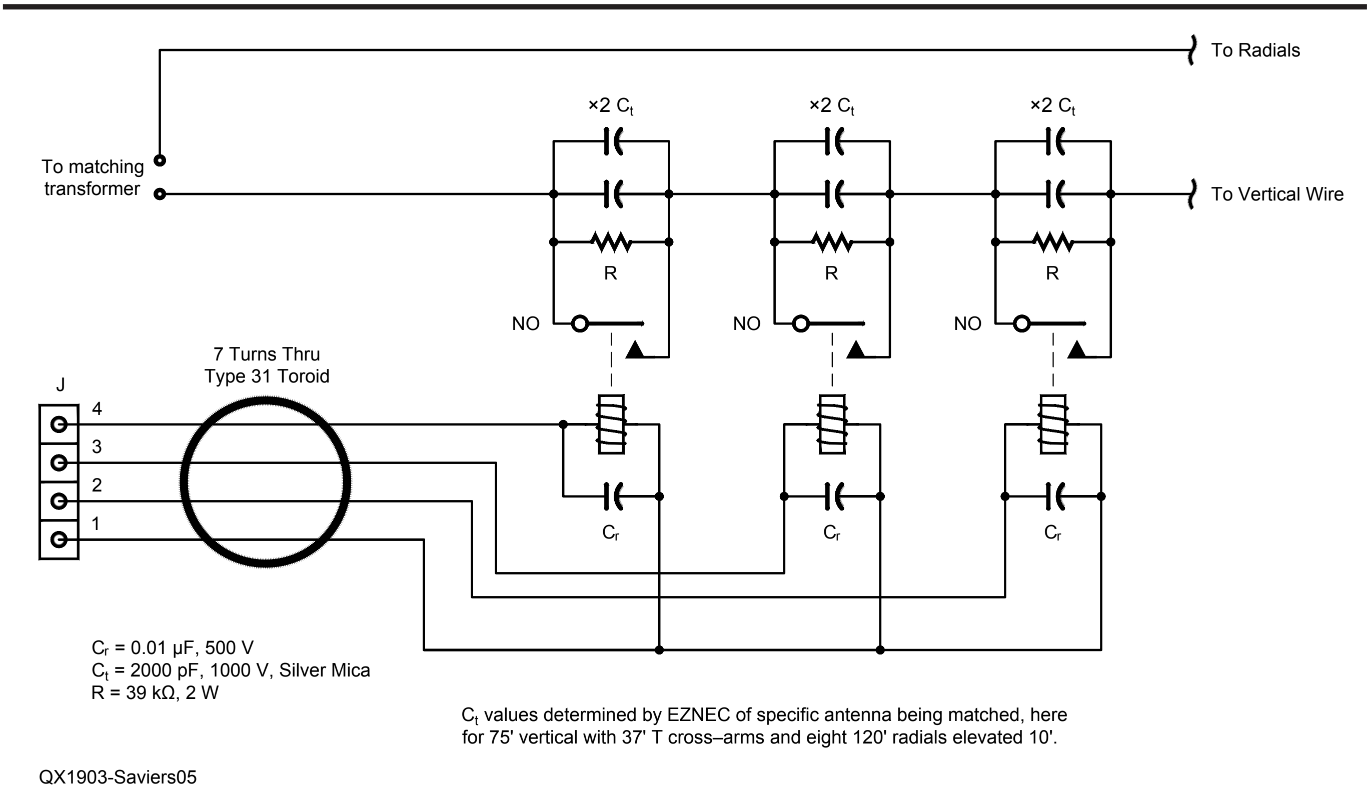

Figure 5 — Schematic of 160 m remote tuner.

For the control head (Figure 6) I use a rotary switch to select, and LEDs to show the selected band segment. It is less error prone than individual SPST toggle switches for each relay. I used a 1N4007 1,000 V 1 A diode tree to select 3, 2, 1, and ‘no’ relay energized. The combinations of relays to open or close is arbitrary. While 1N1418 diodes would handle the relay voltages and current, I’ve had them vaporized by surges from nearby lightning strikes. By-pass capacitors and series inductors on each line help keep RF out of the shack 12 V power system, and noise out of the antenna. I designed a simple PCB for the diode tree, but a perf board would work equally well. Figure 7 shows provisions for up to six relays and switches to make all decodes adjustable

The input of the transmission line transformer (Figure 8) uses four type 31 ferrite cores with RG174 TFE coax wound choke, per the designs of K9YC and G3TXQ for 160 m. The RG8 feed coax and 4 conductor control cable are in buried 1.25” PVC conduit, about 120’ to the shack entrance.

Conclusions

I have built cage dipoles, and I was very reluctant to consider that design for a broadband vertical supported by a tree in a partially wooded area. Top loading and elevated radials make for more than enough wires to manage. For the radials, I use aluminum electric fencing wire, which has proven very durable, stretch-free, and inexpensive. The #12-1/2 AWG aluminum wire has survived 3” branch drops, 2” of ice, but not a falling 12” caliber tree. It is available in #9 to #17 AWG.

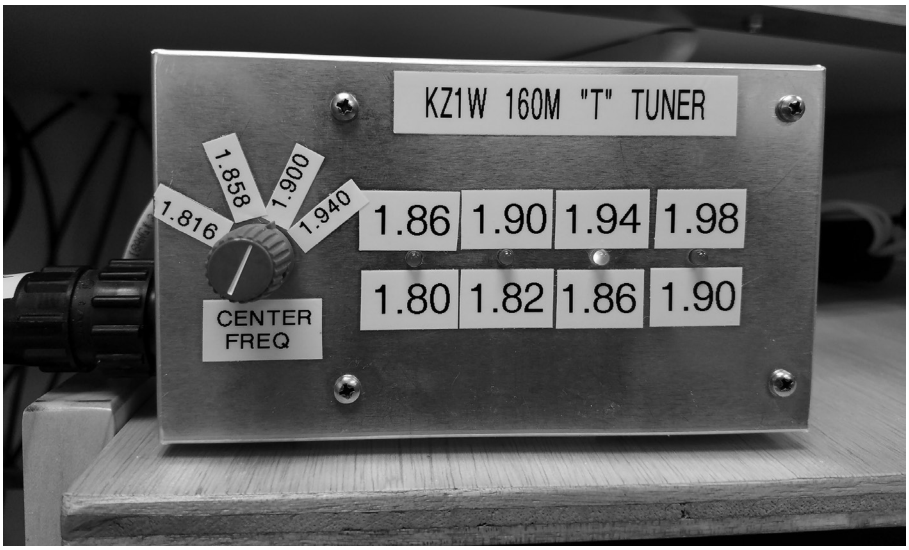

Figure 6 — Control head in the shack.

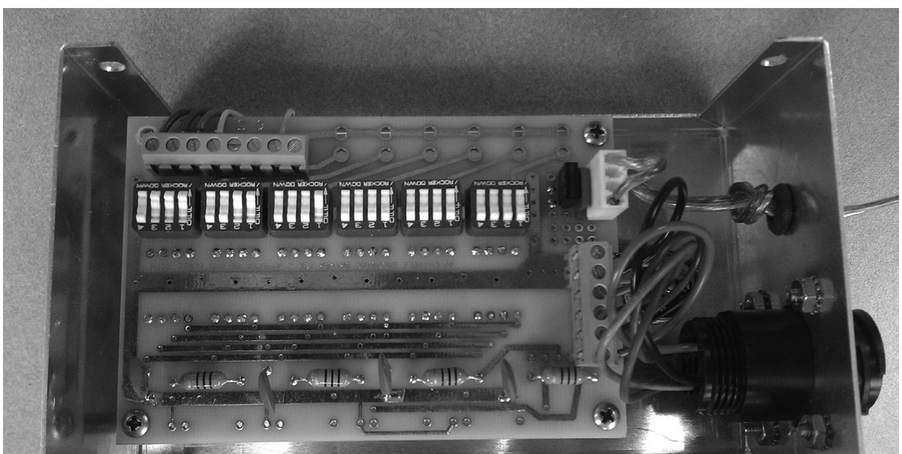

Figure 7 — Provisions for 6 relays and switches to make all decodes adjustable.

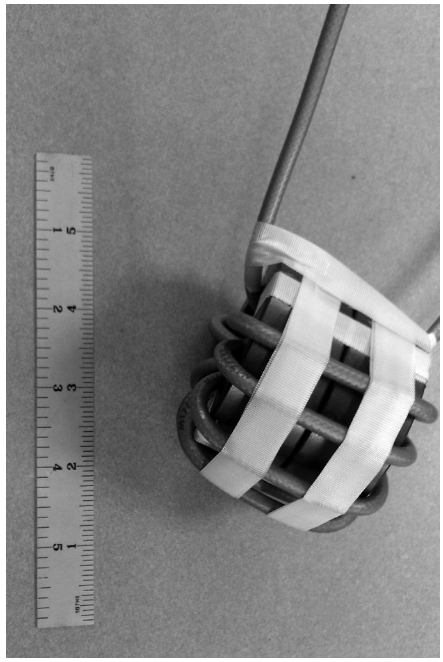

Figure 8 — Feed line choke comprises RG174 TFE coax wound on FT240-31 cores.

Top loading shortened verticals has been shown superior to coil loading in several studies. I am also partial to matching resonant antennas with TLTs since they have very low losses and wide bandwidths. While tuned circuits with variable inductors and capacitors can match over a band, they do so at a higher cost, larger size, longer time to change frequency and greater weather sensitivity. My switched fixed capacitor matcher parts cost was about US$100 for everything, excluding the control cable.

This design is easily modified to broadbanding an 80 m vertical. The capacitor values will be different for different antenna geometries, so an *EZNEC* analysis is a good starting point. It is also possible to automate the segment switching using band decoders with programmable segment frequencies.

My thanks to Rudy Severns, N6LF, for his extensive research about elevated radial systems. See his *QEX* series on this topic.

Grant Saviers, KZ1W, was first licensed K3JEB circa 1958. After receiving a BS and MS degrees in Engineering, he was inactive many years during his career in the computer storage and PC industry. He relicensed as KZ1W in 1982 for offshore sailing communications. His interests are DXpeditoning (E51MKW, TX5D, TX7G, and maritime mobile on cruise ships), modeling and building antennas, and contesting from his Redmond, WA station. He has been chasing DX since 2011 when he started building his current station. Grant also entertains himself in his large hobby machine shop.