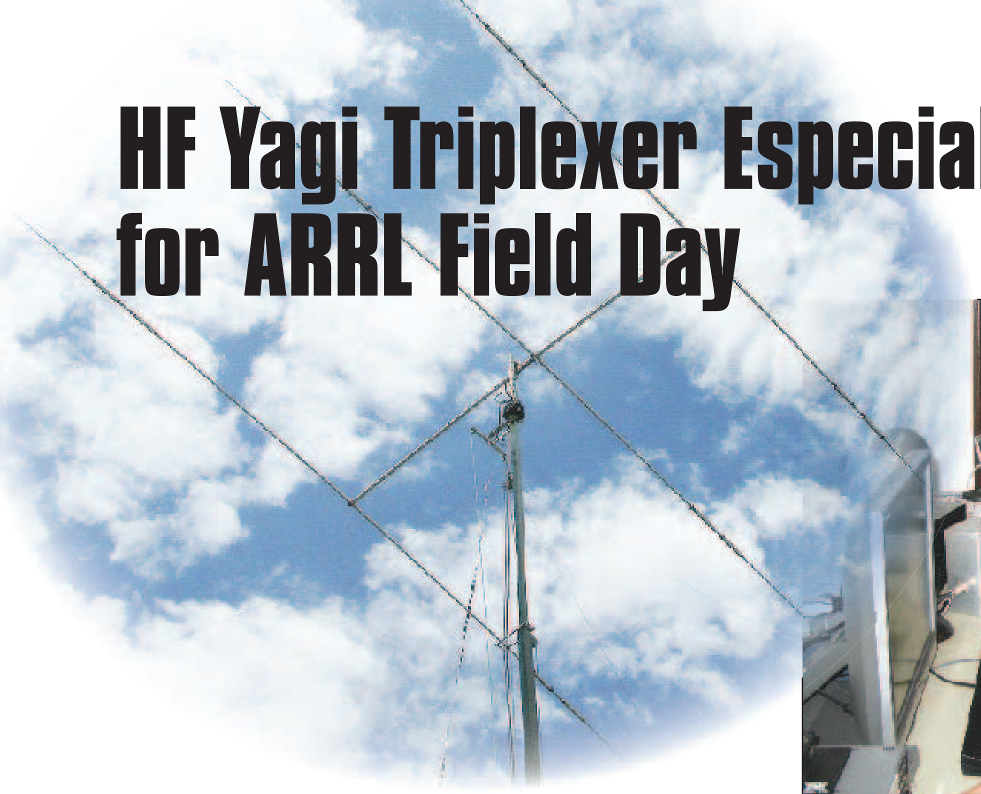

HF Yagi Triplexer Especially for ARRL Field Day

This easy-to-build project lets up to three transceivers on 10, 15, and 20 meters share the same antenna.

Gary Gordon, K6KV

K6KV

Figure 1 — Kenneth Finnegan, W6KWF, in foreground and Phil Verinsky, W6TQG, at Phil's station, competing in the July 2009 NAQP contest in the multioperator two transceiver category. Using the triplexer standing on the table between them, Kenneth and Phil operate on both 20 and 15 meters sharing Phil's triband antenna.

It all started during a WVARA ARRL Field Day discussion.[1] Svend Jensen, KF6EMB, was asking Jim Peterson, K6EI: "If a triband Yagi works on three bands, why do three transceivers need three separate antennas? Why can't they all share the same antenna?"

Whoa — connect my receiver to your transmitter's antenna? It sounded like asking for big trouble. Even with separate antennas, just having one station near to another can cause plenty of interference. Unless precautions are taken, signals from one station will invariably find their way into the other and cause overload or possibly damage.

Fortunately, the nearby radio problem was solved years ago with the introduction of band-pass filters. You connect one between each rig and its antenna, and they'll block signals on other bands from getting through. It's little surprise they've become standard fare on most contest outings.

You might wonder if simply paralleling several band-pass filters together might allow different rigs to share the same antenna. Unfortunately it won't, partly because more isolation is required but mainly because their design is such that they'd simply short out each other's signals. What will work, however, is using a decoupling network in conjunction with band-pass filters as described in this article.

This article describes two designs, one rated for 5 or 10 W and the other for 100 W. Both use commercial band-pass filters to greatly simplify the project. Each has insertion losses, including the band-pass filters, of less than 1 dB. The 100 W triplexer was contest proven during the 2009 NAQP RTTY and SSB contests at W6TQG (see Figure 1). Both versions were used during WVARA's 2009 QRP Field Day. With a triplexer, every transceiver could be operated as though it owned the antenna, even to the point of tuning it for minimum SWR. There was never a hint of interference, and all that was left for the operators to decide was where to point the antenna. One limitation, of course, is that it a single antenna can only point in one direction at a time.

Rig Protection

By now you might be asking, just how safe is my receiver? The short answer is, as long as the band-pass filters stay connected to the decoupling network of this article, it's virtually impossible to come up with any scenario that could damage a transceiver. Rigs are generally safe with overloads up to approximately 1 W of RF power at their antenna connectors; crosstalk from using a triplexer is far below this level. Under the worst conditions with 100 W transmitters, a receiver will never see more than 2 mW of RF, or 1/500 of the damage level.

During normal operation, signals from other transmitters are attenuated approximately 50 dB through the action of both the band-pass filters and the decoupling network portion of the triplexer. Although not immediately obvious, the risk is equally benign should you inadvertently tune your receiver to a band where another rig is transmitting, because 2 mW of RF just isn't hazardous. If another rig inadvertently transmits on your band, your receiver will see even less than 2 mW, because besides the normal isolation the triplexer provides, the offending rig will shut down from being unable to find an impedance match.

If a component fails or arcs over, perhaps caused by running excessive transmitter power, a resonant circuit in the triplexer will either short out or open up. Artificially introducing these failures only lowered the crosstalk, which never measured more than 0.1 mW.

We can also calculate the stress on the feed line. With 100 W PEP transmitters, the feed line might see average power levels around 100 W, and peak potentials of 300 to 500 V.

[1]Notes appear on page 40.

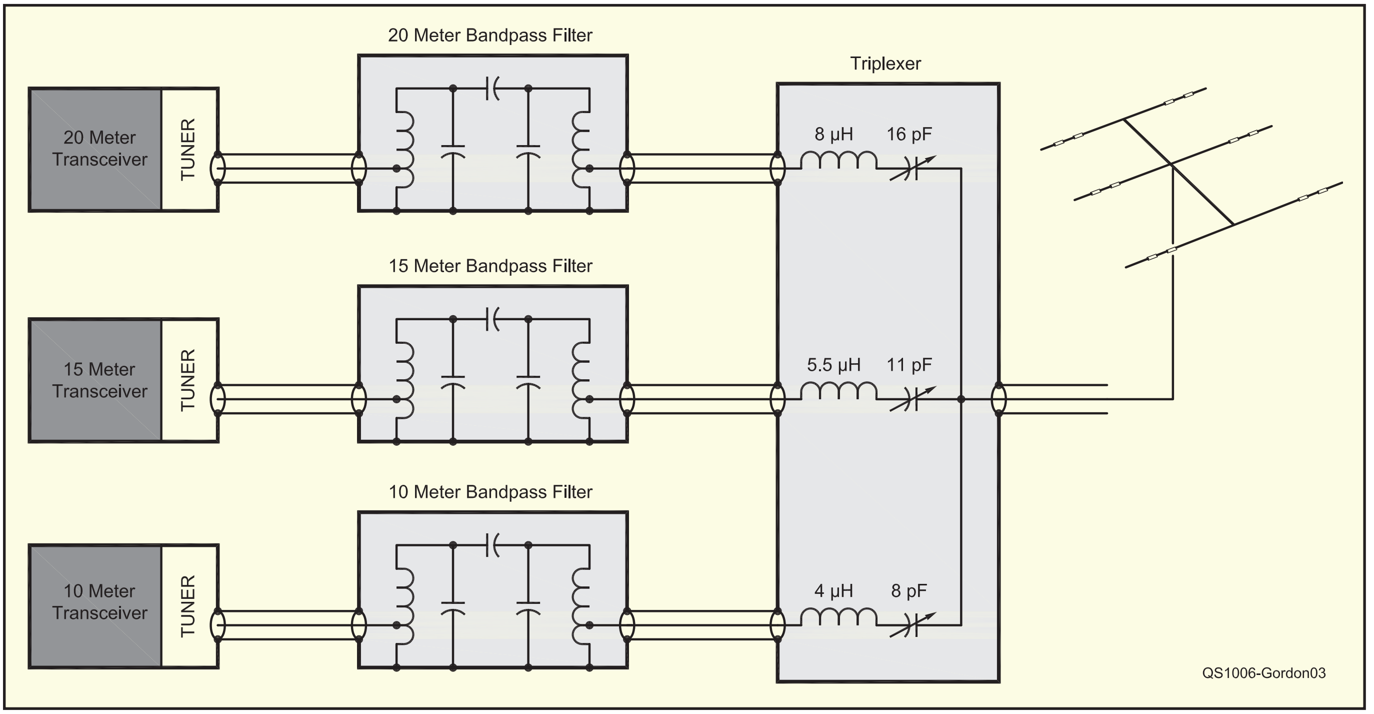

Figure 2 — Triplexer schematic. See the article regarding choosing the capacitors and winding the inductors.

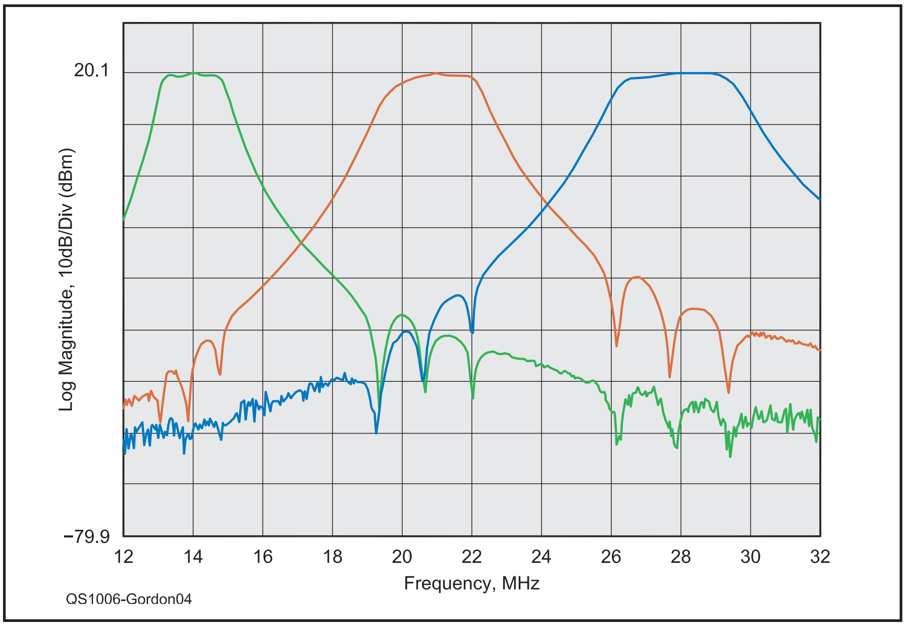

Figure 3 — Frequency response of the triplexer decoupling network and band-pass filters. Next-band signals are attenuated by approximately 50 dB.

These are safely within the 430 W rating for 0.2 inch diameter RG-58/U coax cable and the 1000 V rating for PL-259 UHF connectors.

Note that the portion of this project that you can build, the decoupling network box, is not the entire triplexer, and will not by itself protect transceivers. Only when band-pass filters are connected to it will the transceivers be safe. If you plan to try any automatic antenna or band switching, then be sure to do it outside this regime. That said, it seems inconceivable that any component failure, loose connector or band switching mistake could put a transceiver at risk. With this setup, a receiver should never be subjected to a power level any stronger than 2 mW.

Circuit Description

The decoupling network portion of the triplexer uses three series resonant circuits, one between each input and the common antenna feed line connector (see Figure 2). For example, the 20 meter (top) series tuned circuit is tuned to resonance at 14 MHz to pass signals on the 20 meter band while attenuating signals on all other bands. Each resonant circuit has a loaded Q of 5, chosen to keep insertion losses low while providing sufficient other band attenuation. Figure 3 shows the frequency response for the three channels of the triplexer with Dunestar model 300s bandpass filters, as measured on an HP 2588A spectrum analyzer.[2]

Table 1 shows the insertion losses at five frequencies across the 20 meter band, measured using a JRC JST-245 transceiver, a Daiwa CN-620B power meter, and an MFJ-264 dummy load. Except for the top end of the 10 meter band the insertion loss never exceeded 1.0 dB, one sixth of an S-unit. Figure 4 shows the SWR measurements for the three bands, which rarely exceeded 1.5:1, as measured using an HP 8591E Spectrum Analyzer and a directional coupler.

Construction

Figure 5 shows a 100 W version of the triplexer. A 5 W version was also built. The only differences between them are the voltage ratings of the variable capacitors and the way they are mounted. Either version can be built in a die cast or other metal enclosure that provides shielding and ground continuity between the inputs and the output. An example is the Hammond 1590E boxes that are available as Digi-Key part number HM155. The input and output connectors are SO-239 UHF jacks. Their ⅝ inch mounting holes can easily be drilled using a step drill or ⅝ inch countersink.

Table 1
20 Meter Insertion Losses for the 100 W Triplexer Decoupling Network and Band-pass Filter

Frequency (MHz)	*Transmit Power (W)*	*Filter Loss (dB)*	*Triplexer Loss (dB)*	*Total Loss (dB)*	*Power Out (W)*
14.00	175	0.70	0.30	1.00	139
14.10	175	0.68	0.29	0.97	140
14.20	175	0.68	0.29	0.97	140
14.30	175	0.68	0.30	0.98	139.5
14.35	175	0.73	0.27	1.00	139

Table 2
Winding Specifications for Inductors Suitable for Power Levels up to 150 W
See text. All coils 1 inch in diameter.

Inductor	*Band (Meters)*	*Inductance (μH)*	*Turns*	*Wire Size (AWG)*	*Winding Pitch (TPI)*
L1	20	8	19.5	20	17.5
L2	15	5.3	13.5	18	13
L3	10	4	12	16	11

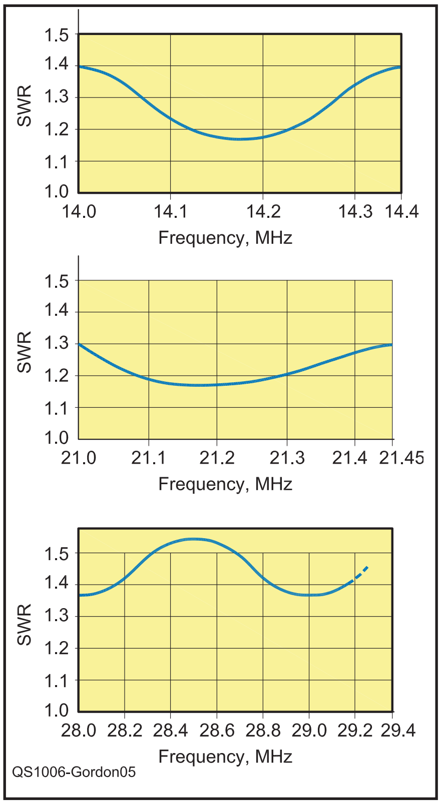

Figure 4 — SWR measurements for the triplexer decoupling network and band-pass filters

Inductor Details

The inductors can be wound on 2 inch lengths of 1 inch polycarbonate tubing (not brittle polystyrene), available from Tap Plastics (**www.tapplastics.com**). Small holes can be drilled near the ends of the forms to provide for anchoring the ends of the windings. Short lengths of ¾ inch polycarbonate rod can be glued into one end and tapped for mounting screws.

The wire can be bare, enameled, tinned, or Teflon insulated wire, depending on what is available. The suggested wire gauges in Table 2 do not need to be followed exactly. A wire kit is being offered by VE2VBR that consists of 25 foot lengths each of #16, 18 and 20 AWG wire. Alternately, short lengths may be available on Internet auction sites and in stores.[3]

If your wire is either bare or has thin insulation, the coil turns should to be spaced apart slightly. You can space the coil turns by interspersing fishing leader between them, added after the wire has been wound, and then coating everything with an adhesive. For my inductors I used a threading lathe to cut a shallow 0.03 inch spiral groove across much of the length to guide the wire, something a machinist could do in half an hour. In either case winding the coil is much easier if the wire is first straightened. Cut generous lengths, perhaps 7 feet for the 10 meter coil and 10 feet for the 20 meter coil, anchor one end to a vice or anything rigid and then use pliers to give the other end a sharp yank, stretching the wire an inch or so. If your wire has Teflon insulation, the turns do not need to be spaced apart.

Capacitor Details

Look for variable capacitors with maximum capacitances ideally of 20 or 30 pF or slightly more.[4] For the 5 W version) the first choice is the miniature APC style. These variable capacitors are compact, inexpensive, relatively available as industrial and military surplus, and adjusted using a screwdriver. Look for capacitors with 500 V or higher ratings, such as the Fair Radio Sales 35 pF 1G-35.

Higher power triplexers call for capacitors with larger plate spacings since, for example to handle 100 W, they will be subjected to at least 1200 V peak. One excellent choice for this power level is the RF Parts 41 μF 48APL41S.

Table 2 lists the recommended voltage ratings for different power levels, and how to estimate the voltage rating based on the plate spacing. If you come across capacitors with higher than optimum maximum capacitances, you might consider modifying them by removing either rotor or stator plates by sawing off a fraction of the lengths. I'll mention in passing that a completely different but more complicated way to make tuned circuits is using fixed capacitors and toroidal inductors that are adjusted by sliding their turns, as described in a *QST* article.[5]

The variable capacitors are not panel mounted but instead insulated from the metal box. In the 100 W version shown in Figure 5, they are mounted to a 1 inch wide strip of aluminum. The aluminum strip is insulated from the box by stand off insulators such as the threaded phenolic spacers manufactured by Keystone. These are available in the ¾ × ¼ inch size from Digikey as part number 386K. This mounting method also provides electrical continuity between the three capacitors. The previously suggested 41 pF part has a ¼ × ⅜ inch shaft, which should be slotted for screwdriver adjustment access through ¼ inch holes drilled into the box. Recessing the adjustment in this manner will discourage knob twiddling, since once the capacitors have been initially tuned they never again need to be touched.

Band-pass Filters

To complete the project you'll need a set of three 40 dB band-pass filters. These are available commercially, or can be home made.[6-9] If you really want to build your own filters I recommend using the step-up transformer approach used in the commercial products and in the referenced articles in order to achieve sufficient Q, although my strongest recommendation is to keep this a simple project by borrowing or buying a set.

Note that band-pass filters have their own power limitations. Those manufactured by Dunestar are rated for intermittent use with transceivers up to 200 W, and with the additional advice that they be operated into low SWRs and with an antenna always connected.

I must reemphasize that in order to protect the transceivers from damage, band-pass filters must be attached to the decoupling network box of this article, and a note to this effect should be placed on your unit. To ensure they stay a permanent part, screw their free ends down to a strip of wood or metal, which also protects connectors from getting broken if

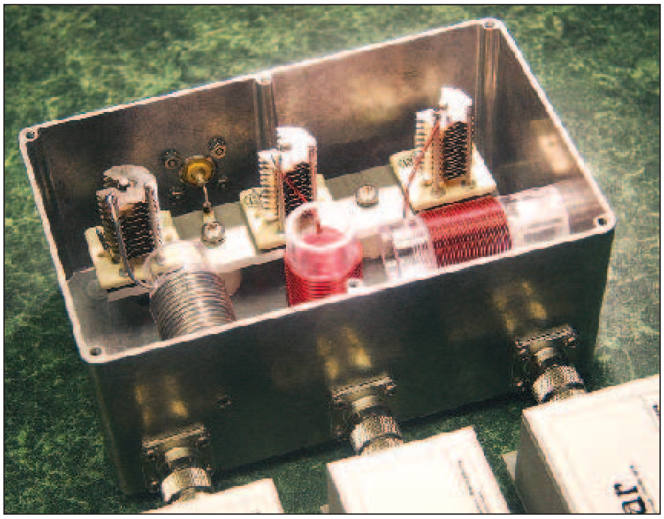

Figure 5 — The 100 W triplexer decoupling network with its cover removed.

cables get yanked on. It would seem a good idea to also label the outboard end of each filter's feed line with its intended band.

Adjustment

Tuning the triplexer's decoupling network consists of adjusting each tuned circuit for resonance on its particular band. The easiest way is to do this is to connect it to a dummy load and adjust the capacitors for maximum power to the load. Start by connecting a transceiver to the input of the 20 meter band-pass filter and the triplexer's output to a power meter and dummy load. You can set your transceiver frequency to either the center of the band or in your favorite segment, although its bandwidth will be wide enough to cover the entire band. Set a low power level, and turn off any antenna tuner.

With the power meter set to a sensitive range, transmit a CW signal and adjust C1 for maximum power using an insulated screwdriver. If you are using an analog power meter, increase the transmitter power if necessary to move the needle up the scale and make the adjustment more sensitive.

The 15 and 10 meter circuits are tuned in a like manner. If your three variable capacitors are identical you should see their engagement angles look something like those in Figure 6, where the capacitance values will be roughly 8, 11, and 16 pF. As a final check of performance, confirm that the insertion losses are not higher than approximately 1 dB (20%), by comparing dummy load power readings with and without the triplexer.

First On Air Test

Since the concept was inspired by ARRL Field Day 2009, the first tests took place at that event, at an open space preserve atop Mora Hill in Cupertino, California. Needing to adjust to the park ranger's new and more restrictive rules regarding how much aluminum we could have, we decided on two gain antennas, one triband Yagi each for CW and SSB. Since the skip was always to the East, neither antenna needed to be rotated, although that advantage might not apply to your location. Each antenna ended up servicing three separate transceivers, giving us nearly the firepower of six monoband Yagis. We placed 12th overall nationally, second in our division and third nationally in the low power (QRP) category.

No Interference (Really?)

Before Field Day arrived, Jim Peterson, W6EI, and I ran a series of interference tests using six different midrange transceivers each running 100 W. The short takeaway is that as long as his triband Yagi was connected we saw no interference whatsoever, regardless of how we mixed and matched the rigs and bands.

That made us curious as how much safety margin existed, and since it wasn't possible to increase transmitter power, we decided instead to eliminate atmospheric noise by replacing his antenna with a dummy load. While this represented an artificial situation, nonetheless it was a useful way to expose underlying interference issues, which we did see in most cases. The only exception was an absence of any interference between two Elecraft K3 transceivers.

Interference can be caused by both transmitters and receivers. If you're looking for a clean transmitter, look for one with low phase noise, as revealed by having low "composite transmitted noise" in the ARRL Product Reviews. For a resistant receiver, according to Elecraft, look for one that has a high out-of-band signal rejection, as measured by its second order intercept point (IP2). That and other useful transceiver specifications can be found at **www.elecraft.com/K2_perf.htm**. Nonetheless, while it's smart to test one's equipment before any important event, you should not expect to encounter any interference whatsoever when using this triplexer with modern transceivers.

Table 3

Recommended Minimum Capacitor Ratings for Different Transmitter Power Levels

Transmit Power (W)	*Capacitor Rating (V)*	*Plate Spacing (inches)*
150	2500	0.062
100	2000	0.050
25	1000	0.025
6	500	0.015

Conclusion

This is an easy to build construction project that will reduce the amount of antenna hardware you'll need for your next multioperator contest. I look forward to others sharing their experiences and improving upon the design.

I am pleased to acknowledge the encouragement and testing help provided by Jim Peterson, K6EI, and to Rene Morris, K6XW, of Elecraft for the frequency response test of Figure 3.

Notes

[1]WVARA, West Valley Amateur Radio Association, San Jose, California. **www.wvara.org**.
[2]**www.dunestar.com**
[3]Wire: Conception R.B., **www.conceptionrb.com/boutique/index.php?cPath=46**, **www.conceptionrb.com/boutique>English>Catalog**.
[4]Variable capacitors: RF Parts, Fair Radio Sales (see their 1G-35) and eBay.
[5]E. Wetherhold, W3NQN, "Clean Up Your Signals with Band Pass Filters," Part 1, *QST*, May 1998, pp 44-51, Part 2, *QST,* Jun 1998, pp 39-42.
[6]**www.arraysolutions.com/Products/wx0bbpf6.htm**
[7]See Note 2.
[8]E. Wetherhold, W3NQN, "Receiver Band-Pass Filters Having Maximum Attenuation in Adjacent Bands," *QEX,* Jul 1999, pp 27-30.
[9]See Note 5.

ARRL member Gary Gordon, K6KV, took a liking to electricity in grade school after reading a copy of The Boy Electrician. *A few years later in Milwaukie, Oregon he built his first Tesla coil and in 1955 became WN7ZKG. The following year, finding war surplus parts both cheap and plentiful, he picked up several 803 pentodes for $.50 apiece and built a 300 W linear amplifier. That, a full size antenna and a swamp front location made for a quite respectable signal on 80 meters.*

Gary went on to study electrical engineering at University of California at Berkeley, and Stanford University. He then enjoyed a productive career at Hewlett Packard where, among other things, he co-invented the optical computer mouse. You can reach Gary at 21112 Bank Mill Rd, Saratoga, CA 95070 or at **gary1@gary-gordon.com**.