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A 10 Band "Stealth" Attic Antenna System for Contesting and DXing

Here's a complete, out-of-sight antenna system that's even SO2R-capabale!

When I began this project four years ago, my dream was to achieve mixed-mode DXCC "eventually." I live in an antenna-restricted neighborhood in Kansas, and my early expectations for an attic-mounted antenna were low. But a barefoot CW contact with a station in New Zealand a couple weeks after I put up my first attic antenna changed my thinking and started me down a road that eventually lead to my current fifth-generation attic antenna system.

The system lets me work dozens of DXCC entities on a contest weekend, even with modest propagation. Even maintaining a run frequency on 20 or 40 is not difficult most of the time. With 10 bands available, I can participate at some level in any operating event from 160 to 6 meters (I prefer RTTY contests for my all-out efforts).

My present attic antenna system incorporates lessons learned from prior attic systems at my location. The first antenna I built was based on LB Cebik's (W4RNL, SK) favorite 88 foot zigzag dipole and was fed with ladder line. An attic-mounted autotuner allowed multi-band operation. Later I replaced the dipole with a set of full-sized delta loops for 15, 20 and 30 meters. As my contesting activity increased, my desire for a directional antenna led to a 3-element reversible V-shaped Yagi design for 20, 30 and 40 that used coax traps. Center-mounted relays with switchable inductors created dual director/reflector functionality for the outer elements. Interest in the lower bands and a few RTTY contesting related trap deaths lead to the development of my initial 10-band design. Modifications made over the last year for SO2R and other improvements have brought the array to its current fifth-generation configuration.

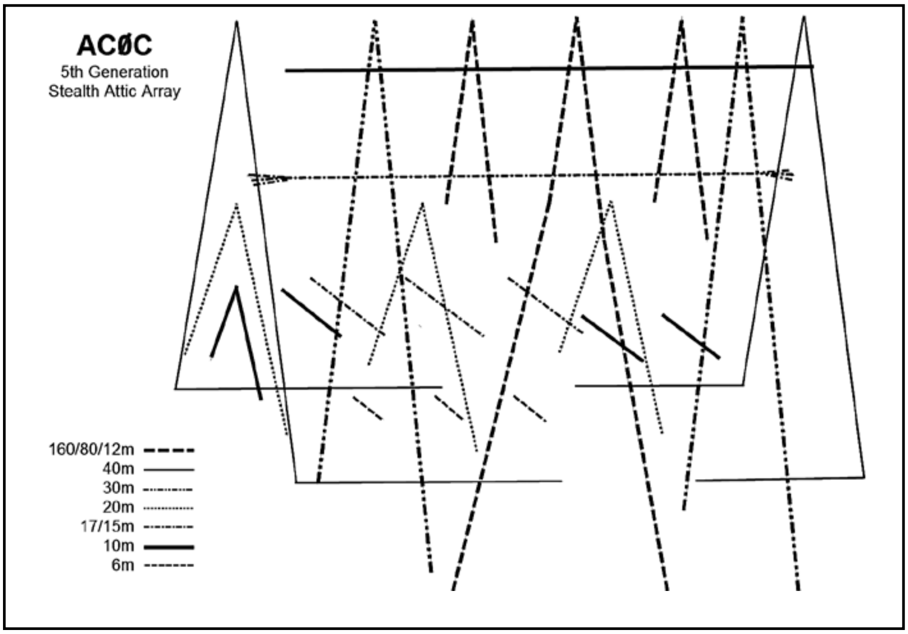

Figure 1 — A diagram of the entire attic antenna system, representing antennas for 10 bands

Key Array Features

My 5G system covers all HF bands plus 6 meters and will handle the legal limit. Wherever possible, I employed monoband, reversible 2-element Yagi designs. Trap use was minimized although it could not be fully avoided due to space constraints.

Many of the antennas consist of three elements with two of the elements active at any given time. The center element is the driven element (DE). On either side of the DE is a split element cut as a director and with a relay in the center. When the relay is closed, joining the halves, the element serves as a director. At the same time, the relay in the center of the other split director is opened, causing the element to become largely invisible from the perspective of the array. Toggling the relays lets you reverse direction instantly!

The antennas are resonant, tuned for the CW/RTTY segments of each band. I've incorporated a tuner, but it's not required except when working band segments far away from the frequency of resonance.

To simplify switching and control requirements, SO2R band selection for one rig is limited to 40, 20 and 15 meter operation and has hardware-based antenna priority for these bands. The second rig covers all 10 bands.

The antennas and associated decoupling/control system are fully automatic and designed to minimize SO2R adjacent-band coupling. Antenna configuration follows the rig's band selection transparently. A virtual rotator feature allows *DXLabs* and *N1MM Logger* to set the array's direction of radiation.

Development of the system made extensive use of *EZNEC* and *MMANA-GAL*. Optimum location of individual antennas was determined initially by moving a 2-element Yagi element pair around inside the model, and then checking to see if the modeled placement was physically possible. Because the attic environment contains so many un-modeled factors, conventional tuning methods are not reliable. Instead, all elements in the array are instrumented with the W8WWV "relative vector meter" (RVM) system,[1] which allows measurement of the actual phase/current relationships in the physical antenna. Trimming of individual antennas is accomplished by setting the element phase relationships to the modeled targets. By using the measured currents/phase values as sources in the *EZNEC* model, azimuth and elevation plots can be generated with higher accuracy than otherwise possible.

Materials used for the system include 1500 feet of RG-213 and RG-11 coax, 2000 feet of multi-conductor control wire, 1000 feet of #12 THHN wire, 150 feet of aluminum tubing, 60 relays, and 200 T240-13 and many hundreds of other ferrites.

Table 1 — A snapshot of my 2012 RTTY contest activity: These claimed scores (and preliminary 3830 rankings) provide a real-world assessment of the array's capabilities in contest service.

Dreaming of a Top 10 Finish

Contest	*Details*	*Claimed Score*	*Preliminary 3830 Rank*
ARRL RTTY Roundup	1451 QSOs, 57 Sec, 50 DXCC	155,257	#24
CQ WW WPX RTTY	1008 QSOs, 1986 points, 406 prefixes	806,000	#36 US SOAB HP
NAQP RTTY	776 points, 163 mults	131,920	#22 SOLP

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Figure 2 — The author switches attic antenna parameters from the control box in his well-equipped shack.

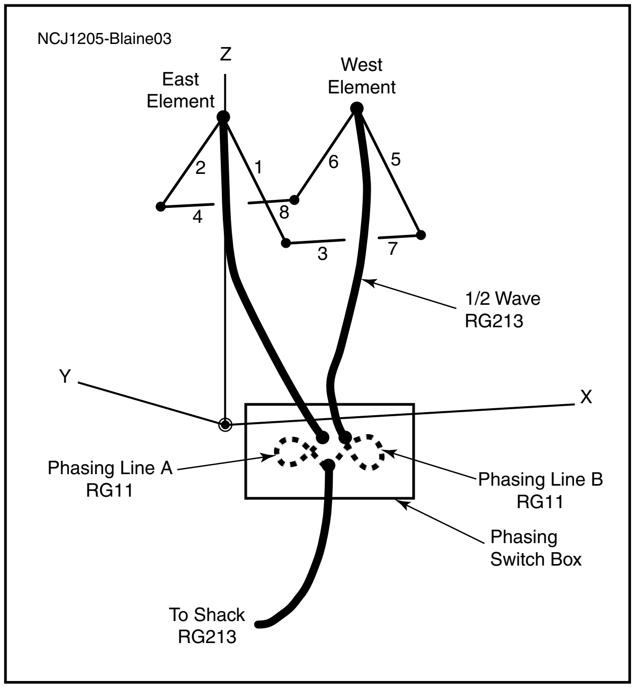

Figure 3 — A diagram of the 40 meter antenna, showing the feed lines and phasing lines

Fitting Antennas into the Attic Space

The area containing the array is triangle-shaped, 16 feet high at the center, 20 feet along the "beam length," and 40 wide at the triangle base. The apex of the attic is about 45 feet above ground level. The house orientation allows the antenna boom to radiate approximately east-northeast and west-southwest. The northeastern sides of the house slope down and away, giving an improved east beaming height-above-ground profile. The attic space is mostly free of elevated metals, with only one vertical stove pipe vent, although the attic floor surface has a full complement of HVAC and ac wiring for house lighting.

The Individual Antennas

- **160, 80 and 12 meters**: The largest of the array elements is a trapped/loaded dipole for 80 and 160. It also serves as the DE for the 12 meter beam. Additional inductance at the ends of the 80 traps provides a mild loading effect on 160 and, combined with capacity hat extensions, resonates the antenna at 3.56 MHz and 1.815 MHz. For 12 and 160 meters, hairpins are switched in at the feed point. For 12 meters, two additional elements adjacent to the DE serve as directors for the 12 meter beam. Relays in the center of each director set the directivity of the 12 meter antenna, as described above. Closing one relay and opening the other yields a 2-element Yagi array.

  A separate patio-mounted receiving loop for 80 and 160 provides low-band receive noise relief and (so far) has not attracted the attention of those who enforce the neighborhood covenants, conditions and restrictions (CC&Rs).

  The traps (see Figure 8) are built from ¼ inch copper tubing wound on a 5 inch form and fixed-value 15 kV surplus vacuum caps. A soldered tap point within the tubing tunes the trap. No trap failures have occurred since I adopted this design.
- **40 meters**: The 40 meter antenna is a full-size, 2-element electrically reversible V beam Yagi. The phase-driven feed system is based on the Lewallen (a-k-a Christman) "simplest" feed system. Feed-line lengths were calculated using the *Feed2EL* spreadsheet tool by Dan Maguire, AC6LA.[2] The elements are fed with half-wave lengths of RG-213, which essentially replicates the feed-point at a much more convenient attic floor level, helping me avoid some rafter climbing. A switching arrangement selects between two separate sets of phasing lines, depending upon the direction desired. In addition, both elements can be driven in phase, providing an omnidirectional pattern.
- **30 meters**: The antenna for 30 is a full-size 2-element V Yagi, presently fixed and beaming east-northeast. Based on the success of the of the 40 meter beam, conversion to the same phase-driven topology is planned for the off-season. That will provide east-northeast, west-southwest and omnidirectional modes.

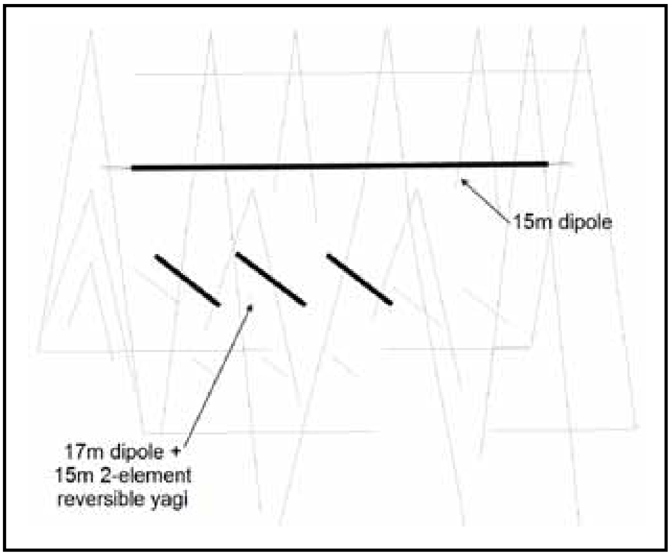

Figure 4 — Arrangement of the 17 and 15 meter array (lower) and the separate 15 meter dipole (top)

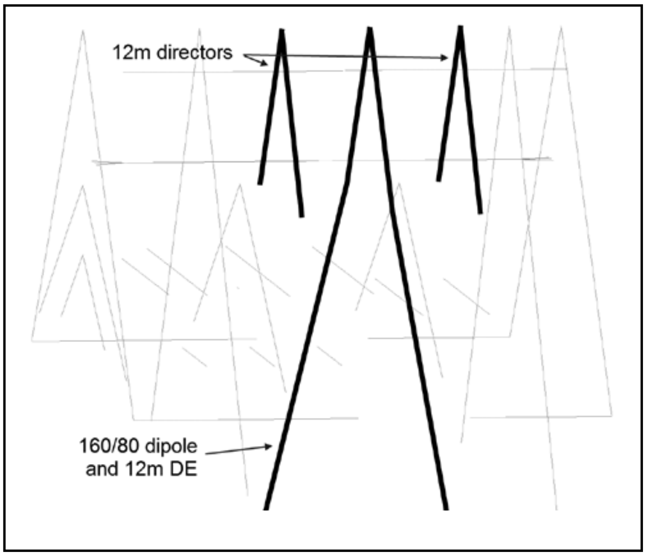

Figure 5 — Diagram showing the integration of antennas for 160, 80 and 12 meters

- **20 meters**: A full-size 2-element electrically reversible V Yagi is the antenna for 20. Similar to the 12 meter design, the antenna is fed in the center element, with the two elements on either side as relay-switched directors. I tried several traditional 3-element reflector/driven element/director designs, with mixed results. Due to the complicated trim and the need for uniform spacing between elements, I went with a 2-element design. The elements are somewhat close-spaced, which helps maintain a high coefficient of coupling between the director and the DE. Feed-point impedances for this design are low, and a hairpin is used to provide a good match to the coax feed line.
- **17 and 15 meters**: The DE for this antenna is built from a modified Mosley 20/15/10 meter dual-trap element. The inner trap was bypassed, leaving a functional 15 meter trap. The stubs extending from the 15 meter trap were trimmed for 17 instead of 20, and this provides dipole-level performance on 17 meters. The 15 meter beam again follows the 3-element, dual relay-switched director format, functioning as a 2-element reversible Yagi. Two 17 meter directors will be added in the off-season to provide similar capability on that band. The Yagi has deep nulls to the JA/SA paths, so I added an additional 15 meter dipole. The

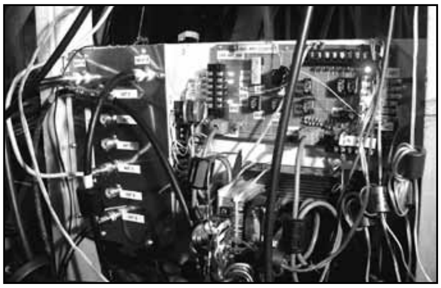

Figure 6 — The attic-mounted SO2R board (upper right) and interconnections demonstrate the complexity of the system design and control gear.

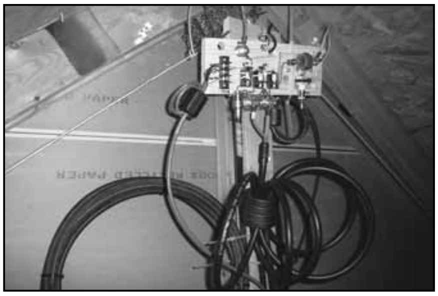

Figure 7 — The feed point of the 40 meter antenna: Note the liberal use of ferrite and coax-coil chokes to minimize common mode and unwanted RF.

Figure 8 — An 80 meter trap made with ¼ inch copper tubing wound on a 5 inch form and fixed-value 15 kV surplus vacuum caps

dipole is oriented along the boom and provides a nice filler function.

- **10 meters**: This band is supported with three antennas — a pair of independent fixed 2-element beams, one facing east-northeast and another facing west-southwest, and a boom-oriented dipole similar to the 15 meter design. I went with this configuration, because the rest of the array exhibits too many unwanted parasitic effects for the normal centrally located reversible solution to provide a clean pattern. The 10 meter dipole serves the JA/SA path so important in DX contesting — if the band is open!
- **6 meters**: For "the Magic Band," there's a 3-element bidirectional beam aiming east-northeast and west-southwest. I put this antenna up on a temporary basis in 2010 to take advantage of band openings. It's configured as a dual-director arrangement for a bidirectional pattern, and that has worked fine for stateside work. Conversion to a dual dedicated set, such as the pair used on 10 meters, is likely for the next iteration.

Decoupling Methods

With so much wire and tubing in such close proximity and with 10 bands to consider, the elements themselves as well as the various control lines are going to function to some extent as unintended parasitic elements. Much of the complexity of the system is driven by the need to contain these.

Ensuring that individual elements carry current only on their designed bands is accomplished through the use of a combination of center-positioned relays and coax stubs. For SO1R operation, relays alone could serve this function, but with the switch to SO2R operation, things are much more complex.

There are many cases where a given element may need to be both simultaneously open (electrically split in the center) for best isolation on one band and also closed (electrically connected in the center) for best isolation on another band. This dual-personality role calls for coax stubs instead of relays. A stub placed in an element's center can appear open on one band and shorted on another band. In some cases, I needed two stubs and a few relays to provide the needed functionality.

The board where the stubs, relays and elements connect is in the center of each element; I call this the "isolation module." The isolation module for the 160/80/12 meter system is the most complex in the array.

Here's the thing: With 22-elements to consider, how do we determine which elements need to be open and which closed? *EZNEC* comes to the rescue here. The best open/short combination for each band was determined by looking at the modeled currents of all elements in the array on a per-band/per direction basis. Results of model testing were saved to a spreadsheet. Then the spreadsheet matrix settings were implemented through a blend of relays and coax stubs.

The relay control lines, relay drivers and power sources are isolated and bypassed with L/C filtering and a huge amount of ferrite.

Transmit/Receive RF Signal Routing

Four antenna switches handle signal routing to the nine individual antenna structures. The 4G SO1R system was built around an Ameritron RCS-12 1 × 8 switch. The shack-mounted control unit would read the band data off the rig and select the correct antenna automatically. With the addition of SO2R capability, the 40, 20 and 15 meter bands are further split out into a separate KK1L 2 × 6 antenna switch,[3] which shares these three bands between the two rigs. Antennas with multiple physical feed points are first switched to a single feed point per band using separate dedicated attic-based

Attic Reality — The Three Cs

Considering your own attic antenna farm? The fifth generation project has yielded excellent results in the performance of the ultimate array. It has also been a great learning experience. A few comments are in order regarding the less-exciting side of attic antenna farming — specifically, the 3Cs: Compromise, Confusion and Cost.

Compromise refers to a house full of potential noise sources, as well as devices that can act as receivers or emitters of RF. Compromise in the design of the array also takes into account the space available, maximizing isolation and avoiding physical obstacles. It's about making something work well enough, not making it work perfectly.

Confusion comes from hidden influences. An antenna constructed in the open, free from metal influences, can be modeled with reasonable certainty. That's not typically the case in an attic environment. The entire house structure participates in the antenna system at some level. This includes such things as stucco, wiring in the attic floor and the HVAC runs, which are not part of the modeled environment. Nonetheless, these are factors that interact with the antenna system in a way that's not easily understood. For that reason, the hidden confusion factors can drive a sane ham crazy.

Cost we calculate both in terms of time and money. Attic antenna farming by nature is iterative. You need to test ideas before discovering the complications. This is hard to do in advance, and problems don't readily unveil themselves. From a decoupling standpoint (both above and below the attic floor line), type 31 ferrites are indeed magic bullets. Unfortunately, with each wire in the attic and with most of the electronics in the house below potentially in need of ferrites, the investment in ferrite materials alone can be very substantial.

Not included in the 3Cs are possibly less obvious: Frost bite from winter farming, heat stroke from summer farming, holes in the ceiling and the joys of rafter climbing.

Having considered the 3Cs at the start of your attic adventure will help you to understand if an attic antenna farm is right for you. The attic can yield a fine harvest, if you can withstand nature's challenges! — Jeff Blaine, ACØC switching boards. The KK1L relay board and the 10/15 meter antenna switches are driven from band decoders built into the shack-mounted 5B4AGN W3NQN-style band-pass filter [4] tied to each rig.

System Automation and SO2R Support

Relays mounted on the element center point isolation modules are driven by an attic-based relay driver board. It serves as a buffer between the various attic antenna configuration relays and the shack-mounted control head. The control head (see Figure 2) is an Atmel AVR microprocessor-controlled interface. Its inputs come from the rig's band data port and the operator's manual direction selection. Firmware translates these inputs into the proper relay combination and sets the attic relay drivers accordingly. This arrangement keeps the currents along the shack-to-attic control wires low, which minimizes switching transients.

Beam direction can be set manually by a button press on the control head or automatically by its rotator emulation function. The rotator emulation allows other software to aim the array without operator intervention, much in the same way a traditional beam/rotator combination would.

An additional control board handles SO2R-related tasks specific to the shared bands (40, 20 and 15 meters). It also serves as a convenient place to stick some miscellaneous circuitry that was added since the attic open/short board was built (see Figure 6). The board design features a manual band lockout, giving the one rig priority on these three bands. The second rig, if set to the same band as the first, will see an open circuit. The shack-mounted N8LP LP-100A[5] supports dual couplers, and its SWR alarm will instantly pull the amp's PTT offline if the rig is keyed. This crude safety feature helps avoid fried front ends due to operator error and is in addition to the shack-mounted hardware/software interlocks.

Inputs for the SO2R board are drawn primarily from band decoder lines on the shack-mounted auto-switching band-pass filter. To control RF pickup in the control system and associated wiring, L/C filtering is incorporated as part of the board's design on each I/O line — power and ground. Control lines are individually fitted with ferrite materials at multiple places along their run. The RVM sensor runs employ a similar multiple-ferrite decoupling treatment.

Antenna direction-setting is automatic for the first rig. The beam direction for the second rig's antenna is set manually via toggle switches in the shack. I plan to eventually roll the existing control head into a new unit that will incorporate a second rotator-emulation port. This should allow both rigs to function in an automatic direction-seeking role.

SO2R BPF and More Stubs

Wrapping up the equipment list for the system are a pair of 5B4AGN W3NQN-style auto-switched BPF sets and nine attic-mounted coax stubs. These are in addition to the programmed open/short relay decoupling and element stubs mentioned above. The combination of these three result in an excess of 100 dB of isolation between the SO2R rig coax feed lines on all adjacent bands of operation.

A Word on RF Exposure

I've mentioned that the system will handle full legal output power, which may raise questions about RF exposure to those living below or in the vicinity. By design, power capability on all bands is legal limit, although the actual power used is less, due to amplifier capability and to ensure compliance with the FCC's RF exposure regulations. This antenna system has no coax traps, and I've designed things so all antenna components will stand up reliably, to head off problems that may lead to mid-contest antenna failures.

To determine maximum permissible exposure limits (MPE) for my station, I used the WØJEC calculator (**www.qsl.net/w0jec/index.htm**). On 10 and 15 meters I run into excessive exposure limits at 800 W or so. No one's within range during daylight hours, however, and those bands typically are unusable in the evening, so it all works out. On the lower bands, there are no RFX problems.

To Learn More

More information on the antenna and control system, including AZ/EL plots based on the RVM measurements, construction details, additional diagrams and photos and more are on my website, **www.ac0c.com**.

Credit Where Credit's Due

Many individuals have contributed to this project over the years, providing ideas, materials and time. I am deeply in their debt. Special thanks to Greg Ordy, W8WWV; Bill Carver, W7AAZ; Larry Benko, WØQE; Dan Maguire, AC6LA; Jack Smith, K8ZOA, and Rob Underwood, KØRU.

Notes

1 Ordy, Greg, W8WWV. "A New Approach for Measuring Complex Antenna Currents in a Vertical Array," 2008 Dayton Hamvention antenna forum, **www.kkn.net/dayton2008/W8WWV08.pdf**

2 Maguire, Dan, AC6LA. *Feed2EL*, **www.ac6la.com/feed2el.html**

3 Rossi, Ron, KK1L. "KK1L 2 × 6 Antenna Switch," **home.comcast.net/~kk1l/kk1l_2x6switch**

4 Henderson, Bob, 5B4AGN. "W3NQN Multiband Transmitting BPF Project," **www.5b4agn.net/TX BPF.htm**

5 Phipps, Larry, N8LP. "Dual Coupler Option for LP-100A," **www.telepostinc.com/Dual_coupler.html**