

Designing a Flexible SO2R Receive Antenna Distribution System

Receive antenna distribution and management is an important part of the low-band contester's toolkit. A full-featured switching system fosters more effective and efficient use of available receive antenna resources. Unfortunately, it is also an area with poor representation in the commercial market, so it is still in the realm of the do-it-yourself amateur. My initial search for an existing solution was met with disappointment. All fell short of meeting the demands of a truly comprehensive solution.

It's important to define what constitutes a comprehensive receive antenna distribution system in the context of an SO2R station. SO2R implies two radios, thus at least two receivers. A proper receive switching system needs to provide a way for each receiver position to independently select and, if necessary, properly share an antenna. This is further complicated by an operating technique I use — I call it "SO2R-3RX" — where audio from three receivers is streamed to the headphones.¹ In this situation, at least three receivers need independent — and potentially shared — antenna routing.

In addition a reasonable, expandable number of antenna terminations are required. This permits adding receive antennas without creating undue complexity or having to redesign the switching system.

Existing Designs

Off-the-shelf SO2R antenna switches intended for transmit antennas are sufficient for situations requiring receive antenna distribution to a pair of receivers in the same radio (ie, SO2V), where antenna sharing is not really needed. For true SO2R, though, they do not provide the ability to properly share antennas among multiple receivers, since they lack any kind of splitting devices that are important for isolation and impedance preservation. While external splitting could be implemented, the situation becomes cumbersome when you need additional flexibility, such as expanding the number of antenna terminations beyond the basic switchbox.

There are numerous documented solutions for switching receive antennas, but

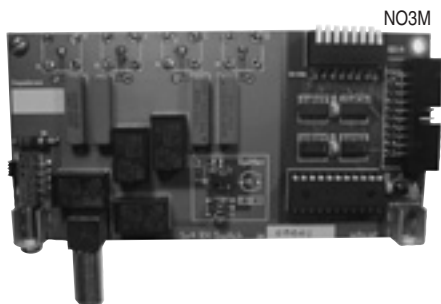


Figure 1 — Antenna switching board: Receiver ports are at the top, the antenna port (type F connector) is at the bottom.



Figure 2 — Antenna switching matrix in its enclosure: Radio ports at the top are wired in parallel. The microprocessor board is in front.

they also lack inherent splitting abilities, especially for same-band operation and are severely limited in the number of antenna terminations. A design I found to be the most promising for further development was published by Stu Mitchell, W7IY.² While his current implementation is still limited in the number of antenna terminations, the modular approach he has taken could be easily expanded to essentially an unlimited number with further development.

Starting in the fall of 2010 I began developing the system I currently have in place. It addresses all the requirements I've outlined. It has a generous number of antenna ports, is easily expandable and is capable of proper antenna sharing among up to four receivers. Numerous features

and capabilities provided by the user controllers in the shack also make the system a powerful tool for managing the receive antenna farm.

Switch Matrix

The remote switching matrix is based on W7IY's concept of individual antenna routing boards for each antenna (see Figure 1). Each board is basically a four-way switch — one antenna input and four receiver outputs. By connecting the respective receiver outputs of eight of these boards together, an additional splitter board, and a microprocessor board, a complete 8×4 switching unit can be built. It is capable of providing independent selection of any antenna to any receiver as well as proper splitting of an antenna, even to all four receivers at the same time.

When a particular antenna is unselected, the antenna can be terminated directly to ground, through a resistor (50 or 75Ω) to ground, or left open. This feature is useful for reversible Beverages that have two feed lines, where the unused one is terminated into 50 or 75Ω .

The onboard splitter is based on the ubiquitous Magic-T and provides approximately 30 dB of port-to-port isolation in addition to maintaining the characteristic system impedance at each port. Typical signal loss on the order of 3 dB results from splitting. This onboard splitter can be used to share the antenna between "opposite" radio receivers.

Receiver ports are connected via SPST coaxial reed relays. The use of this type of relay was based on RF isolation testing that W7IY performed with various relays.³ I used COTO 2200-2302 relays, because of their small, narrow form factor, and I was able to obtain them cheaply at the time.⁴ You could use any SPST relay that has suitable RF isolation, however. Receiver ports A and B share a common connection on one side of their respective SPST relays, considered to be "same radio, adjacent receiver" ports. This simplifies the onboard splitting. However, if receivers A and B need to share an antenna, only the receiver A port is connected to the antenna, and the signal is split between A and B using an additional

splitting board (discussed later). The same applies for the C and D receiver ports.

To create the switching matrix, each switch board's respective receiver ports are connected in parallel (see Figure 2). Any number of boards can be connected, but all my switchboxes are limited to eight antenna boards to reduce the length of the "stub" (ie, the unused portion of the interconnecting wire). The interconnections between receiver ports could have been made with mini-coax (RG-174), but when I did that initially, it turned out to be quite time consuming and tedious. Using bare, unshielded copper (solid center conductor from RG-6 coax) was quick, easy and, based on isolation tests, sacrificed an insignificant amount of isolation between radio ports.

The receiver port interconnection wires finally terminate into a self-contained splitting board (see Figure 3). This board provides two additional Magic-T splitters, whereby same radio, adjacent receivers (ie, A and B) can also share an antenna. In conjunction with the splitters on each antenna board, all four receiver ports can properly share the same antenna, which results in approximately 6 dB signal loss to each receiver. The termination board also brings the receiver port lines out at the bottom of the board via type F connectors, consistent with the antenna connectors on each antenna switch board, so all coaxial connections are facing the same direction for mounting in an enclosure for outdoor use.

A microcontroller board (see Figure 4) interfaces the complete switching unit to the outside world and provides the relay control signaling to each antenna board and the terminating splitter board. It contains an Amtel ATmega328 microprocessor, programmed in C using the Arduino IDE.⁵ The microprocessor accepts plain-text commands over an RS-485 serial connection from the user controller(s) in the shack. These commands contain, at a minimum, the receiver number and antenna number. The microprocessor then interprets the serial command data and produces an 8 bit address and 8 bit relay data over a parallel bus connection (20 conductor ribbon cable) to each antenna board and terminating splitter board.

Each antenna board and the terminating splitter board have a parallel input, current sourcing IC (Micrel 58P01) for driving their relays. The 8 bit address on the parallel data bus from the microcontroller is decoded using some logic ICs and user-settable DIP switches. Each board has a unique binary address, and when the address on the parallel bus from the microcontroller board matches the DIP switch settings of a particular board, that board's 58P01's

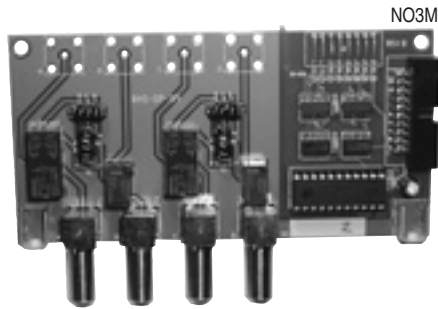


Figure 3 — Terminating splitter board: Receiver ports at the top connect to switch boards. Type F connectors at the bottom go to receiver feed lines.

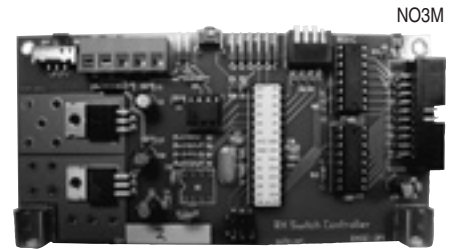


Figure 4 — Antenna switch microcontroller board, connected to the antenna and splitter boards with ribbon cable.

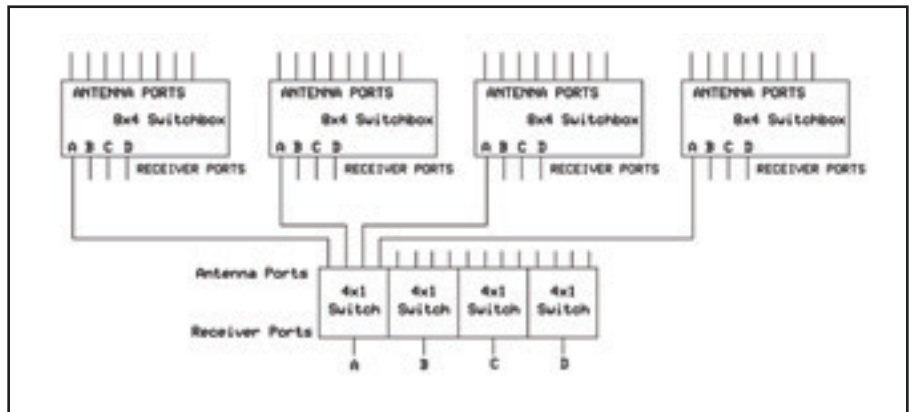


Figure 5 — Diagram of the 32 x 4 switching system: Only the coaxial connections for receiver A are visible.

strobe pin is activated. This pushes the 8 bit relay data on the bus to the IC's outputs, activating the appropriate relay(s) on that board. The microprocessor also tracks per-receiver antenna selections and determines if any splitting is needed, setting the appropriate bits in the 8 bit relay data to activate the splitter relays on the respective board. This includes the terminating splitter board when same-radio receiver splitting is needed.

For reception of the serial data commands from a user input controller in the shack, an RS-485 serial bus⁶ was chosen, since it supports connections among serial devices up to 4000 feet. It is a robust serial network, based on differential signaling, over a twisted pair that has high noise immunity. The RS-485 topology also supports multiple slave devices, so adding switching units is a matter of daisy-chaining the serial connection between units and placing a resistive termination at the end of the chain (set with jumpers on each microcontroller board).

If more than eight antenna ports are needed, additional 8 x 4 switching units can be used to create a larger switching system. The microcontroller board in each unit has its own DIP switch addressing, which de-



Figure 6 — The desktop controller sends serial data over an RS-485 network to slaved switch controllers.

termines the antenna port numbers it manages. For example, the first switching unit handles antennas 1 through 8, the second 9 through 16 and so on. To handle routing among multiple 8 x 4 boxes, an intermediate switching unit is constructed with four antenna switching boards and a microcontroller board. The antenna switching boards function in reverse (ie, they become 4 x 1 switches. What were formerly receiver outputs become switchbox inputs, connecting to the respective receiver ports on the 8 x 4 switchboxes. The former antenna input port is treated as a single receiver output, routing back to the shack and connected to the respective receiver. This combination

creates a 4 × 4 intermediate switchbox. Expansion in this method results in an overall switching structure for up to 32 antennas routed to four receivers (see Figure 5). The use of additional intermediate switching units can expand this even further.

In-Shack User Controller

To make the most of the switching system, an easy-to-use ergonomic interface is important; a standalone controller unit is not absolutely necessary. Since the remote antenna switches process plain-text serial data, many control solutions could be used. This includes a software-only implementation, where a program sends out data commands via a RS-232 serial port on the computer. A RS-232-to-RS-485 converter could be used to get the serial data onto the RS-485 bus that connects to the remote antenna switches. USB switches and knobs (ie, Griffin Powermate or XKeys Jog&Shuttle) could also be used to provide an ergonomic user interface with the software.

I chose to implement self-contained desktop controllers (see Figure 6). This eliminates the need to depend on a computer during operation. Each controller handles two receivers (assumed to be in the same radio). An Amtel ATmega644 microprocessor, programmed in C with the Arduino IDE, stores all antenna, radio and controller configurations, interprets user input and transmits control data to the remote switches or any other device on the RS-485 bus. Configuration settings are written to a simple text file and uploaded via a standard RS-232 serial connection from a PC using a serial terminal program.

Twelve buttons provide up to 36 functional selections through the use of TAP, TAP-TAP, and HOLD key presses and a 128 × 64 pixel graphic LCD displays all current information regarding selected and available antennas, settings and so forth. Optical encoders are used (one per receiver) for antenna selection navigation, where antennas are grouped around a compass-rose display according to their assigned azimuth bearing ranges or as a simple list. The knobs used with the encoders are the same as those used on the Elecraft K3 main VFO.

The desktop controller, being micro-processor based, provides a powerful platform for various advanced features. In the current implementation, the controller also provides antenna scanning between transmissions, per-antenna gain adjustment (used with per-receiver signal processing units), band decoding to mask invalid antennas for the current band, and locking same-radio receivers to different antennas aimed in the same directions (useful for diversity reception).

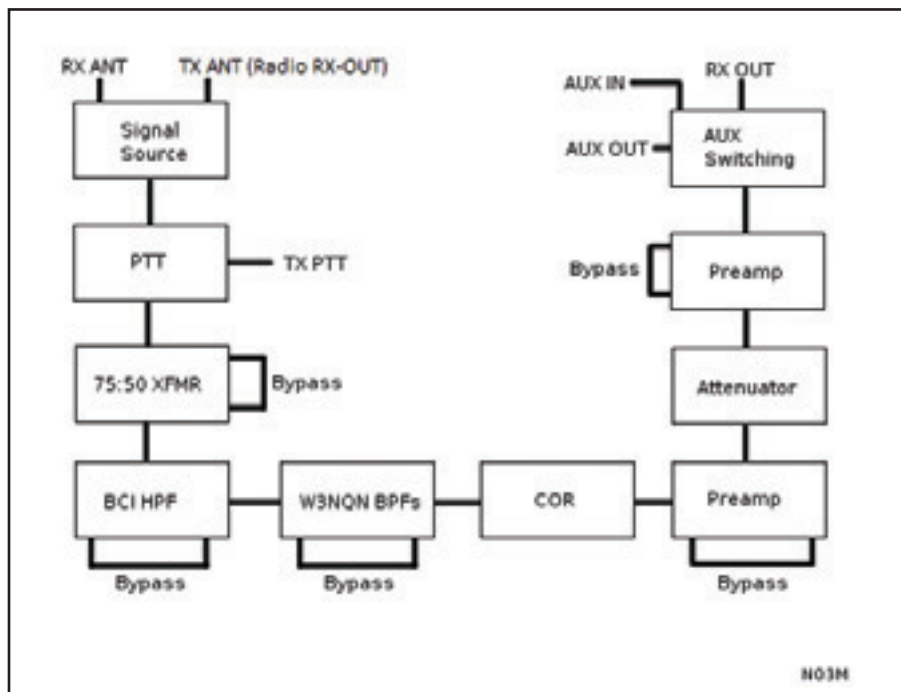


Figure 7 — Signal-processing unit block diagram

Conclusion

The microcontroller-based switching system I've described has greatly improved the efficient and effective use of receive antennas at my station. It provides the hassle-free expandability as well as proper antenna sharing that were primary goals in developing a receive antenna switching system. In addition, numerous features were realized by using programmable master controllers in the shack. The possibilities are only limited by the software, even more so if a PC-based application is developed. Over the past year that it's been deployed, the system has proven reliable. No hardware failures have occurred, nor have there been any behavioral issues that weren't a result of programming errors in the user controllers.

In addition to the switching aspect, I have also developed accessory devices that are controlled over the same RS-485 serial network via the desktop controllers. These devices include a generic relay driver (for controlling vertical array steering) and signal processing units for each receiver (see Figure 7). The signal processors automatically adjust user-defined gain settings per antenna (particularly useful for gain normalization across antennas), compensate for splitter losses in the switching system, provide selection of the radio's transmit antenna, and offer auxiliary signal routing to external devices, such as a phasing controller, SDRs, transverters



Figure 8 — The signal-processing unit with its top cover removed

(think 600 meters!) and other accessories.

More information on the switching system and accessory devices, including schematics and further technical details, are available on my Web site, <http://no3m.net/index.php?page=receive-system>.

My thanks go to K8GU and KK7S for discussions regarding microcontroller platforms at the conception of this project and also to W7IY for sharing information about his particular switching implementation.

Notes

- ¹ <http://no3m.net/index.php?page=so2r-3rx>
- ² Beverage Antenna Switch — v 2.0, Stu Mitchell, W7IY, www.stu2.net/projects/bev2/
- ³ www.stu2.net/projects/bev2/relayIso.pdf
- ⁴ www.allelectronics.com
- ⁵ www.arduino.cc/
- ⁶ <http://en.wikipedia.org/wiki/RS-485>

