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**QST Issue:** Dec 2010

**Title:** A Switchable Sense HF Receiving Antenna (sidebar to Gimme an X, Gimme an O, What's that Spell? -- Radio)

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## A Switchable Sense HF Receiving Antenna

One possible objection to the use of circularly polarized (CP) antennas for HF is the fact that they use a bit more real estate than other antennas, at least for transmitting. However, one can take advantage of the CP properties of HF propagation by simply using CP antennas for *reception*. We'll describe a simple semi-compact CP turnstile (crossed inverted V) antenna for 15 MHz, so you can demonstrate X and O propagation using WWV as a test generator. Once you see how this works, you'll probably want to modify this antenna for your favorite ham band — or even several of them.

It's a simple matter to build an HF CP antenna with 30 to 35 dB of discrimination between clockwise and counterclockwise waves. There are two factors that determine how much discrimination you can get. First, you want to have an accurate 90° phase shift between your two crossed dipoles. Secondly, the arriving signal has to arrive on axis. For a CP turnstile antenna, the proper angle of arrival is perpendicular to the plane containing the two dipoles.

However, even if your turnstile is not oriented ideally, you can still get useful discrimination between modes, certainly enough to demonstrate that the X and O modes exist. In fact, a horizontal turnstile antenna at reasonable height is capable of separating X and O mode signals at most angles of arrival you're likely to encounter.

### A Little Geometry

It's a bit of a curiosity that a horizontal turnstile antenna (two horizontal crossed dipoles fed 90 electrical degrees apart) transmits and receives an *omnidirectional horizontally polarized* signal off the edges — that is, radially from the antenna. Looking straight down upon such an antenna, you will have an ideal circularly polarized antenna. This isn't too hard to visualize if you have some experience with NEC antenna modeling. For a simple dipole, of course, polarization is undefined off the ends. Also, any dipole has the greatest polarization sensitivity to signals arriving broadside, with progressively less polarization sensitivity for signals arriving off axis.

Such a turnstile antenna can be modified into the form of an inverted V with little sacrifice of performance; in

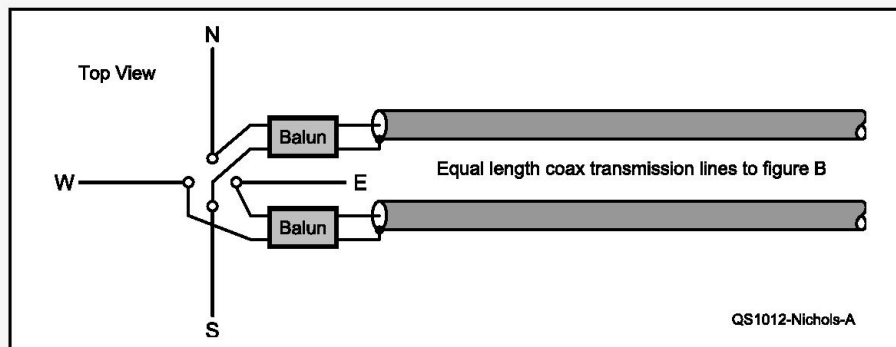


Figure A — Connection diagram of HF turnstile antenna.

fact it may have a little better overall sensitivity to low angle signals. At HIPAS observatory, we had a large array of such antennas, as well as a few portable ones for on the fly propagation studies. This configuration only needs one tall support, and it doesn't have to be a very tall one at that.

### Free Ticks

Most hams know a little bit about WWV, but we seldom take advantage of all that the stations have to offer. See [tf.nist.gov/timefreq/stations/www.html](http://tf.nist.gov/timefreq/stations/www.html) for more information on the opportunities. There's a bunch of great information there.

Since WWV's signal is so well defined, it's an ideal test generator for our X and O demonstrations. We all know about the frequency accuracy of WWV, but beyond that, the radiation characteristics are also rather precise. WWV transmits an ideal omnidirectional, vertically polarized signal with a very closely controlled effective radiated power (ERP).

At 15 MHz, the true ground wave of WWV attenuates rather rapidly. Unless you happen to live in their back yard, you won't need to unduly concern yourself with it. Also, as with any vertical antenna, there is a substantial *cone of silence* directly overhead, so you won't be led too far astray if you happen to be in the near vertical incidence skywave (NVIS) zone of the station.

The 1 s time ticks broadcast by WWV are of particular interest, as they give us reliable differential propagation information. Even with a linear polarized receiving antenna, you can see the two separate reflections of

the ticks with an oscilloscope bridged across your audio output. (With a little more sophisticated setup, using a dual trace scope and two CP antennas, one for each sense, you can accurately measure the difference in tick times for the X and O mode) In either case, the ticks give us a great time of flight marker for X and O demonstrations.

### So Simple A Caveman Can Do It

The actual construction of a 15 MHz CP inverted V is so straightforward as to be trivial. You can adapt the basic design described to your available materials. The only thing you need to worry about is symmetry.

Using a 20 foot section of 4 inch diameter PVC plumbing as a center mast is quite convenient. The four half Vs act as guy wires. For 15 MHz, you want each half V to be about 5 meters long. The exact length is not too critical, but you want each of the two Vs to be identical (see Figure A). You want each the Vs to cross each other at 90°. You also want to drop them down from the mast at the same angle. 45° is a good choice, but not too critical. Just be sure they're all the same. Use enough rope or cord at the bottom end of the Vs to reach some ground stakes. Again, be sure the stakes are all the same distance from the base of the mast, so that the angles are all the same.

You want a good balun at the apex of each V. At HIPAS we used W2AU baluns, but anything is fine as long as they're the same model.

### Saving Phase

Once you've built your symmetrical

crossed V antenna, only one thing is critical, the 90° phasing network. You can build a 90° coax stub at the feed point of the antenna, but you'll have a lot more versatile (and verifiable) antenna, if you run two identical runs of coax into your shack. If you do the phase shifting in the shack, it's a lot easier to change frequencies, which you will eventually want to do. It also makes it easier to gain access for various test instruments.

You will want to cut a quarter wave chunk of coax (at 15 MHz) for your phasing section. Be sure to compensate for the velocity factor of your coax. When in doubt, you can short one end, couple the opposite end to a grid dip oscillator with a small loop, and see that your grid dip oscillator (GDO) or antenna analyzer dips at exactly 15 MHz. Once you have the phasing section cut, simply add it in series to one of your transmission lines, and then feed both lines into a coaxial T. The output of your T goes to your receiver. To switch between X and O modes, insert the series section into the opposite transmission line. Eventually, you will want to build some sort of switch for this (see Figure B),

or use a couple of coaxial relays. (PIN diode switches work great for this as well, and allow you to do very rapid X and O switching for some interesting experiments.)

Although it isn't critical for demonstration purposes, in ionospheric research it's standard practice to orient the antenna with magnetic North. You might want to clearly label your EW and NS transmission lines inside your shack, if you decide to align your antenna. More importantly than magnetic orientation, however, is your relative EW and NS phasing, if you want to positively identify your X and O modes. Your north and east legs should be attached to the center conductor of your transmission line, while the south and west legs should be connected to the shield. If you're using a voltage balun, the north and east terminals of your balun should correspond. If you delay the NS by 90° with respect to EW, using this polarity, the result will be clockwise CP (O mode in the northern hemisphere).

By the way, this is reversed if you transmit through the array. Just to keep things simple, we'll only deal with this as a receiving array.

### The Proof

In all likelihood, your O mode signal will be a little stronger, all things being equal. Since WWV transmits an omnidirectional signal, you probably won't be able to discriminate azimuth skewing too well. However at low takeoff angles, there will be a large difference in distance between the X and O modes. If you have access to a local digisonde (see [ulcar.uml.edu/slist.htm](http://ulcar.uml.edu/slist.htm)) you can make an educated guess as to whether the X or O mode is landing at your location. The closer you live to WWV, the more likely you will be to receive the O mode, assuming you're near the maximum useable frequency (MUF). If WWV is a long distance from you, you're more likely to be receiving the X mode, at least on the first hop.

The best way to get the feel for how things are at your location is as follows: Tune in WWV with just the NS antenna connected. Note the signal strength. Switch to the EW antenna. If everything is working reasonably well, the signal strength should be nearly identical.

Now connect both antennas. Your signal will either increase by 3 dB or drop precipitously. If it increases by 3 dB, you know your polarization sense is matched to the mode of the incoming wave. If it goes way down, you're on the wrong polarization — at least for that mode.

Jim Parkinson, W9JEF, is one of my handful of "CP Envoys" in the lower 48, where conditions are likely to be a lot more typical than they are up here in the subarctic. Jim reports that upon first firing up his antenna, he was astonished at the difference in signal strength between the X and O modes — on just about any signal. This is a very typical response on one's first encounter with HF CP antennas. The shocker isn't so much that it's a great antenna by most standards, but that there is such a huge difference in sensitivity between modes — something alien and jolting, to even seasoned old timers — and impossible to experience on any linearly polarized antenna. As much as a 3 S-unit difference is easily achieved on even a haphazardly assembled CP antenna.

Don't take our word for it. Build it and see. For those who want to go into this one step deeper, an advanced I and Q polarimeter receiver is described in the QST-in-Depth Web site ([www.arrrl.org/qst-in-depth](http://www.arrrl.org/qst-in-depth)).

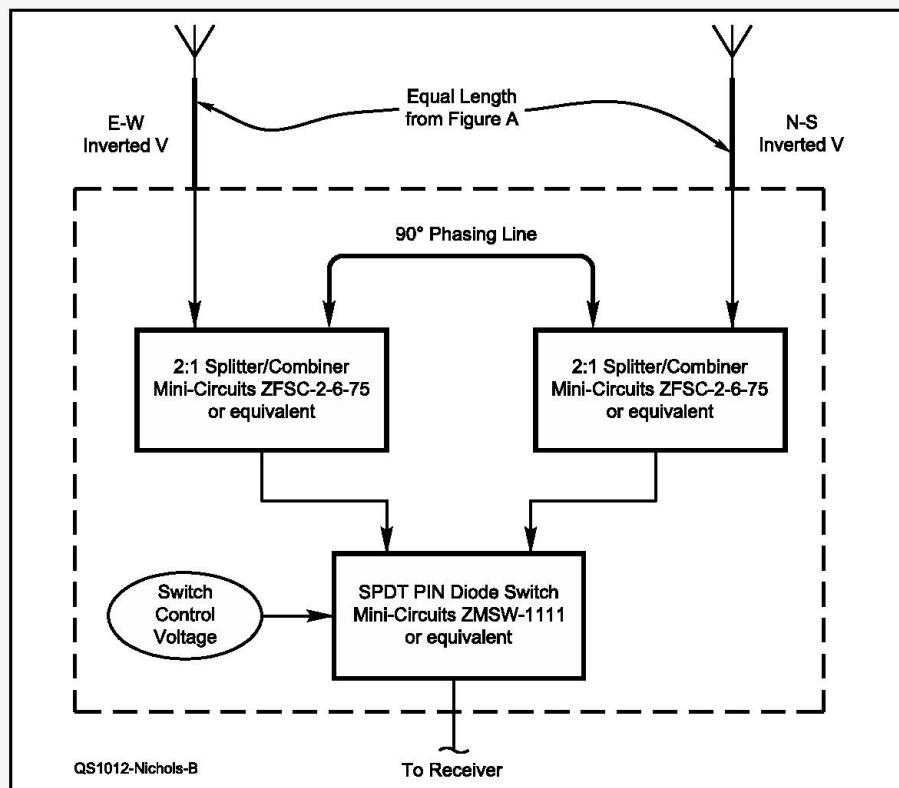


Figure B — Simple X-O switch for 15 MHz.