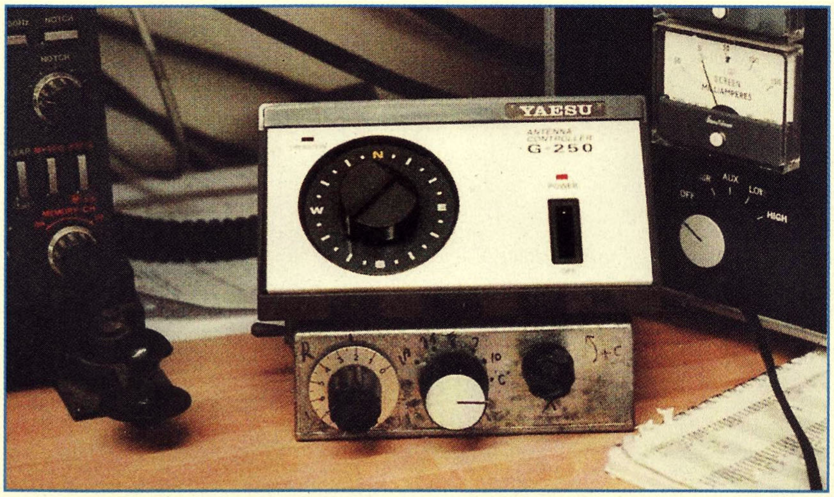
An Orthogonally Steered Antenna that Reduces Interference

You may be able to eliminate interference more effectively than by just shifting antenna azimuth.

Tony Preedy, G3LNP



Directional receiving antennas, such as small loops that can be steered in azimuth, have traditionally been used to help separate radio signals that arrive from different directions. If two transmissions share both frequency and bearing, this technique is not effective. If the signals originate from different distances relative to the receiver and are propagated via ionospheric reflection, however, they will generally arrive at different angles of elevation. An antenna having a reception pattern that is steerable in the vertical plane can then help to separate the signals. In the general situation of receiving in the presence of interference, if signals arrive from different distances, but on the same channel, we need an orthogonally steered, or OS antenna.

The Solution

Gary Breed, K9AY, described a terminated triangular wire loop antenna in 1999 that offered to improve reception on the lower HF bands by virtue of its directivity.[1] Figure 1 shows a typical azimuth plot for a K9AY loop at 45° elevation with a termination of 470 Ω. This design is popular because it is quieter than many antennas designed primarily for transmitting on 160 meters and the lower HF bands. To cover more than one band usually requires careful choice of both antenna dimensions and the termination impedance. Commercial versions are available that use pairs of reversible crossed loops to give four null directions. The effectiveness of such antennas is dependent on both the vertical and horizontal arrival angles of the interference.

[1]Notes appear on page 33.

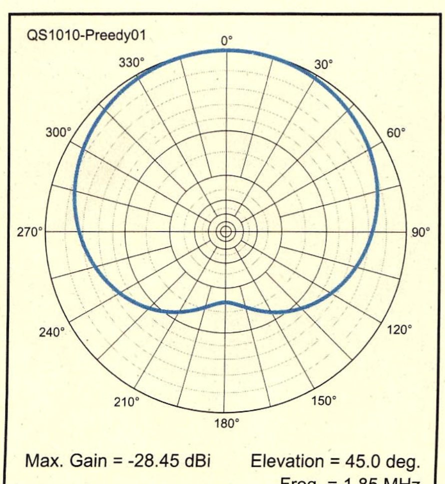


Figure 1 — 160 meter azimuth pattern of K9AY loop at 45° elevation.

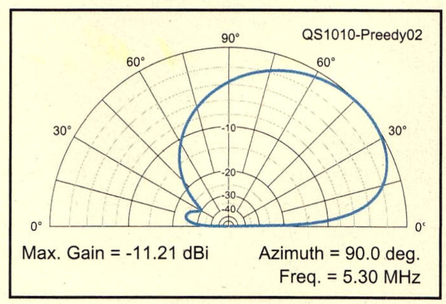


Figure 2 — 60 meter elevation pattern of K9AY loop terminated for maximum front to back ratio at 30° elevation.

Refining the K9AY Loop

A computer simulation of the K9AY antenna indicated that the optimum termination impedance depends on frequency, ground conductivity and resistance of the ground connection. In one commercial version this dependence is accommodated by making the termination resistance variable from the operating position. By making the termination a complex impedance (reactance plus resistance), not only can the frequency range be extended and compensation made for ground conditions, but the null can be controlled in the elevation plane as shown in Figures 2 and 3. Here we see null elevations of 20 and 60°, respectively. The

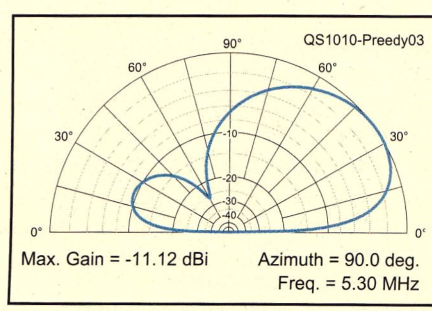


Figure 3 — 60 meter elevation pattern of K9AY loop with terminated adjusted for elevation null in rearward lobe.

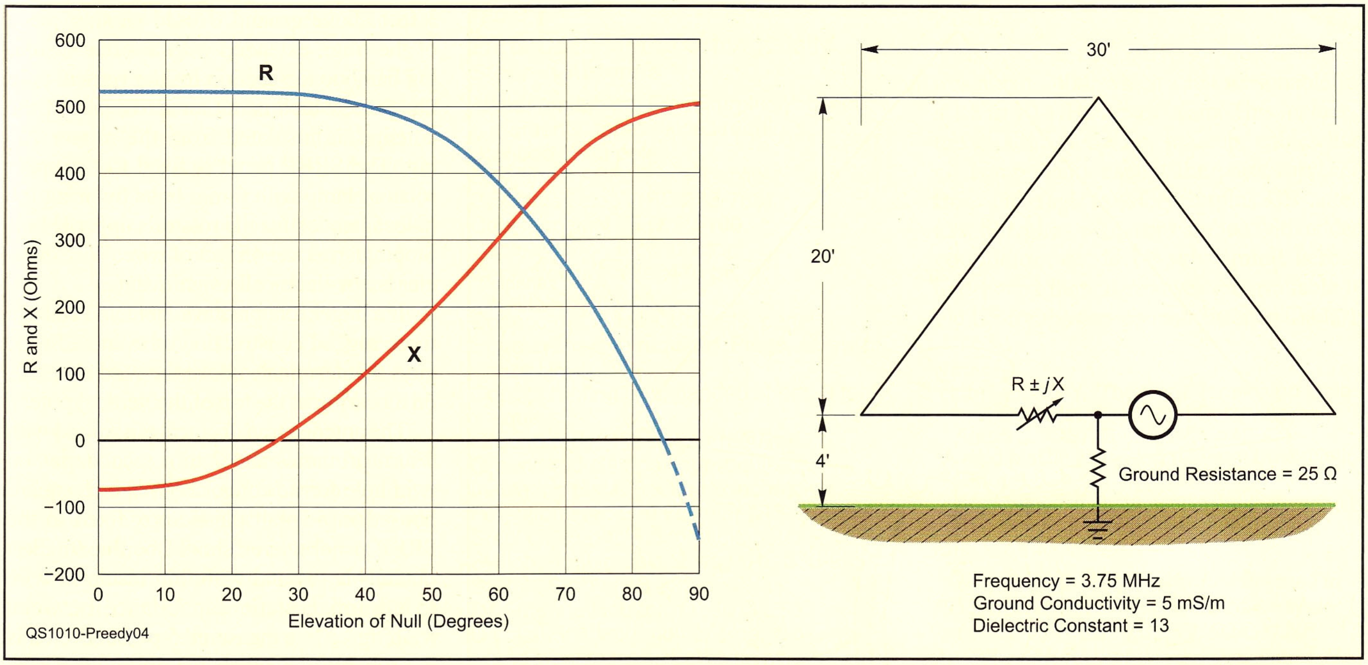


Figure 4 — Plot of angle of elevation null versus complex termination impedance at 3.75 MHz.

corresponding horizontal patterns remain substantially the same as that shown in Figure 1. Once you have control of the termination impedance, the dimensions of the antenna also become less critical.

My modeled loop had apex height of 20 feet and base of 30 feet. In this case, the null could be steered from 0° to at least 80° elevation over the range 1.8 to 10.2 MHz. Above 85° an unrealizable negative resistance is required. A null depth greater than 60 dB could be achieved for a wide range of ground parameters and for anticipated values of ground connection resistance. Figure 4 is a plot showing the typical relationship between termination impedance R +*j*X and null elevation of the modeled antenna.

Remote Control of the Termination

By replacing the usual termination resistor with a wideband transformer and transmission line, such as is used on the feed side, it is possible to provide a remote variable termination in which values are modified both by the square of the turns ratio and by the transformation due to the length of the transmission line. A wide range of reactance values down to 0 Ω can be obtained from a series resonant L-C circuit as it is tuned away from resonance. This principle is used in the remote termination unit of the OS antenna. If combined with a rotation system it is thus possible to place a null on an interfering signal arriving from any likely angle of azimuth or elevation.

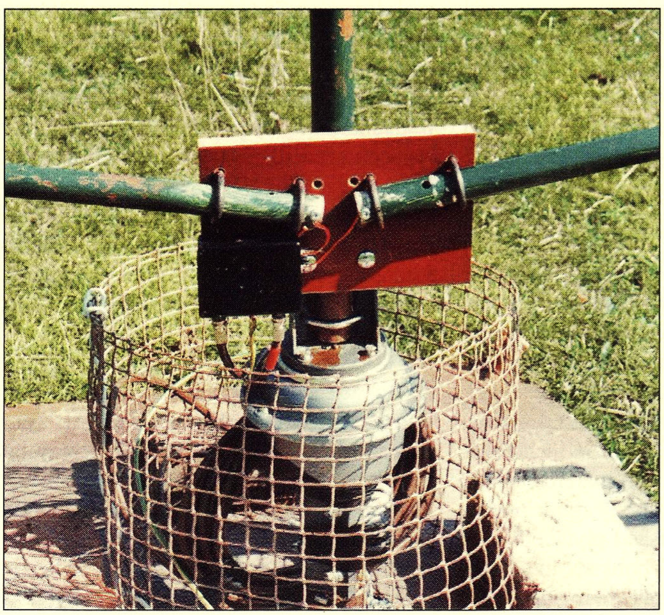


Figure 6 — Antenna base mechanical construction details showing TV rotator for azimuth control.

Construction

The OS antenna does not require a large area or much height. A version of half the size of my design will be suitable for 3.5 MHz and above if you accept 12 dB less sensitivity. Figure 5 shows the circuit of the termination unit and how it interfaces to the loop. The unit is built in a metal screening box that fits below the rotator controller.

The X control is a 470 pF air dielectric variable capacitor. The inductor, nominally 30 μH, for 1.8 MHz, consists of 32 turns of 0.5 mm (#24 AWG) enameled copper wire, close wound on a 32 mm diameter photographic 35 mm plastic film can. Taps are provided at 23, 19, 16 and 13 turns, with unused turns shorted by a single pole switch, for the 80, 60, 40 and 30 meter bands, respectively. A sixth switch position shorts the inductor and capacitor for less critical, resistance only, wideband operation. A 220 Ω noninductive linear variable resistor serves as the R control. A double pole reversing switch is used to swap feeders.

The antenna, as shown in Figure 6, was made rotatable by attaching it to a Yaesu TV antenna rotator. This rotator has filters built into the servo system that help make it immune to transmitted fields. The use of an ac motor avoids commutator interference. Plastic netting and bricks were added to prevent rabbits from chewing on the cables. The

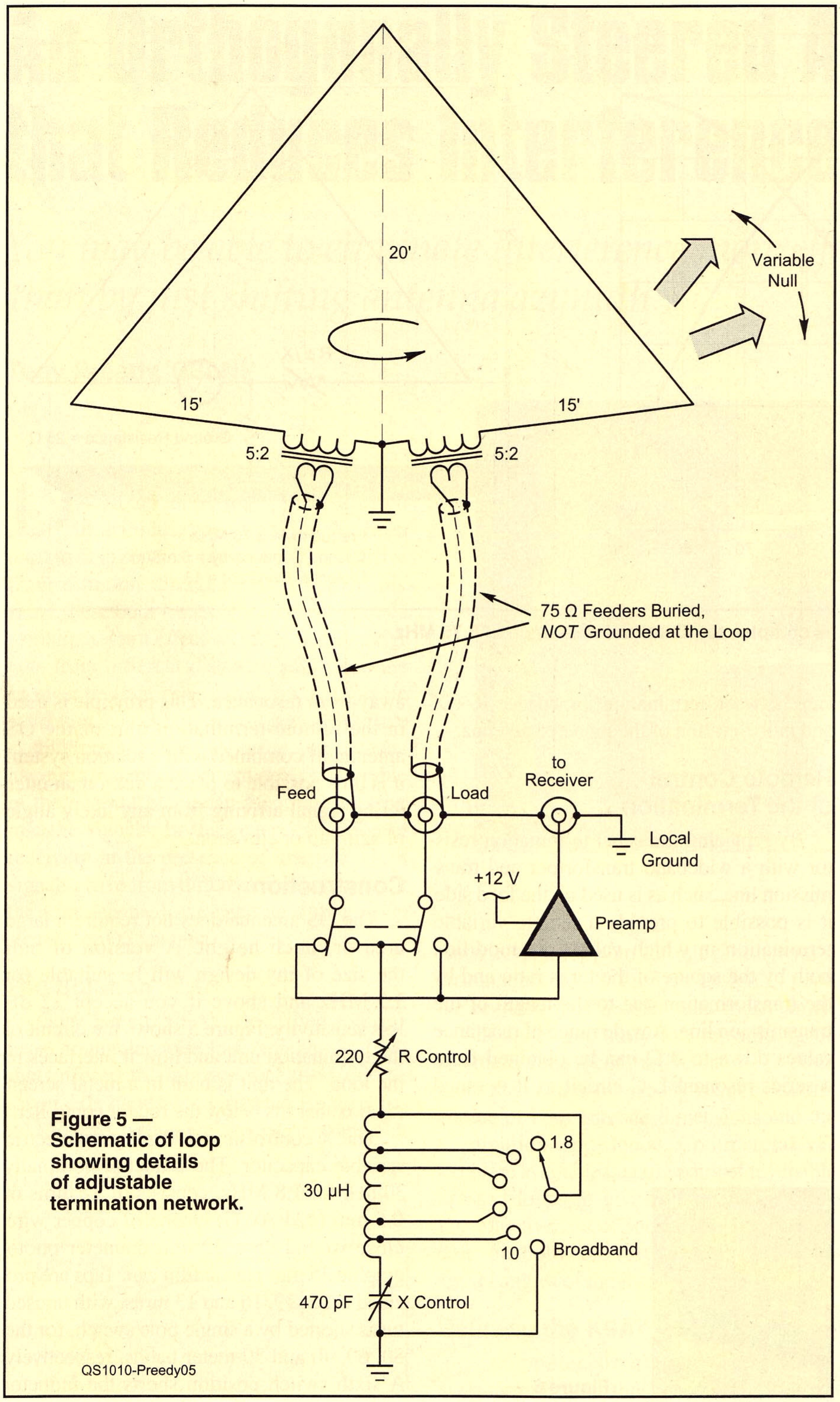


Figure 5 — Schematic of loop showing details of adjustable termination network.

rotator is fixed to a 4 foot length of steel pipe driven vertically into the soil with a 6 inch projection. This has its lower end flattened to resist rotation but is not connected to the copper ground system because of the risk of electrolytic corrosion. Four 4 foot ground rods at the corners of a 3 foot square copper sheet are used for the loop's ground connection. This is all that is necessary because a better ground connection only makes the feed VSWR excessive for higher elevation null angles.

The horizontal arms of the antenna are each made from aluminum tubing salvaged from an HF Yagi antenna. The dimensions tapered from ⅞ inch to ¼ inch. These and the 20 foot vertical pole are clamped to a central 8 inch square plate of ⅝ inch thick SRBP (Paxolin) insulating material using pairs of U bolts.[2] Almost any rigid insulating material, even varnished plywood, will be suitable here. The U bolts set the slope of the arms to 10°, to put their tips about 3 feet above ground. I used another piece of the Yagi, extended with a 4 feet insulating bamboo top section for the vertical pole. The pole, which is not an active part of the antenna, is insulated from the rotator casing. The SRBP panel is fixed to the upper rotator clamp with 6 mm bolts by using the holes intended for the rotator's upper U bolt. Sloping arms use 45 feet of wire. Wire diameter is not electrically significant.

If a larger rotator is available you can use more rugged construction or even add rope guys that terminate above the wire elements on a bearing at the top of the vertical pole.

The antenna transformers are wound with 5 turn primaries and 2 turn secondaries on twin hole ferrite cores, about ⅝ inch square, housed in a small plastic box fixed to the SRBP panel. Cores should be the smallest obtainable, wound with thin insulated wire to minimize static capacitance between windings. Mine measured 5 pF but even this is probably too much for optimum performance on the higher frequencies.

Cable Decoupling

A significant potential problem with this type of relatively insensitive antenna is the effect of pick-up on the outer conductor of the feeders. This can introduce unwanted signal voltages into the radio via the ground connection impedance or the capacitance between transformer windings. Cables should therefore be buried and the outer conductors not grounded at the antenna but where they emerge at or near the radio. The rotator cable was decoupled by winding as many turns of cable as possible through a 2 inch ferrite toroid near the rotator before it joined the buried coaxial cables. Because the motor only consumes 10 W, the cable is thin six core alarm type that allowed 16 turns on the ferrite core.

Feeders are 75 Ω foam dielectric TV type and should not exceed 200 feet in length or losses may make it impossible to get sufficient range of load control on the higher frequencies. Waterproof PF100 type cable is recommended if they are buried directly. Mine are in an MDPE water pipe for protection from moles. Identical feeders allow switched interchange between load and feed connections so that the antenna can be reversed without rotation or load adjustment.

Operation

Be sure to connect the OS control unit in a receive only path to the radio. If your transmitting antenna is nearby it may be necessary to ground the feeder to protect the 220 Ω resistor and preamplifier while transmitting. You may also need to detune the transmitting antenna when receiving in order to achieve the deepest null. Relays controlled by the PTT line can automate these functions if desired.

If R is set to ⅓ of maximum, around 75 Ω, and the band switch is at the BROADBAND position, the antenna termination will be near 500 Ω, regardless of feeder length or frequency. These settings should allow the antenna to work as originally designed by K9AY. Use this condition to find the bearing of a signal you want to eliminate, or for general listening. As the controls are moved from these settings the load will become complex but actual values will be influenced by feeder length unless it is a multiple of 180° at the operating frequency.

Adjustment is straightforward. Just select the band, rotate the loop for minimum interference, or use the great circle bearing if you know the direction of the interfering signal. Now adjust the R and X controls successively to further minimize an unwanted signal or noise. Use the reversing switch to satisfy yourself that the antenna is effective or to confirm that the interference is still there!

Results

Forward gain with 180 feet of feeder, assuming a 2:1 VSWR, was predicted to vary from –28.6 dBi at 1.8 MHz to –6.4 dBi at 10.1 MHz and this appears to have been achieved. On all bands noise from the OS antenna exceeded that due to the receiver. Additional amplification above that from the preamplifier in the radio may not have been necessary if the antenna was only used in the forward direction. In this application, while receiving off the back, an additional amplification stage may be needed, especially on the lower bands.

The antenna was very effective at locating the source and reducing the effect of local interference. Because of the intermittent nature of amateur signals I found AM broadcast signals more useful while getting familiar with the controls. The antenna worked well in the broadcast band with the switch in the 160 meter position.

Daytime ground wave signals at MF could be reduced by more than 60 dB, such that it was possible to completely separate a distant radio station from a closer one sharing the same frequency. The reversing switch then gave a choice of programs, both free of interference. Daytime rejection was often more than 50 dB on 1.8 MHz, falling to about 30 dB at 10 MHz. In late afternoon I could reduce S9 German signals on 1.8 MHz to inaudibility while being able to copy more distant Polish stations on the same frequency and bearing. I tried this on 3.7 MHz with a pair of French stations, one in the north and one in the south, both on the same bearing. Again I could control the vertical null to attenuate one relative to the other. On 3.7 MHz the daytime sky wave signals from stations in Jersey, Scotland, Ireland and the Isle of Man could all be reduced by more than 40 dB without significant loss on closer near vertical incidence skywave (NVIS) signals.

As dusk descended, results on 1.8 MHz remained good. I could still reject East European stations, but I found 7 MHz propagation at this time to be unstable making it difficult to obtain a consistent null because the apparent arrival direction was changing. On a 7 MHz East European broadcast station, for example, the front to back ratio would change rapidly from a worst case 10 dB to troughs of 40 dB, even though in the forward direction fading was only a few dB. After midnight, when 7 MHz propagation was more stable, I could get continuous 30 to 40 dB rejection of Russian and other East European stations. Before dawn I listened on the transmitting antenna to an eastern USA net on 1.85 MHz. It was obliterated by a Russian station on that frequency. Using the OS, I could choose which contact to listen to. Near sunrise, on 3.7 MHz, I found it impossible to reduce an Italian by more than 20 dB, presumably because there was more than one propagation mode, whereas at the same time I could reduce USA stations by about 30 dB.

With experience and logging of termination settings I could estimate arrival elevation of signals and follow this as propagation changed. The loop was not quite as quiet as a Beverage antenna but this loop can be rotated.

Table 1
Parts Used for the Orthogonally Steered Antenna

Aluminum tubing. From surplus Yagi half elements, three pieces required.
Bamboo bean pole.
Box, small ABS. RS or Maplin.*
Box, small steel. (RS 232-780).
Cable, coaxial 75 Ω, PF100.
Cable, rotator, 6 conductor.
Capacitor, variable, 470 pF (Jackson type L).
Connectors, F type. Sockets, panel mounting, five required. Plugs, screw on, size L.
Copper roofing or expanded sheet, 3 feet square.
Ground rods, 4 feet, four required.
Ground rod clamps, four required.
Insulating plate, 8 × 8 × ⅝ inches.
Potentiometer, 220 Ω linear (RS 162-782).
Steel pipe up to 1.5 inch diameter × 4 feet.
Switch, double pole, 2 way (RS 330-985).
Switch, 6 way (RS 320-685).
TV Antenna Rotator, Yaesu G-250.
U bolts for 1 inch muffler pipe, with nuts and washers; six required.
Wire 0.5 mm enameled copper (for inductor, antenna and transformers).

*RS parts from RS components at **www.rswww.com/electronics**. Other parts may be used.

Parts

Total cost, using UK sourced materials, was about $400, which I felt reasonable for a 1.8 to 10 MHz rotary beam. This included the rotator, hardware, preamp, cables and all components except the parts salvaged from the Yagi. Possibly surplus CB antennas, fiberglass whips or bamboo with added conductors could be substituted here. I understand that alternatives are available in the US for the components listed in Table 1.

Notes

[1] G. Breed, K9AY, "The K9AY Terminated Loop — A Compact, Directional Receiving Antenna," *QST*, Sep 1997, pp 43-47.

[2] A rigid plastic insulating material available in Europe. See **www.croylek.com/download/49_srbp_(paxolin).pdf**.

Photos by the author.

Tony Preedy, G3LNP, was first licensed in 1957. In addition to his current call, he has held calls ZD8ARP, 9M2BQ, 6O/G3LNP, A45ZZ and EI6AS while working abroad. He has also operated briefly from 5B4, ZC4 and 5HØ. Tony is a Chartered Electrical Engineer and a Fellow of The Institution of Engineering and Technology. Tony trained in the defense industry and spent most of his working life in broadcast transmission.

In 1996, Tony retired to a sheep farm on the border of England and Wales. He enjoys operating the lower amateur bands. You can reach Tony at New Mills Farm, Worthen, Shrewsbury, SY5 9JQ, UK or at **preedy216@btinternet.com**. QST