Three Loop Antenna Array with Electrically-Rotatable Nulling

Mark Connelly, WA1ION - 5 OCT 2000

By using three broadband loop antennas set up at 120 degree bearing differences, a fully rotatable single-null (cardioid pattern) can be achieved by combining given pairs of loops. Furthermore, the three inherent figure-of-eight (double null) patterns produced singly by each loop can be "slewed" by as much as 30 degrees off their normal axes when the loop in question is phased against one or both of the remaining loops.

Good broadband results may be obtained with each loop element consisting of a 2.5 m (8.2 ft.) per side square: 10 m of wire total per loop. This is mounted in the vertical plane with the bottom side of each square no less than 0.5 m (1.6 ft.) above ground level. The wire comprising the loop may be formed on a non-metallic frame structure or simply held in place with ropes to tree branches or other supports. The feedpoint of the two wire ends is usually at the center of the bottom side (1.25 m from each low corner) and these wire ends connect to the primary of a 1:1 balun transformer, Mini-Circuits T1-6-X65 or a suitable homebrew equivalent. The balun should be mounted in a weatherproof connectorized box for permanent installations. The balun's secondary winding connects to coaxial cable which goes back to the operating position. Satisfactory results should be possible with cable runs up to 50 m / 164 ft. and perhaps longer. The minimum distance between the winding of any one loop and the nearest part of any other loop should be at least 5 m / 16 ft. to reduce unintended pattern alterations.

The maximum pick-up of each loop element is in the two directions obtained if one extends an imaginary line from the top or bottom (horizontal) parts of the square. Nulls are at a right angle to the plane of the loop. Figure 1 (after this article's text) shows the inherent pick-up patterns if the three loops are set up for 0:180, 60:240, and 120:300 degree peak orientations. (Note: 0 deg. = north, 90 = east, 180 = south, 270 = west.)

At the operating position, the coaxial cables from each of the three loops go to inputs of the Loop Switch / Amplifier box (figures 2, 3). This box has a fourth input jack, the auxiliary (AUX) input, that may be used for an omnidirectional horizontal loop, a vertical whip, a random wire, or any other antenna that the operator feels would enhance the usefulness of the set-up.

Switches on the box allow any of the four inputs to be directed to the Line 1 amplifier or to the Line 2 amplifier. Low noise amplification of about 15 to 25 dB is usually necessary with the relatively small broadband loops being used. One could connect two or more inputs to a single line amplifier for potentially unique null solutions, but I won't try to figure out when that could be helpful: that's better left to the end user.

The box's Ground Switch connects loops' coaxial shields to "station ground" (common) or allows them to float. Different locations will exhibit different results in terms of which Ground Switch setting yields the better ratio of desired signals to local electrical noise.

A cardioid pattern, or a close approximation thereof, can be produced with a given pair of loops having a minimum of 60 degrees and a maximum of 120 degrees between the peak pick-up axes of each. Optimum (truest cardioid) nulls will be on the bisector angle between a maximum pick-up lobe of the first loop and that of the second loop. If two loops were oriented so one pointed north-south and the other east-west (90 deg. spread), cardioid nulls would set up best on northeast, southeast, southwest, and northwest axes. As you choose bearings farther from bisector values and closer to inherent loop nulls, the patterns produced by phasing two loops

would more closely resemble the figure-of-eight patterns of a single loop because one of the two loops is doing most of the work creating the null and only minimal added signal from the other loop is needed to move null depth from moderate to maximum. There are some situations in which a somewhat rotatable figure-of-eight is the desired pattern instead of the fully rotatable cardioid. The three loop system gives both options.

Looking at the 0:180 loop combined with the 120:300 loop may be instructive.

The 0:180 loop has inherent figure-of-eight nulls at 90 and 270 degrees. By coupling in a little RF from one or both of the other loops, slewed figure-of-eight nulls can be obtained +/- 15 degrees from 90 degrees and from 270 degrees, i.e. in the 75-105 and 255-285 degree ranges. The 120:300 loop has nulls at 30 and 210 degrees that can be similarly "stretched" to 15-45 and 195-225 degree ranges.

Bisectors for cardioid nulls are at 60, 150, 240, and 330 degrees. These are halfway between lobes at: 0 and 120, 120 and 180, 180 and 300, 300 and 360(0). Cardioid null ranges can be stretched to be 45-75, 135-165, 225-255, and 315-345 degrees. At the edges of the stretched ranges, the cardioid starts to degenerate into an asymmetrical figure-of-eight with one major null and one or more minor ones at bearings not quite opposite the major one. If a true cardioid is desired and a certain pair of loops is causing reduction of desired direction DX as well as signals to be nulled from the opposite direction, use a non-directional antenna (whip or horizontal loop) at the AUX input to phase against one of the loops for better results.

Pairs of loops to be used for movable nulls (cardioid pattern, figure-of-eight pattern) are shown in Figure 4. Loop #1 is oriented for maximum pick-up on the 0:180 axis, loop #2 is aligned for peaks at 60:240 degrees, and loop #3 has peaks at 120:300 degrees.

A simple-to-use (preferably broadband) phasing unit should be used on the two outputs of the Loop Switch / Amplifier box. The DXP-3 model should well for this, at least in medium frequency (300 kHz - 3 MHz) applications. Links to design documentation for DXP-3 and several other suitable phasing units may be found at my RF Circuit page "http://www.qsl.net/wa1ion/index.html". (If, at a future time, this URL becomes unusable, contact me for updated information.) Some phasing unit construction articles may be obtained in paper form from the National Radio Club reprints service.

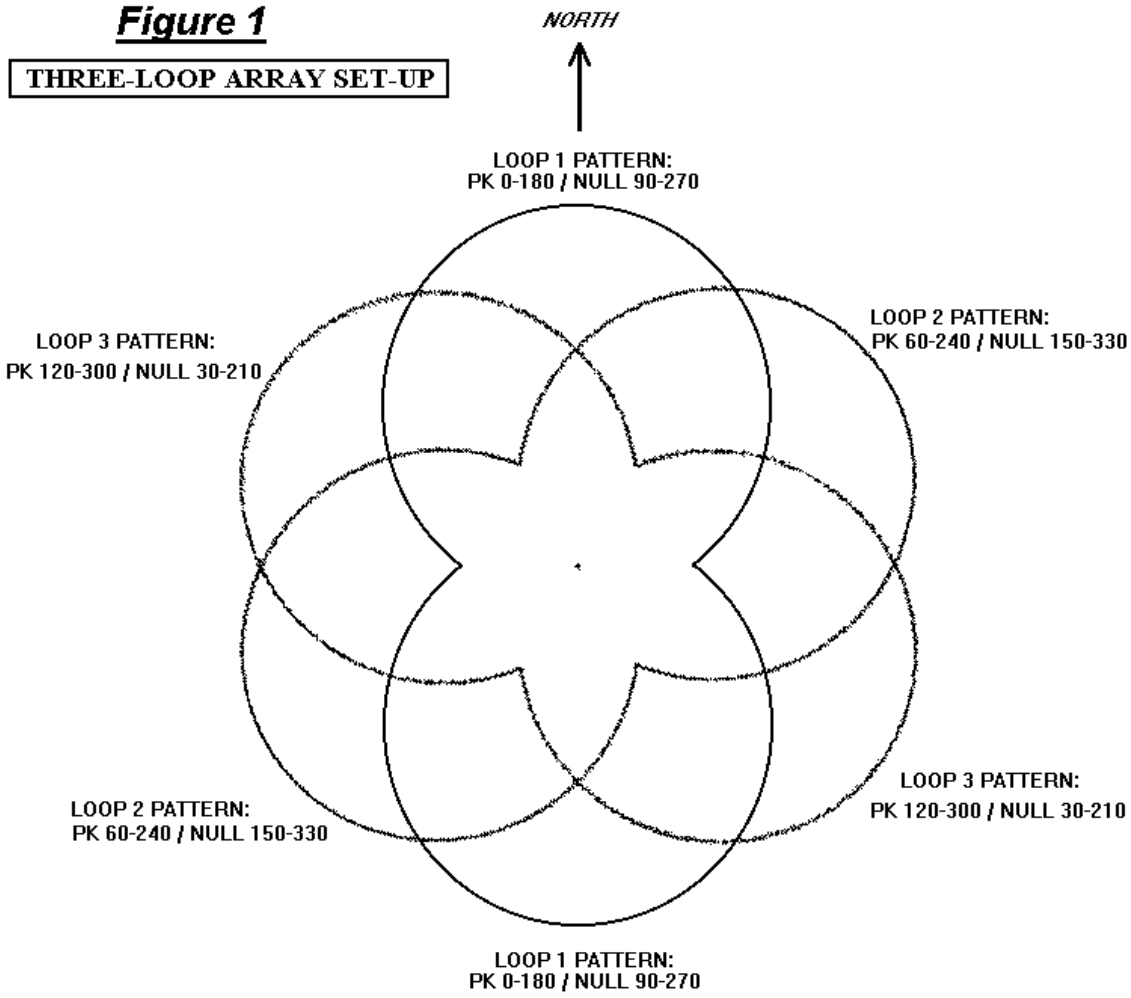


Figure 1 (above): 3-Loop Array Set-Up showing each loop's inherent pattern

Figure 2

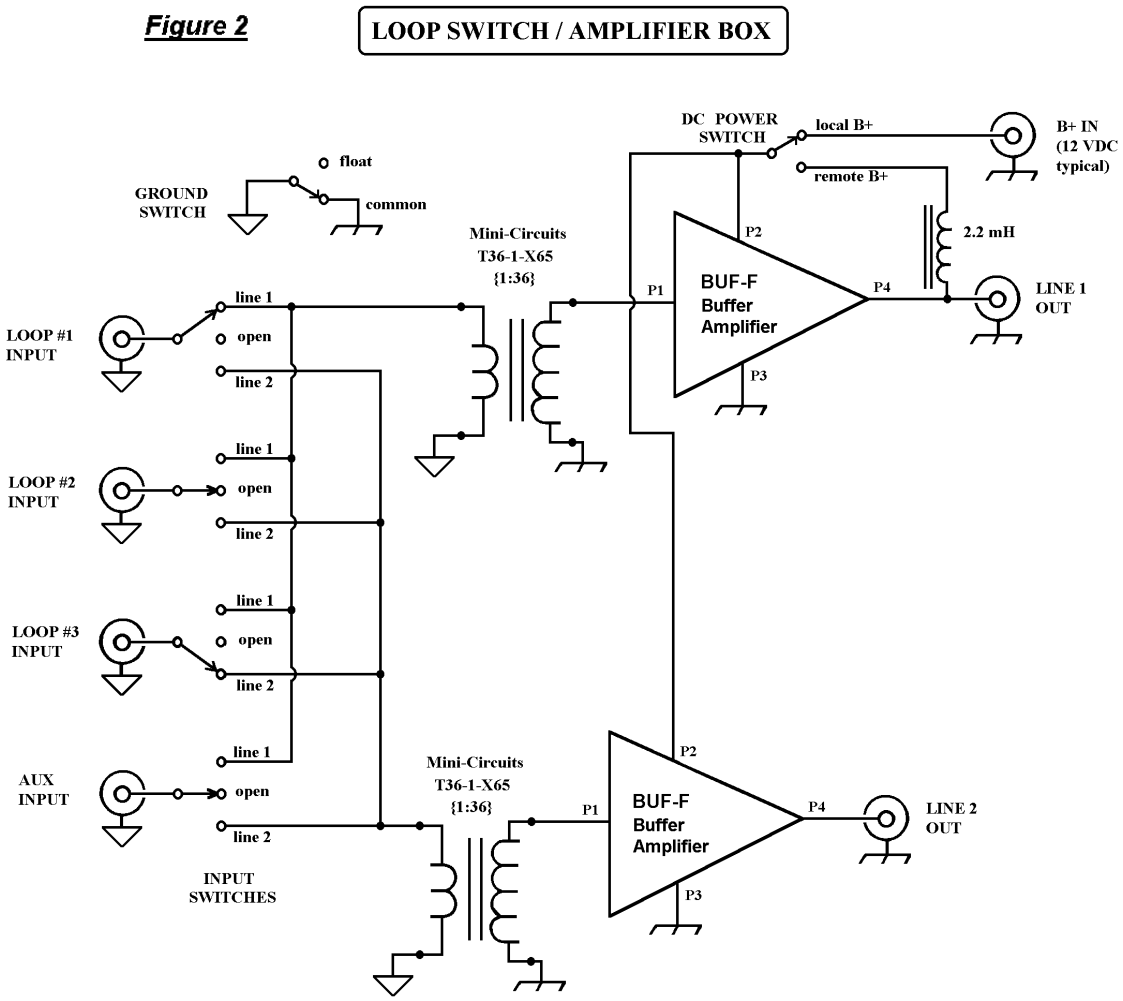


Figure 2 (above): Switch and Amplifier Box for 3-Loop Array

Figure 3

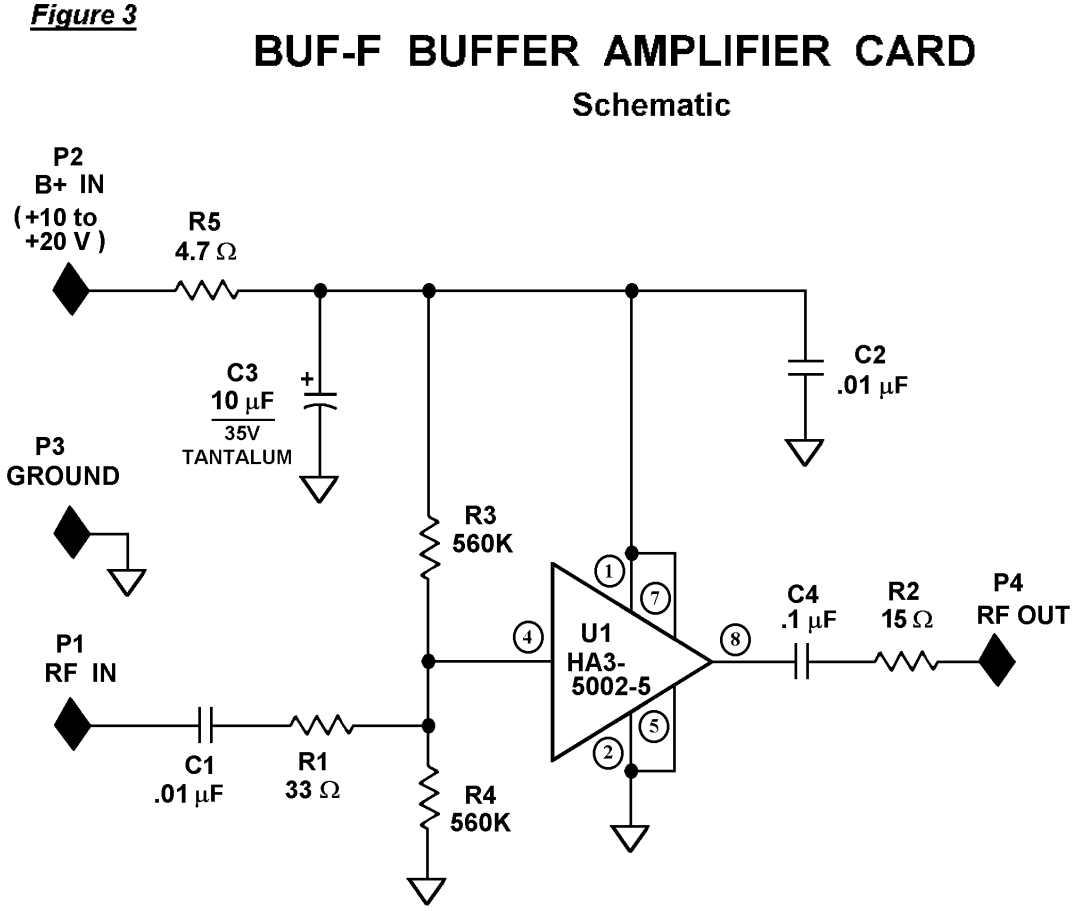
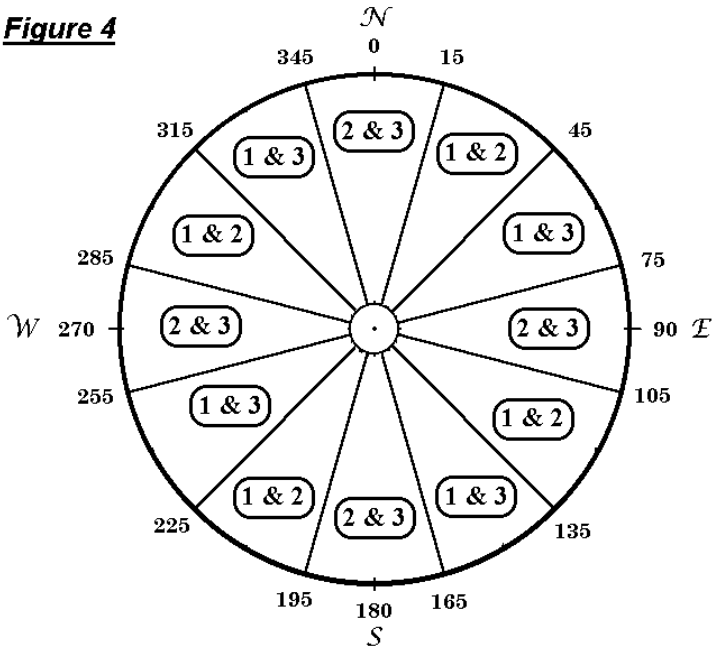


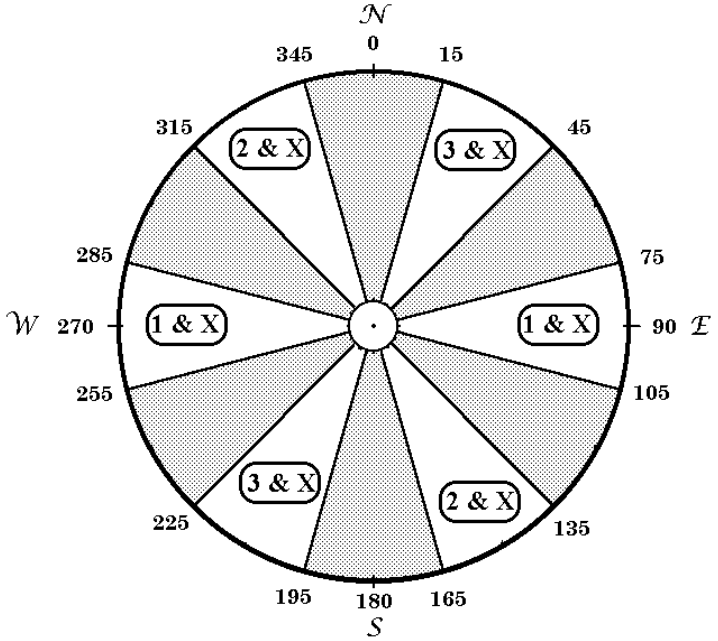
Figure 3 (above): BUF-F Amplifier Schematic (two per Switch / Amp. Box)

Loop Pairs to Use for Cardioid Nulls in Directions Specified

Figure 4



Loop Pairs to Use for Figure-of-8 Nulls in Specified Directions



where X = either or both of the loops other than that listed ahead of the '&'

Shaded areas may lack figure-of-8 null coverage.

Figure 4 (above): Loop Pairs to Select for Desired Directionality