A136-3-1

Antenna Experiments - Summer 1994

Mark Connelly - WA1ION

Trying out different antenna systems has always been a good way to get some new stations into the logbook. DXers frequently swap around antennas to keep receptions from getting "in a rut". During the summer of 1994, I experimented with several designs. This article covers some of the results.

I. Loop phased against Whip for Cardioid Pattern

This concept, used commercially in automatic direction finders for pilots, has a long history in our hobby as well. Ron Schatz's Loop - Sense Cardioid Array (LSCA) is one of the better known early designs. His scheme was somewhat tricky to build and to adjust properly and it did not lend itself readily to in-the-field use. Dallas Lankford's LIL-1 and LIL-3 designs are simpler to use, but are still intended for home-QTH use as the inverted-L sense antenna is not amplified and, therefore, must be at least 15 m / 50 ft. long to deliver adequate signal levels.

Many home locations have too much manmade electrical noise for both the sense antenna (wire or amplified whip) and the loop antenna to deliver clean signals. At noisier locations, a possible solution is phasing two noise-reduced wires; another method is phasing a remotely-tuned loop in a quiet area against a noise-reduced wire or against another quiet-area loop at a right angle to the first one. Phased noise-reduced slopers have proved to be the best DX antenna system at my home QTH. Whips and loops pick up way too much noise from TV's and light dimmers in the neighborhood and I do not have sufficient room for Beverages. Encouraging noise reduction results have been obtained with balanced center-fed wire antennas: this is discussed later in this article.

It is on car-based "mini-DXpedition" trips to high-quality, electrically-quiet locations that the loop-versus-whip (or wire) scheme has had the greatest benefit. Therefore, I have customized the improvements with the idea of mounting the loop and sense antennas on the car roof and controlling their tuning by means of DC bias voltages fed from an in-car controller (DCP-1) to the varactor diodes in the tank sections of each of the two antennas. The null, as described in the DCP-1 article, is unidirectional. When a bi-directional null (figure of eight) is needed, the loop can be used alone and when no nulls are desired, the active whip (sense) antenna is used alone.

Although nulls are best when the Q (selectivity) of the loop's tuned circuit is closely matched to the Q of the tuned active whip, and when the "pest" station output levels of the loop and the whip are comparable, surprisingly good results have been had using an untuned (i. e. broadband) active whip. The loop should be Q-spoiled by approximately 22000 ohms across its L-C tank. The whip's amplifier should have sufficient strong-signal handling capability not to create objectionable spurious responses at the DXer's location when the whip is operated in an untuned configuration. In urban areas, this can be hard to attain. Really good whip amplifiers might be able to handle the RF, but the receiver might kick out spurs due to its own inadequacies. Fortunately, urban areas are not the first choice of most DXpeditioners.

Question: If tuned whips give better results then why use an untuned one in cardioid pattern generation ? Answers: It is very useful to have a broadband active whip as one of the two antennas because it can allow quick bandscanning and parallel-frequency checking. Also, the whip - if mounted properly - allows in-motion DXing and general listening. Exact placement of the whip on the roof may be critical with some vehicles to eliminate ignition noise when the engine is running. On a recent ride out to Rockport (MA), I had the Drake R8 in the car connected to a modified MFJ 1024 whip on the car roof. Both the whip and the R8 were powered from the car's lighter socket. It was enjoyable to listen to loud and clear BBC shortwave for entertainment while driving along Route 128. Reduced knob-twiddling is another benefit to having a broadband rather than a tuned whip involved in a loop-versus-whip scheme. Nulls of as much as 30 dB can be dialed up quickly by tweaking the loop tuning control, a level-balancing pot, and the switch combining the outputs in or out of phase. A 30 dB null is often enough to uncover good DX under pests.

As Dallas Lankford noticed in his LIL-1 / LIL-3 research, the nulls created by a loop-versus-wire (or active whip, in my case) setup are broader and, therefore, more effective against "jumpy" high-angle skip than the nulls created by a loop used alone. I have had fun out at beach DX sites recently by knocking down strong 200-mile distant New York City stations to hear co-channel Venezuelans and Colombians. With just the loop, nulls were elusive and had to be "chased" more.

I would recommend the loop-versus-whip setup as the primary system for temporary field operations, especially when land for longwire / Beverage antennas is not available or not permitted to be used. For the greatest versatility, the active whip should be configurable for both broadband and tuned modes. The receiver, antennas, and the phaser / controller box (e. g. DCP-1) should all be powerable from the car's 12 VDC power as well as from separate battery packs when desired. As my Mini-DXpedition article states, setting up wires at a field site is not always practical. The loop-versus-whip scheme can give you the pick-up characteristics of either antenna operated singly; even better, when you phase the two, you can obtain single-direction (cardioid) nulls normally associated with wires of considerable length.

The DCP-1 can be used for remote loop versus untuned noise-reduced longwire operation if you use a small adapter consisting of a Mini-Circuits T1-6-X65 transformer with DC-blocking capacitors (0.1 mF) on its input and output leads. This DC-blocked 1:1 transformer is placed between one of the DCP-1 input BNC's and the coaxial cable from the noise-reducing wire's field-site 9:1 or 4:1 step-down transformer. "DCP-1A" is a version of the dual-controller / phaser with a switch and this transformer arrangement installed for such operation. The untuned wire acts similarly to an untuned active whip, although it will sometimes show directional effects that can be beneficial in setting up some nulls.

II. "Snake" Antenna

The April 1988 issue of QST Magazine published an article by Doug DeMaw (W1FB) entitled "On-Ground Low-Noise Receiving Antennas". It describes the "snake" antenna which is essentially a long terminated transmission line that got its name from the fact that it is usually placed directly on the ground. Some have even buried the antenna in a trench a few inches below ground. When installed above ground, it is seldom above the 3 m / 10 ft. level. Conventional wisdom would indicate that a terminated transmission line "antenna" should act not much differently from a short piece of coaxial cable connected to a 50-ohm dummy load (such as the famous Heathkit Cantenna) located in the shack: little or no signal should be received. Things get a bit more complicated when a transmission line becomes very long - e. g. Beverage length, over 300 m / 1000 ft. According to the tests run by DeMaw and others, transmission line leakage does allow antenna-like performance. Although received signals may be weak, superb rejection of local electrical noise and a single-direction peak, like that of a correctly-terminated Beverage, are claimed to be the benefits.

Terminating a Beverage has always been the major hassle in the pursuit of a unidirectional pattern. In the New England states, a common goal is reducing westward pickup (domestic QRM) to get foreign stations from the northeast, east, and southeast. Ground quality for terminations can range from poor (rocks, sand) to excellent (salt water or marsh). Pounding in ground rods and adjusting a termination resistor over 300 m from the receiving position, even with two DXers linked by walkie-talkies, is not a simple task or even one that, when done, produces the desired result. Running a wire, in the 25 to 75 m length range, after a 560 ohm series resistor at the end of a Beverage can help in situations where ground rod use is impractical. Neil Kazaross, a developer and long-time user of this method, should soon writing an article on it and on some of his other experiments including the "Kazaross Antenna". The resistor plus 50 m (approx.) wire scheme yields front-to-back ratios that have a certain degree of frequency dependence; this was noted on the October 1993 Newfoundland DXpedition. (Resistor plus ground rod terminations are not without frequency-related effects on front-to-back ratios either.)

If the snake antenna could achieve Beverage-like gain and unidirectional performance across the 500 to 2000 kHz range, that would be a major step forward. If the idea "flew", it would make the terminated Beverage, as we know it, obsolete. DeMaw's article states that any kind of transmission line, balanced or unbalanced, could be used as long as its far end is terminated with a resistor equaling the proper characteristic impedance for that line and if the receiver is matched to the near end of the line through the correct transformer when using lines which are not 50 ohm unbalanced coaxial. I purchased a 762 m / 2500 ft. roll of 120-ohm twisted pair balanced line at the Electronics Superstore, a local surplus outlet in Woburn, MA, specifically for this project.

The snake antenna was checked out in a series of daytime field tests on 7 JUL 1994. I set up operations at the "Nutco" site off of Cook Street in Billerica, MA between the Nutcracker Snacks Co. and the Wheelabrator / Memtek Co. buildings. There is a driveway, well away from the buildings, about 100 m / 328 ft. long at the site; this is followed by a dirt trail heading northwestward for at least 400 m / 1312 ft. through typical sandy dry-site vegetation (pitch pine, bear oak, sweet-fern, etc.). This site east of the Shawsheen River is less than a mile from my house and is one of the few open-space areas left around here that is suitable for Beverage testing and is free of power lines. When it is claimed by further development, a virtual certainty in 5 to 10 years, I'll have to drive quite a bit farther for such field tests.

I used a steel tape to measure out a 366 m / 1200 ft. run of the twisted pair. I cut this section off from the remainder of the roll and laid it out along the driveway and trail. Tests were tailored to compare signal strengths and directional properties of the twisted pair configured as a snake antenna and as a standard unterminated Beverage. For these tests, I used the Drake R8 receiver powered from the car's 12 VDC lighter jack.

For snake tests, the far ends of the twisted pair wires were connected to a 120 ohm non-inductive resistor (equaling the approximate characteristic line impedance). Measuring the receiver ends of the twisted pair with a portable digital Multimeter gave a resistance measurement of about 137 ohms: 120 ohms attributable to the load resistor and 17 ohms due to a total wire run of 2400 ft. (1200 ft. down, 1200 ft. back). The receiver ends of the twisted pair were connected to the secondary (pins 4 and 6, impedance about 100 ohms) of a Mini-Circuits T2-1T-X65 transformer. The transformer primary (impedance 50 ohms) leads were connected to the receiver input (transformer pin 1) and receiver ground (pin 3). The secondary winding center-tap (pin 5) could be connected to receiver ground or left to float: there was little observed difference either way.

For Beverage tests, the snake setup was removed from the receiver and a different scheme was used. The twisted pair wires at the far end were shorted together and the receiver end wires were shorted together. The result was a simple unterminated Beverage of 366 m / 1200 ft. To match the Beverage to the receiver correctly, a Mini-Circuits T9-1-X65 transformer was connected to the Beverage on its (approximate) 450 ohm side (pin 6) and to the receiver on its 50 ohm side (pin 1). Receiver ground was connected to transformer pins 3 and 4 (the "bottoms" of the primary and secondary windings).

In both sets of tests, a 50 ohm attenuator was occasionally used ahead of the receiver to observe frequencies that were otherwise pestered by spurs caused by strong local stations on 680 and 1510 kHz.

General scans were made of the medium wave band to get a feeling of directional characteristics and signal strengths, then individual channels were checked and strengths were jotted down on paper. Channels with two or more occupants were useful in directivity determinations.

The first thing that became apparent is that the snake antenna is very lossy. Of course, it's better than a dummy load at the end of a short piece of coaxial cable in the shack, but it was far less sensitive than the Beverage. On the average, differences of 15 to 18 dB, approximately 3 S-units, were seen between the two antennas. I kept on with the testing, despite this obvious failing grade for the snake, because if its directivity was demonstrably better than the unterminated Beverage, it would still have a "raison d'etre". After all, the use of a quiet, high dynamic range amplifier could offset the lossiness.

Both antennas had interesting directional effects. Nulls off the side were very effective in some instances. Stations to the north-northeast (e. g. WNNW - 1110 Salem, NH; WNBP - 1450 Newburyport, MA; WHAV - 1490 Haverhill, MA) were reduced substantially. The positions of the side nulls varied slightly between the snake antenna and the Beverage.

Many stations in NH, VT, and upstate NY were, as expected, doing well as they were in the forward lobe to the northwest. The big remaining issue was "What's happening off the back ?". I turned my attention to any evidence of reduction of Boston, South Shore, and Cape Cod stations off the southeast end (back). The hoped-for substantial advantage of the snake wasn't there: at best, only a modest (5 dB or so) improvement in front-to-back ratio was noted by using the snake instead of the Beverage. In many cases, the front-to-back performance of the two antennas was identical.

The directivity tests showed that a snake antenna is not significantly better in back-end nulling than an unterminated Beverage antenna of comparable length. Certainly, in view of its high loss, the snake antenna is not an acceptable substitute for either a terminated or unterminated Beverage in normal circumstances.

The only value the snake might have is in local electrical noise reduction. I had no way to test out this theory. Good noise reducing properties are obtainable from a Beverage worked against a field-site ground rod system (isolated from receiver ground) and fed through a 9:1 (or 4:1) step-down transformer through coaxial line to a 1:1 transformer at the receiver input. 20 dB or more noise suppression can be provided by this setup: this was demonstrated during DXpedition activities in Cappahayden, NF. Whether the snake antenna could improve on this remains to be tested out by someone with a location having both adequate land and a noise source in need of "squashing".

III. Balanced Wire Antennas for Noise Reduction

Reduction of local manmade electrical noise has been done successfully by Denzil Wraight, Dallas Lankford, myself, and others through the use of "clean" grounds and isolation transformers. Another way to reduce such noise is to use a center-fed wire antenna with isolation transformers at both the antenna and receiver ends of the coaxial feedline. A resonant dipole for medium wave has an overall length of 468 / F feet or 142.65 / F meters (where F is the frequency in MHz). At the bottom of the dial (530 kHz), this works out to be 269 m / 883 ft. Two drawbacks to resonant dipoles are the often-unmanageable lengths and that they require mounting at impractically great heights. A non-resonant balanced antenna will not deliver as much RF as a resonant dipole but it can still provide rejection of noise far better than that obtainable from an end-fed (unbalanced) wire not used with a noise-reducing ground system. Noise that is distributed over a long run of electrical power line may be difficult to reduce with any system, except (perhaps) phasing or looping it out.

Typically, on medium wave, the wires used in a balanced antenna system are shorter than those which would be customarily used for a resonant dipole. Shorter than optimum wires may be matched coarsely to 50 ohm feedline through a 4:1 transformer such as the Mini-Circuits T4-6T-X65 or the 9:1 Mini-Circuits T9-1-X65. One side of the balanced wire antenna would be routed to one end of the transformer's higher-impedance winding (pin 6) and the other antenna wire to the other end of that winding (pin 4). The transformer's lower-impedance winding leads (pin 1, pin 3) can be connected through a low-loss pad to the coaxial cable that runs to the receiving position ("shack"). In this pad setup transformer pin 1 connects to an 8.2 ohm resistor R1, the other R1 lead to another 8.2 ohm resistor R3, the other R3 lead to the coaxial cable center conductor, and the R1 / R3 junction via a 150 ohm resistor R2 to the coaxial cable shield and transformer pin 3. The pad introduces less than 3 dB of loss and maintains VSWR of under 3.2:1 for all wire lengths and frequencies. Keeping VSWR under control helps to prevent stray feedline pickup which could degrade the noise reduction and directional characteristics of the antenna. For permanent installations, the antenna's center assembly (with the step-down transformer, pad resistors, and connectors) should be weatherproofed and protected from mechanical stress.

The "shack" end of the coaxial cable from the balanced antenna should go to one side of a 1:1 transformer (e. g. pins 4 and 6 of a Mini-Circuits T1-6-X65) and the cable to the receiver input / station ground should go to the other transformer winding (T1-6-X65 pin 1 = center conductor to receiver input, pin 3 = receiver ground). This will usually improve signals relative to local electric noise.

Daytime tests were run in Harwich, MA with such a balanced antenna system. The two wires were in a horizontal-V configuration with one leg running northeast and the other leg running northwest. Each leg of the V was 60 m / 200 ft. long. The balanced scheme (using transformers, pad resistors, coax. as explained above) was substantially quieter than either wire singly connected directly to the receiver and quieter than both wires tied together and connected directly to the receiver. Desired signals lost about 5 to 10 dB (versus the directly-connected wires), but electrical noise from SCR light dimmers in a nearby house dropped about 20 to 25 dB resulting in an overall improvement of 15 dB in signal-to-noise ratio. On some frequencies, signal-to-noise improvements of up to 25 dB were noticed. A number of weaker stations went from poor readability to good. Lost signal level was easily recovered by using a regenerative preamplifier box (Mini-MWT-3) or by switching on the internal broadband amplifier during phasing unit operation. The balanced wire antenna system is almost as good as the system using field-site ground rods. It might actually do better in circumstances where the effectiveness of the ground rods is low due to poor soil, sand, or rocks. A drawback when using short (under a quarter-wavelength) wires, as noted above, is less gain than obtained with a similar length of wire worked against ground.

Center feeding a large (over 30 m / 100 ft.) single-turn closed wire loop that is horizontal, vertical, or tilted is a scheme worth investigating. You could put a potentiometer or a switch at the halfway point on the large single turn (opposite the feedpoint) to play around with the effects of directivity and noise reduction as obtained with short-circuit, open-circuit, and variable resistance conditions. Center-fed V's

A136-3-3

may be mounted upside down (inverted V), right side up, horizontally, or tilted. The V angle doesn't even have to be 90 degrees; anything above 45 degrees is probably useful. Straight center-fed "dipole-like" antennas could be horizontal, vertical, or sloped. I find that slopers 30 to 50 degrees from the vertical axis (60 to 40 degrees from horizontal) have desirable directional characteristics otherwise not easily obtainable with wires of fairly short electrical length.

For two antenna phasing, I would recommend center-fed slopers going down in opposite directions from the same tree, tower, or other vertical support. Alternately, you could have slopers going off the same support but separated by 90 degrees (as seen in an "aerial view" looking down at the top of the support). Three slopers separated by 120 degree horizontal-plane angles could give additional nulling versatility. A coaxial switch would be used to select the optimum 2 out of the 3 antennas to set up the best null solution.

Concluding statements

The above experiments were done to help DXers hear more stations and to stimulate further research and development. Lengthy mathematical modeling was not done here; rather, real-life tests were the backbone of the experimentation. There are many good software packages out there for antenna design. Reduction of manmade noise (EMI) has become its own branch of engineering: Interference Control Technologies, Inc. in VA devotes a 12-volume set of books (priced at around $1000 US) to it. The National Security Agency spends a lot of money on keeping RF where it belongs and out of where it doesn't. RF design continues to be a strong field despite defense cuts. It would be interesting to see what can be done for the medium wave DXer through a rigorous application of state-of-the-art software and the latest engineering textbooks (blended with the accumulated wisdom of tube-era old-timers, where applicable). As sophisticated new designs are brought to the fore, real-life field testing will still be the final judge and jury.