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THE CASE FOR THE

FULL SIZE/FULL PERFORMANCE

LOOP ANTENNA

During the past two decades the type of loop antenna used by most serious MW DX listeners has changed from full size air core loops to small, amplified ferrite or air core devices. Yet for the organization or individual who needs the ultimate in performance there are still compelling reasons for using the full size air core loop.

The loop antenna is used by the serious DXer for a number of reasons. (1) It is the only practical high performance antenna most of us can erect. (2) It is quieter and thus provides a better signal-to-noise ratio than long, high wires. (3) It can null interfering stations and local QRN. (4) It is a precision direction finding device when properly constructed and used. (5) The loop responds only to the magnetic component of the radio wave and most local noise is propagated largely by the electric component thus further improving the loop's S/N advantage.

While loops can sometimes be used to prop up economy receivers, this article is concerned with their use with top-of-the-line receivers. The receiver should do what it does best, provide low noise gain and adjacent channel selectivity. The antenna should do its job of providing the best possible S/N ratio on threshold signals with perfect 180 degree symmetry.

HISTORY

Loop antennas were widely used with home broadcast receivers in the 1920's (Figure 1) but had disappeared from the scene in favor of outside antennas by 1930. Around 1938 they reappeared mostly in small table radios. They were basket wound on cardboard or fiber forms about 12" X 8" and attached to the back of the sets. Zenith and GE had more advanced versions. GE called theirs the Beam-a-Scope and it consisted of a small air core loop which could be rotated within a Faraday shield. Zenith's was known as the Wavemagnet and was a conventional flat, basket wound loop sandwiched between a pair of Faraday shields. Neither was of much use for DXing.

The 1950's saw the ferrite rod antenna replacing the pancake loop in home broadcast receivers. These were the forerunners of today's amplified ferrite loops and are still used in most home and portable radio receivers.

Meanwhile, in 1946 the writer was the first to use the loop for serious foreign Medium Wave DXing. It was a 40" square box loop feeding an HRO receiver. It proved to be effective and attracted some of the prominent DXers of the day. Evan Roberts, the great foreign DXer (64 Australian, 21 Japanese veries from Massachusetts,) visited me and made a copy of my loop. Carlton Lord, Count de Veries, of RADEX fame, also visited me in the 1950's and published plans for the loop which he called the Moore-Roberts loop. I wrote the first article on the construction and use of the loop for MW DXing for DX Horizons magazine which they published in October, 1960.(Figure 2) The information in that article was widely copied. Just recently the Canadian International DX Club published a reprint of a British article on loops which was based largely on the DX Horizons article, including the drawings.

The best known of the large air core loops is the NRC alt-azimuth loop perfected by my late friend Gordon Nelson, the legendary DXer who heard over 130 countries in an urban location near Boston using only a loop antenna. His loop was a 35" square box type with a neutralized, balanced FET amplifier. It could also be used passively with link coupling. Nelson's main contribution was his introduction of tilting which allowed phenomenal null depths on local stations and the use of the amplifier which isolated the loop from the feedlin. This made possible unprecedented direction finding capability on sky wave signals. With the proliferation of amplified ferrite loops precision direction finding has become a lost art until recently.

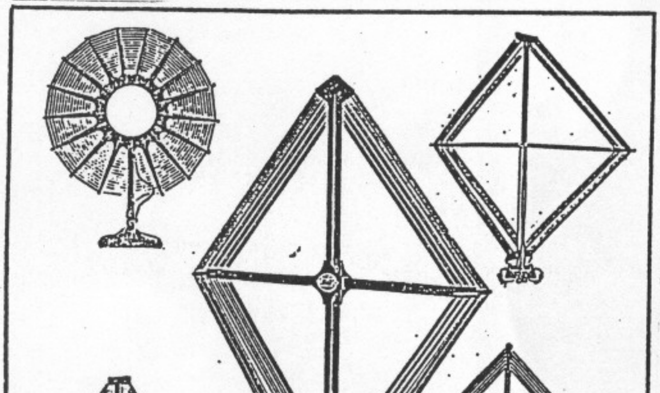

FIGURE 1. A sampling of loop antennas advertised in Citizens Radio Call Book and Radio magazines in 1925.

In the early 1970's Joe Worcester introduced an amplified ferrite rod antenna which he called the Space Magnet. It was the first of many small amplified loop antennas, both ferrite and air core. Their only advantage when used with a top flight receiver is small size.

LOOP CHARACTERISTICS

There are six characteristics by which one judges the quality of a loop's design and construction. Most can be measured using the proper equipment.

1. MECHANICAL: The mechanical quality of a loop is as important as the electrical. For long term use and satisfaction the loop must have the feel and looks of a well crafted piece of equipment.

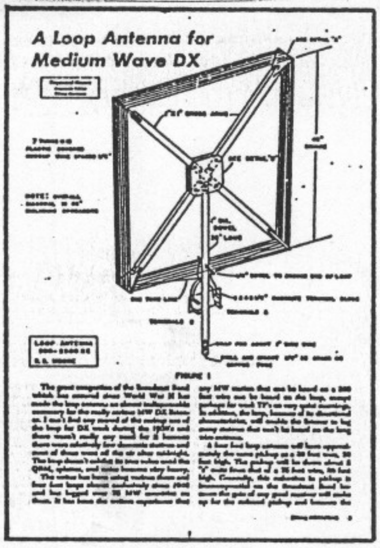

FIGURE 2. First page of an article on loop antennas in the October, 1960, DX Horizons.

Full size loops used by DXers in the past were bulky, top heavy and ugly. Lord's version, for instance, was four feet square with cross arms of 2" X 2" timbers, heavy metal angle brackets supporting the spreaders, all held together with 3/16" stove bolts. The average loop support was equally crude and unattractive.

2. SENSITIVITY: Calculations based on data in CCIR Report 322 show the minimum loop size required to reach the background noise level at all times and locations is approximately one meter square. There is a rule of thumb that the pickup of a ferrite loop approximates that of an air core loop with the same diameter as the length of the ferrite rod. Here is a table comparing the pickup of various loops relative to the pickup of a one meter square loop.

Loop Size	No. Turns	Relative Pickup
48" Square	7	+1.4 dB
39" Square	9	0 dB
35" Square	10	-1 dB
24" Square	14	-4.7 dB
12" Square	22	-13 dB
7" Ferrite Rod	30	-19.5 dB

These figures are not as damning as they appear for small loops since the background noise level increases dramaticaly during the period from just before sunset to just after sunrise. Therefore, a small amplified loop will probably resolve 95% of the signals that a full performance loop will just as a Sony 2010 will resolve 95% of the signals that the most expensive receiver will. However, the remaining 5% are the very stations that the avid DXer is after. Sensitivity is not the most important loop characteristic and it is in the other areas where the small loops are most deficient.

Passive loops have a noise figure of one since the S/N ratio at the output equals the S/N ratio of the signal induced into the loop from the passing wave. The noise figure of an amplified loop will always be greater than one because the amplifier will generate some noise.

3. DISTORTION: High gain, high impedance amplifiers used with small air core and ferrite rod loops are prone to generate distortion products in strong signal areas. Full size, passive loops, on the other hand, generate no distortion products.

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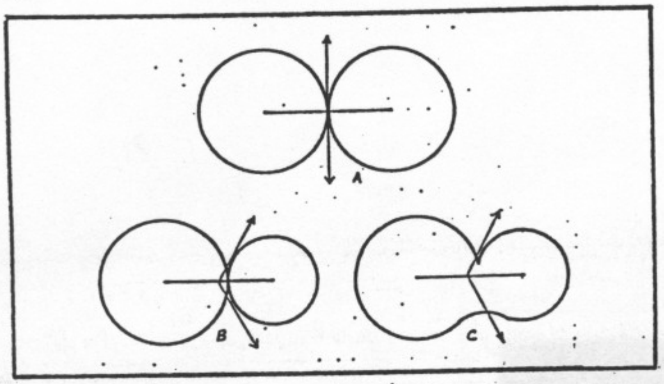

FIGURE 3 - Normal (A) and distorted (B,C) loop directional patterns.

4. 180 DEGREE SYMMETRY: This is the single most important measure of the quality of a loop's design and construction. The nulls must be identical on the two faces of the loop. The depth and direction of the null on one face of the loop should be exactly the same as that on the other face except that the bearing must be offset exactly 180 degrees. If not, the loop will give unreliable bearings when used for precision direction finding.

Figure 3A shows the directional pattern of a perfectly balanced loop. There are two nulls of equal depth exactly 180 degrees apart at right angles to the loop frame. Figures 3B and 3C show the affect of imbalance on the directional pattern. The nulls are not exactly 180 degrees apart and/or they are of unequal depth.

The cause of loop asymmetry is imbalance to ground and antenna effect. Imbalance to ground is the result of poor loop construction and reflection of feedline imbalance into the tank circuit. Antenna effect acts like a sense antenna to distort the loop's pattern. The cause is extraneous signal pickup in the tank circuit and transmission line. The signal can be picked up from long leads to the tuning capacitor, a physically large tuning capacitor, a range extending capacitor along with its switch and wiring, an uninsulated vernier dial, improperly terminated transmission line, and on and on.

5. NULL DEPTH: A perfectly balanced loop should exhibit the maximum theoretically attainable nulls. In practice the actual null depth depends on external factors such as the wavefront characteristics of the signal. The maximum achievable null depth will vary from station to station.

6. OUTPUT IMPEDANCE: The loops of the 1940's through the '70's ignored the output impedance of the loop and were just connected to the receiver via any old cable. Fortunately, receivers in those days had medium (300-500 ohms) to high impedance inputs and thus were not a disastrous mismatch to the 3000 ohm output of a MW loop with a single turn link. Run that 3000 ohms into the 50 ohm input of a modern receiver and you are practically shorting the loop.

The solution is to transform the 3000 ohms to 50 ohms and connect it through a 1:1 balun to 50 ohm coaxial cable to the receiver. The transformer and balun are wound on toroidal cores to prevent direct pickup (antenna effect) of signals. If the receiver does not have 50 ohm input you should use another matching transformer at the receiver. If the transmission line is mismatched at either end you will again introduce antenna effect.

There are a number of advantages to using a 50 ohm system. Standard 50 ohm cable is easily obtained and used properly eliminates direct pickup of the signal by the transmission line. Standard 50 ohm line amplifiers can be switched in and out which you can't do with the high impedance amplifiers in direct coupled loops. Most modern receivers use 50 ohm inputs.

Mismatches between the loop, transmission line and receiver can reduce the loop output by 10 dB or more. Such mismatches account for most of the reports that a loop did not have enough output to drive a particular receiver while it worked well with other receivers.

Matching of the loop, the transmission line and the receiver allows the loop to deliver the maximum possible signal power to the receiver witout adding noise or distortion.

SMALL LOOPS - UNDER 24"

Small loops can be either air core or ferrite core. They must be amplified because their signal pickup is from 5 to 20 dB below that of a full size loop. Even with amplification the signal-to-noise ratio cannot match that of a full size loop under marginal conditions.

1. ADVANTAGES: The sole advantage of a small loop is that it is small and thus can be made unobtrusive and sometimes attractive.

2. DISADVANTAGES: The disadvantages of small loops are (a) reduced signal pickup making amplifiers mandatory (b) degraded signal-to-noise ratio (c) susceptibility to intermodulation products in high signal areas (d) excessive loaded Q resulting in critical tuning, hand capacity and sideband cutting. (e) difficult to balance well enough for precision direction finding.

Most small loops are direct coupled into high gain, high impedance amplifiers. They are difficult to design and implement for superior intermod and noise performance and they can't be switched in or out as needed. Adding regeneration compounds the problems. In addition, the loaded and unloaded Q's are essentially the same resulting in critical tuning, hand capacity and sideband cutting.

LARGE FERRITE LOOPS

Jim Hagan described a 48" amplified ferrite loop in DX NEWS in 1976. He had some problems with 180 degree symmetry and said "Weak signal performance is very good, although not quite equal to the NRC (Nelson) loop" The amplifier was one of the best designs of the time, an FET push-pull circuit with source follower output to match a 50 ohm line. It would have been interesting if he had used it as a passive loop without the amplifier.

Almost in the large ferrite loop category was the Radio West 22" model. My unit had a noisy amplifier but when it was replaced with an amplifier similar to Hagan's it was a good performer. Properly matched it also worked well as a passive loop.

LARGE AIR CORE LOOPS

State-of-the-art performance requires a full size, passive loop. Modern design practices allow us to build loops with a new level of performance and appearance. Slim and light weight, sensitive, perfectly balanced, immune to overloading and distortion, the modern loop is a precision instrument to enhance the performance of even the best receivers. There are two types of air core loops.

1. BOX WOUND: This is the most common method of winding a loop but it has a couple of serious disadvantages (a) it requires a massive and heavy frame because the outside turns, when pulled taut, place heavy torque on the frame (b) it has a large width to diameter ratio which degrades the nulling and direction finding ability.

2. SPIRAL WOUND: The spiral wound loop overcomes the problems of the box wound variety. It has an almost perfect width to diameter ratio since all the turns are in the same plane. Also, it is much lighter and more attractive because pulling the winding taut does not torque the frame so it can be made of lighter material.

The disadvantages of the spiral loop are (a) the difficulty in winding it when using the preferred method of placing the support holes through the center of the supports. It must be wound on a jig like a tennis racquet (b) it is almost impossible to center tap a spiral loop for use with a balanced amplifier which is why Nelson didn't use it for the NRC loop. Since additional gain is not needed and there are better ways of impedance matching this is not really a disadvantage.

RSM COMMUNICATIONS MODEL 105 LOOP

The RSM Communicaions Model 105 series of loops are wound on a 35" square frame and cover the frequency range from 150 to 7600 kHz. The antennas are designed for commercial and professional users who need a precision direction finding instrument sensitive enough to reach the atmospheric noise level. The loops are capable of unprecedented direction finding accuracy on both local and distant (sky wave signals). The antennas are also suitable for discriminating low band amateur operators and dedicated MW/LW/tropical band DX listeners.

The Model 105 evolved during two years of design and testing. More than a dozen prototypes were built and evaluated. Thousands of observations have been made and thousands of

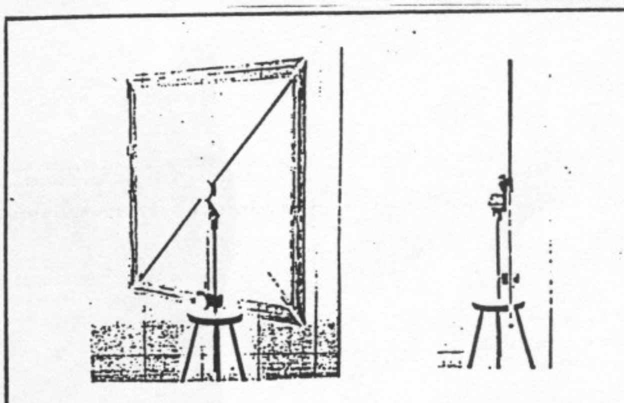

Figure 4. Front and side views of Model 105 Medium Wave loop.

bearings have been taken and continue on a daily basis. We are particularly proud of the mechanical design. The 105 has the same area and pickup as the NRC loop but weighs only two pounds and is so slim in profile that we considered calling it the "Stealth" loop. (Figure 4) It is assembled and sealed with West System epoxy and finished with marine polyurethane paint. No mechanical fasteners are used in assembling the frame yet it is stronger than any previous design and is immune to warping. The light and attractive Model 200 tripod is designed for use with all RSM loops. It features a precision 8¼" compass rose calibrated in one degree increments.

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Figure 5 is a schematic of the Model 105 series of loops. A variable capacitor tunes the main winding to resonance. The capacitor is selected for its small size and bulk to reduce antenna effect. A one turn link is embedded in the main winding and applies the signal to T1, an impedance matching transformer which transforms the 3000 ohm output (MW model) of the link to 50 ohms. The signal is then applied to T2, a 1:1 balun, which isolates the feedline imbalance from the loop. The 50 ohm output goes to a SO-239 connector. T1 and T2 are wound on ferrite toroidal cores to prevent direct signal pickup.

SPECIFICATIONS

Following are the specifications of the Medium Wave Model 105 loop antenna.

FREQUENCY COVERAGE: 440 to 1855 kHz in a single range.

MECHANICAL: The Model 105 loop is 35" square, spiral wound and weighs two pounds. It is constructed and encapsulated with West System epoxy using no mechanical fasteners in the frame. Standard finish is two coats of black marine polyurethane paint.

MOUNTING: Model 105 can be supplied with either a straight azimuth mount or an alt-azimuth mount which allows tilting for deeper nulls on local noise or stations. Both mounts terminate in a 5/8" diameter rod to rotate in the Model 200 tripod or any other support with a 5/8" inside diameter.

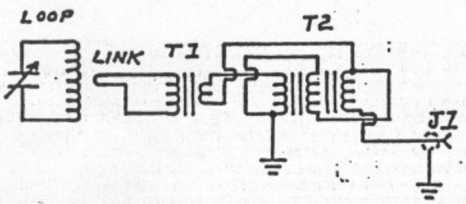

Figure 5. Schematic diagram of the Model 105 series loop antennas.

OUTPUT IMPEDANCE: The output impedance is 50 ohms to a standard SO-239 UHF connector.

SENSITIVITY: The loop reaches the atmospheric noise level when impedance matched to any good receiver.

180 DEGREE SYMMETRY: Measured at 790 and 1300 kHz.
Null depths symmetrical to better than one dB.
Null directions skewed less than one degree.

NULL DEPTHS: Attains maximum theoretically achievable nulls for a balanced loop. Actual depths depend on external factors such as wavefront characteristics and null blunting from local reradiation.

DISTORTION: No second or third order distortion is produced by the loop.

INTERCHANGEABILITY: All loops fit the Model 200 tripod and can be interchanged in 15 seconds.

PROOF OF THE PUDDING

Well, enough esoterica. How does it work? The proof of any piece of radio equipment comes on the air under real world conditions. Laboratory measurements are necessary but the true story emerges when trying to extract intelligence from a threshold level signal mired in noise with interfering stations all around. Too many people judge an antenna by its gain. How high it pushes the "S" meter. This is wrong. The right way is to find the quietest spot on the dial (1625 kHz works fine for me) and see if you can hear the atmospheric noise level. Then you find a threshold level station, preferably a TA or TP, and compare the readability of the station on your various antennas.

The Model 105 loops have achieved the high performance goals for which we aimed. With only a single, smoothly operating control they are a pleasure to operate. They rotate precisely and have near perfect symmetry. They easily reach the atmospheric noise level when matched to any good receiver and have demostrated unprecedented DF ability.

Weak signal performance is outstanding. We have heard TP carriers on over 50 frequencies from Japan in the north (once) to New Zealand in the south. In between (according to DF bearings) have been Australia, Tonga, Fiji, Samoa, Marshall Is., Kiribati and Tahiti. We have heard audio on six different frequencies, all in Australia some 10,000 miles away. TA's are strong year round here and are not a great test of sensitivity although they are equally challenging for DF purposes. As sunspot cycle 22 declines we expect to get audio from more of the TP's over the next couple of years. Indeed, DX listeners in the Northeast and other parts of the country where noise levels are 10-15 dB lower than here in the tropics should be able to be able to get audio from many of these stations right now.

The most exciting feature of the Model 105 MW loop is its direction finding ability. You are able to determine what station is coming through with just a quick bearing. For instance, on 774 kHz there are three likely TP's, Japan (328°), Fiji (258°) and Australia (240°). The dominant station is 3LO, Melbourne, and it is right on 240° when alone on the channel. Fiji is also often present causing a pronounced SAH which pulls the null to about 247° as expected for two equal strength stations. Fiji has never been heard alone on the channel. We have taken hundreds of bearings on 774 kHz over the years and only once has it deviated from the Fiji/Aussie direction. In September, 1993, on a poor Aussie morning, there was a strong carrier, verging on audio, bearing 326°. This was almost certainly JOUB. Just this month we were unable to get a null on the 774 kHz carrier for the first time. This can happen when two equal strength stations are 90° apart as are Japan and Australia. Each will then fill in the null of the other.

The advantage of this type of DF ability is obvious. If you have already logged 3LO, for example, but need Fiji or Japan you just take a bearing and in ten seconds you know who is coming in. No waiting around for audio to fade in only to find it is 3LO.

One of my most coveted DX targets is Ascension Island. It has been heard in eastern US and its bearing is 108°. There are stations on both 1485 and 1602 kHz and I check those frequencies nightly. All I do is tune to the frequency with the bfo on and take a bearing. So far they have been 50-60° (Spain) but one day I will get 108° and hit paydirt.

A final true story. DXers in the northwest US reported a new unidentified Pacific station on 1557 kHz in the July issues of <u>DX News</u> and <u>DX Monitor</u>. Speculation placed it from the Philipines to New Zealand. We had been hearing the carrier here for several months and had taken many bearings on it because it lay considerably north of most TPs. We reported in the August issue of the magazines that our average bearing of 285° placed it on a great circle path between Kiribati and the Marshall Is., through the Solomons, across Papua New Guinea and into Australia's Northern Territory. If a tentative ID in the September <u>DX News</u> is correct the station is on Majuro in the Marshall Is. with a true bearing of 284°. Not too far off.

CONCLUSIONS

Our experience with the Model 105 loops convinces us that the principles of good loop design discussed here are valid and produce a loop with a superior level of performance and appearance. The small air core and ferrite loops with their high gain, high input impedance amplifiers have their place, but ultimate performance is realized only with a full size air core loop properly designed and matched to the receiver.

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