Loop Antennas

The Principles of the Loop Antenna article was in a newsletter of the MDXC. The next three were from a talk that Mike Bates and James Dale gave to the Northland Antique Radio Club's Radio Workshop at the Pavek Museum of Broadcasting.

Principles of the Loop Antenna

A loop antenna is an antenna primarily for the AM broadcast and the Longwave bands. There are two different types of loop antennas, one is the ferrite bar (as in your am radio), the other is wound on an air core form. A loop antenna is very directional. The pickup pattern is shaped like a figure eight. The loop will allow signals on opposite sides to be received, while off the sides of the loop the signal will decrease or be nulled out. The nulling feature will allow you to remove a local station on a frequency and pick up another on the same frequency by removing the local signal. A loop may have an amplifier or may not.

Air core loop antennas come in many sizes. The larger the loop the more gain there is. A small loop will actually lose part of the signal. That is why most small loops will use an amplifier. There are two ways a loop can be wound, box or spiral. In the box or solenoid loop the plane of the winding are wound perpendicular to the diameter of the loop, so each loop is the same size. In the spiral loop the plane of the windings are wound parallel with the diameter of the loop, so each loop gets smaller as you wind into the center of the loop. A loop needs to be able to rotate to null out a station. And a loop also needs to be able to till from vertical. This also helps in in nulling of a signal (altazimuth feature).

The number of turns the loop needs is determined by the size of the loop, the frequency range that you want to tune and the value of your tuning capacitor. The larger the loop the fewer turns you will need. A 4 foot loop needs 8 turns and a 2 foot loop needs 18 turns. The capacitor that is used is the standard AM tuning capacitor with a range of 10 to 365 pf. The tuning capacitor is used to tune the loop to the frequency that you want to listen to. When you are tuned in to the frequency the signal will peak. You may not be able to tune the full frequency range that you want to tune. So you will need to use a 2 section capacitor and switch the second section in. (more capacitance)

There are three ways that you can connect your loop to your radio.
One way is not connecting it at all. (This requires a portable radio with a internal loop antenna.) The field of the loop will radiate the peaked signal and you will be able to pick it up with no connection to the radio. You can move the radio around to get the best reception.

You can also direct couple to the loop. This way you connect to each end of the loop and also to the center tap of the loop. Using this method you will need to use it with an amplifier.

The last method is to use a pick up coil. This consists of one turn of wire that is placed inside the loop on the cross arms. This is then connected to the radio.

The distance from the main tank coil can be determined by using a pocket radio and moving it inside the loop to find the place were the signal is strongest, and were it peaks sharpest.

In the past loops were made from wood. I have built them and found them to be heavy, clumsy, and flimsy. The mounting system were not very stable. In talking with Mike Bates, he came up with the idea of using PVC to build loops.

PVC is easy to cut and because you use PVC molded parts, the loop that you make are is stable. By using PVC cement for some gluing and small nylon screws to connect parts you have no metal parts except the wire and tuning cap to throw the pattern of the loop off. Using PVC it helps to have a drill press, but if a person drills very carefully there should be little problems.

<u>What is a loop and why use it?</u>

1). A loop antenna is a small multi turn loop of less than 1/10th wavelength in length. The loop is wound on a form, which may be either box (solenoid), or spiral (pancake) wound. The core material can either be air, or a powdered iron compound (Ferrite). The gain of a loop is much less than a longwire, but it has much less noise pickup. A properly designed Loop primarily responds to the magnetic component of the radio wave. Note that noise resides primarily in the electrical component. A vertical antenna responds mainly to the electrical component.

2). Why use a loop?

A). No available space for a longwire antenna

B). To eliminate unwanted signals, and noise

C). Radio Direction Finding

D). To improve the performance of a simple receiving system, by providing pre-selection which improves image rejection, and adjacent channel selectivity.

3). History

A) 1915-1920’s Early receivers used loop antennas, until they were discontinued in favor of long wire antennas, prior to 1930.
The loop antenna appeared again about 1938. This time it was used to eliminate the need for a longwire antenna, and to provide for safer operation of the small midget AC/DC sets that came into wide use at that time.

B). The first known use of a high performance loop antenna is the box loop made by Ray Moore in the mid 1940’s(1) This antenna was written up in DX Horizons in 1960. The Moore Loop was wound on a 40" square box frame. Note: Ray Moore is the Author of the book on the history of Communications Receivers, and a new companion book on Transmitters.

C). The next major advance in Loop Antenna design came about as a result of advances by Gordon Nelson of the National Radio Club. The NRC Loop Antenna(2)was designed by Nelson in the Mid to Late 1960's time frame, Nelson was at M.I.T. at the time. The major advance that Nelson made was allowing the loop to rotate in the vertical as well as horizontal plane. The addition of the Alt-azimuth adjustment allows for the elimination of the effects of "wave tilt" and allows for much deeper nulling of certain stations. This loop was a 35" on a side and wound on a wood frame. In one form it utilized another Nelson first, a direct coupled Balanced amplifier using 2N4416 J-FET's with the outputs fed to a balanced feedline. The other version was link coupled to the receiver.

D). Sanserino Loop (1970-1985) This is a 2 foot Air core box loop designed by Ralph Sanserino, and later marketed by Radio West. This loop antenna used a Differential Amplifier similar to Nelson's except the output is not balanced. This antenna also has the Alt-azimuth feature. (available as a kit) The amplifier was later used in the Radio West Ferrite Loop Antenna (see below) .

E). Joe Worchester (1970-1977) a retired GE engineer developed the "Space Magnet ", a small 12" ferrite rod loop antenna using a Bipolar Junction Transistor amplifier(3). Nulls were not as deep as with the Nelson Loop.
This is also probably the first loop antenna commercially available to the hobbyist, at a cost of about $45.00 if I remember correctly. Later versions utilized the Nelson Alt-azimuth feature. This antenna also used a Faraday Shield around the Ferrite Bar.

F). Mackay Dymek (1974-Early 1980's) , Palomar Engineers (1977-current). These are small ferrite antennas made by larger commercial concerns. The Mackay Dymek was primarily for the Broadcast Band, where the Palomar has plug in coils for ranges from 10Khz to 15Mhz. Note that both of these antennas incorporated alt-azimuth design.

G). Radio West(1979-1985) 23" ferrite rod assembly using Sanserino Differential Amplifier, direct coupled, Has Alt-azimuth feature, $160.00 in 1979.High performance for its day, quieter than the "Space Magnet"

H). Quantum Loop (about 1990) by Gerry Thomas is a small ferrite rod less than 1' in size (length), with a high gain 40Db amplifier. has Alt-azimuth feature, in current production in various forms $135-$200.00.

I). KIWA Loop 1992 First Air core available since Nelson/Sanserino. Uses IC amplifier Opto isolated regeneration and varactor tuning. High performance, solidly built, in current production. $360.00.

J). RSM Communications (Ray Moore) RSM-105 (1994) A high performance transformer coupled, non amplified antenna described by Moore in Dec 1994 IRCA DX Monitor, Later in March 6 1995 issue of NRC DX News. Still in production? Price?? 35" spiral wound.

4). Electrical Design Characteristics

A). Two main types of Loops available 1). Directly Coupled and 2). Indirectly coupled (Transformer coupled) The Directly Coupled Loop has its windings directly attached to an Amplifier. Usually the main Tank Coil (parallel tuned circuit that forms the loop primary) in the loop is grounded at the center of the winding (center tapped), to allow for electrical balancing. The Amplifiers are usually but not always J-FET's, with 2 FET's in a Differential configuration, where the ends of the tank winding go to each FET gate. The Transformer coupled version uses a link winding to couple the signal to the receiver. This version can be amplified or non amplified.

B). The pick up pattern of a properly designed loop should be a figure 8 pattern. The null should be of the same depth, if the antenna is rotated 180 degrees horizontally (loop should not be adjusted for alt-azimuth, but left vertical 90 degrees from the ground). The 180 degree symmetry should be the same + or - one degree. If this condition does not occur the Antenna is not properly balanced. In a transformer loop balance deals with the signals being equal on both lines of the feed line (equal potential to ground). The feed line should preferably be shielded with the shield being grounded to the receiver chassis. If the line is affected by an electric field signal, a metallic object, or some other imbalance to ground, the loop will become unbalanced, resulting in a distortion of its pick up pattern. Balance is critical to getting the best nulls, and for precision Radio Direction Finding. The use of a broadband balun allows for better balance, but thought should be put into the design of the link winding, and receiver feed line, as well as the mechanical integrity of the coil.

C) The transformer coupled loop is the easiest to balance, especially if it is an air core loop. Ferrite loops are not as easy to balance due to the compression of flux lines in the ferrite. These antennas seem to be somewhat more prone to pick up electric fields.

D). In a directly coupled loop, the balance is affected by the gain of the amplifying devices on either side of the center tap being equal. If they are not very close to, or equal, they will cause the voltage in the tank coil to be imbalanced with respect to ground causing the same undesirable effects that the feed line caused in a Transformer Loop.

E). Some loops utilize a Faraday shield to maintain balance (4) Usually a one turn loop. these are usually circular, and are used on ships and other areas where direction finding is necessary. An example of this antenna is the 160 meter loop wound out of coax described by Doug DeMaw (5) Using a Faraday Shield will affect the pick up gain, as well as the "Q" of the tank coil(3) Another variant of the shielded loop is the Mike Hawk Loop(6)

Also note that imbalance is sometimes referred to as "Antenna Effect"(4) Also please note that a balanced loop antenna can be spoiled to a cardioid pattern by putting a vertical sense antenna within its field.(4)

F). The amount of coupling (placement of the link turn) is critical to the performance of the Transformer Coupled Loop. The placement can vary depending upon the load that the antenna sees. The best way to obtain optimum performance is to experiment with various distances from the Tank Coil.

Most designs call for this to be wound amongst the tank coil windings, however this coupling is much too tight for most uses, and allows for tuning to be too broad, Q to be too low, and sensitivity to be not quite optimal.

G). The physical size of the Loop Tank Coil affects the overall pickup (capture ability) of the loop. The larger the winding size the greater the pickup. Larger loops will also be easier to balance than smaller ones.

H). The Tuning Sharpness "Q" is determined by the size of the wire (surface area). The lower the resistance the higher the "Q" will be. The loading of the Tank Coil also affects the "Q". This more than wire resistance affects the Transformer Coupled Loop. In a Transformer Loop, the placement of the Link Coil in relation to the main tank (distance) determines the amount of coupling, and hence the loading of the tank circuit. The point of critical coupling can be found by varying the coupling link distance, while comparing tuning sharpness and gain. the critical coupling point will be found at the sharpest tuning before the gain starts to drop. Tuning will continue to sharpen (slightly), but gain will fall off more rapidly, as one couples more loosely (moving the link physically farther from the Tank Coil). Further improvement can be had by matching the load impedance to the link coil with a matching transformer. This can be done as part of a balun, or following the balun (lead-in side). For optimum performance all impedance’s in the system should be properly matched.

I). The L/C ratio and mechanical design of the coil should be considered when looking at a good design for a loop. The loop should be mechanically stable (wires not flopping loose) The distributed capacitance between turns should be kept low by proper design to allow for wide tuning range, but not too wide to degrade the length to diameter ratio of the coil. Note that the best null performance occurs with the best length to diameter ratio of the Tank Coil. A spiral wound coil affords the best performance in this regard, but does not afford as great a signal pickup as a solenoid coil of the same diameter. (A Trade off)
Also note that the L/C ratio should allow for one 10 to 500pf variable capacitor to tune the whole Medium Wave Broadcast Band.(530-1700 KC)

J). Performance can be further enhanced if the amplifier following a transformer coupled loop is tuned. This provides still better image rejection, and adjacent channel selectivity. It is important that the amplifier be isolated from the loop by a transformer to maintain balance and pattern integrity.

K). Note that the spacing of the windings determines the inter-electrode capacitance. The wider the spacing between windings, the lower the capacitance, and the higher in frequency the loop will tune. the use of interlaced spreaders further reduces this effect (solenoid loop) provided that the spreaders are of sufficient width. Also note that the winding spacing is a compromise with the length to diameter ratio.

Construction Principles

5). Mechanical design

A). Up to now, loops were made from wood. It was used because it was readily available and easy to work with. Wood does have disadvantages. They are, finding good wood, making accurate cuts, and heavy weight.

B). In a wood loop, the alt-azimuth tilting mechanism does not work very well. Wood loops use a bolt for the alt-azimuth tilt. It uses an arm that goes from the loop to a clamping setup on the mounting post. This does not work very well, as you need to tighten the bolt every time that you change the vertical tilt. The bolt will become loose, and on high angle tilts does not hold very well.

C). Most loops use a pipe mounted vertically with a dowel to do the horizontal rotation. This does not work well, as it allows the loop to move on it own. Wood will also wear after some use. This allows the loop to lose its square ness which can affect the loops pick up pattern.

D). The first loop I built was the Harley Loop(7). It is small spiral loop that was easy to build, but had no Alt-Azimuth feature, so the loop would not vertically tilt. It uses two cross arms with saw kerfs part way through to hold the wire.

E). I then built the 4 foot NRC Loop(2). This loop worked well, but the Alt-azimuth tilt needed work so I did some modification on the tilt mechanism. I wanted to design a tilt that would be easy to tilt and would stay in place. I tried different ideas and in my design I used a 3 inch PVC pipe for the mast and the loop head would tilt off that, this did work better but was not perfect.

F). While talking to Mike Bates(1995) about loops, He had the idea to build a large spiral octagon loop(5ft), out of PVC pipe and Alt-azimuth tilt it with a tripod. We built the loop, and this got my interest in using PVC for designing and building loop antennas. The tripod did not work very well due to the heavy weight of the loop head, but the performance was quite good.

G). My next design was a 4 foot PVC spiral loop that is collapsible. New features added to this loop was the use of a lazy susan for the horizontal rotation of the loop, however, you need to use a liberal amount of grease to give it tension. For alt-azimuth tilt I took a 3/4 inch PVC tee, reamed out the inside smooth, and cut a slit length wise. Through this I ran a piece of PVC pipe and with the use of elbows and tees attached it to the loop head. I then used plastic hose clamps to adjust the tension. This worked better, but still did not work very well. It is hard to get the angle just right, it does not move smooth enough.

H). Then I built a 4 foot Loop modeled from the NRC plans(2) out of PVC. For this loop I added the use of PVC in the base. I used the same type of Alt-azimuth tilt mechanism as the earlier spiral. To mount it to the loop head, I used a hole in the crossover of the loop to attach to the alt-azimuth mount. This was done to allow for having the ability to build different loop heads, like one for the longwave beacon band. This allowed the loop head to rotate on the mounting mechanism which made the loop unstable, and not very easy to use. I decided to make the mounting like the spiral loop, but to add the tees, I needed to cut part of the tee to mount it on the loop arms.

When I assembled it for fit, I found out that cut out tees worked much better for tilting, and hose clamps are no longer needed. The alt-azimuth tilt mechanism now works very smooth and holds well at all angles.

I). The 2 foot loop was also built based on the NRC plans(8), it employs a gimbal mount for alt-azimuth tilt.

J). These loops are made entirely out of PVC except for the base plate that employs a lazy susan to rotate the loop. I built jigs to drill the holes in the cross pieces. A drill press helps a lot, but with very careful measuring and drilling, a hand drill may work. In my first loops I used PVC cement to glue the loops together. This cement sets up very fast, so you have to be very careful assembling it. I found out that some parts can be glued, but on some it is better to use a small nylon screw. This allows for you to align the pieces right on. To do this drill and tap a hole for the screw and run it though both pieces of plastic (PVC).

K). It helps to make a jig to wind the tank coil onto the frame. To accomplish this I mounted a Lazy Susan to a board, and ran a board with two vertical pieces of PVC Pipe The loop frame slides over the pipes, allowing the loop to be rotated while the wire is brought off of the spool in the same direction, while being laced through the holes in the frame. This helps greatly, in minimizing twisting of the wire.

L). Reasons for using PVC in loop construction:

1). Readily available, at low cost

2). Easy to work with, Saw and drill are main tools required, however, a miter box saw allows for clean perpendicular cuts.

3) Very symmetrical loops can be built, because the fittings are identical, and pre made.

4). Very low weight

5). The ability to come up with modular designs

6). The ability to design a collapsible loop that can be mechanically strong, allowing for easy transport

7). The use of spacers will tighten up the wires, so that they do not flop around, and distort the pickup pattern, as well as reduce inter-electrode capacitance. This makes for a very stable loop.

M). Notes:
Loop shapes: Triangle (Wedge), Square (Also called box, this is the most common shape) Octagon, Circular.

Note that the box loop is used because it is the simplest to build. The circular loop provides the nearest to the perfect shape electrically, but it is very difficult to fabricate a multi turn loop of this type. The octagonal loop is the practical compromise. Also note that the Octagonal is more difficult to fabricate due to it having 8 arms instead of 4, for the box loop.

What Can I use a Loop For

6). Using the Loop practical applications
The small loop is a versatile antenna, and can be used for many different applications, here are a few.

A). The loop can be used for improving the performance of a poorly designed broadcast receiver. Depending on the type of antenna that is in the receiver determines how the loop can be attached. It may be attached via a transmission line if the set has wire or screw binding posts for the Antenna, or it may be inductively coupled (transformer) for a receiver using a very small loop.

In the case of the receiver with a small loop the coupling rules apply as if the receivers loop is the link turn in the Transformer loop. (Note that the link coil is not needed for the loop to work for this, as the internal loop in the receiver is receiving the signal from the main tank circuit). The distance from the receiver to the larger loop will determine the amount of coupling, and tank loading. One can vary the pick up pattern by varying the angle of the receivers internal antenna to the external loop.

The antennas provide maximum transfer of signal, and closest to a figure 8 pattern. when the pick up angle of the antennas is opposite parallel (90 degrees) (Beams of the antennas aimed at each other) Minimum pickup occurs at 180 degrees. The pattern can be spoiled to a cardioid (null in only one direction) by varying the angle. Please note that the pattern will probably be somewhat spoiled from a figure 8 at the maximum signal 90 degree points. Please note that there are 2 commercially available products designed to inductively couple to the receiver, and improve its signal. These are the "Select A Tenna", and the "Q Stick" by Radio Plus (Gerry Thomas). However a 2ft or larger loop provides for much better performance provided one properly adjusts the coupling. A Large loop (4 ft) can cause a poorly designed receiver to overload. Loosening the coupling will allow for the overload to be eliminated. One must also be sure for proper operation that the loop is tuned to the same frequency that the loop is tuned to, or unwanted overload effects will likely be noted. All tuned circuits should be "aligned" to the same frequency. Also note that high Q tuned circuits can sometimes be touchy to adjust "spot on", some practice will probably be necessary. One can be amazed at the improvement in performance when using a properly designed loop. Stations can be brought from out of nowhere on a poor set. Images at the low end of the broadcast band will be cut down significantly or completely eliminated. As stated previously, adding a properly designed tuned amplifier further improves the performance of the system. The amplifier can be fed by feedline to a coupling link that couples to the receivers internal loop, or can be direct attached to a receiver with antenna connections.

B). A loop when properly balanced can be used to "null down" AC Line noise, TV Sweep Harmonics, or other locally generated interference. The Alt-azimuth feature helps greatly reduce, sometimes totally eliminating the noise. This feature is also quite useful for nulling of co-channel, or adjacent channel broadcast band stations. If properly balanced, nulls of over 60 dB may be attained by using the Alt-azimuth feature. Deep nulls can be difficult to find and maintain. A larger antenna allows for one to find the null more easily due to the larger pick up(field) created by the loop. Loops of 2 ft and smaller in diameter, can be quite touchy to null, and electrical balance can be quite hard to attain.

Hand capacitance can also affect the null in these small loops, causing the null to move as ones hand is moved away. This effect is minimized when using a large loop, as your whole body is within the pick up pattern of the loop, and it will be less likely to distort the pattern. One needs to be 6" to 1' away from the small loop(2ft and smaller) to avoid the hand capacity effects. It is also notable that nulling works best on local ground wave signals. Distant sky wave signals can be more difficult to null. It is difficult to get a null of greater than 30 dB on a sky wave signal at the top end of the broadcast band at night. For Sky wave, phased antennas provide for much better nulling, but are much more complex, and difficult to operate. Also note that the higher the Q of the tank coil, the sharper the null. Sometimes the null will be excessively sharp, and difficult to find, or the null will be so narrow in bandwidth that the carrier of a station will be deeply nulled, but the sidebands will be well received as slop(splash). This affect is more noticeable in small, or amplified direct coupled loops.

C). Radio Direction Finding
One can accurately direction find signals provided that the antenna is properly balanced as described above. The general concept is that the deepest null will be in the direction of the signal being checked. You cannot use the Alt-azimuth feature, you must keep the loop perpendicular 90 degrees to the ground. An accurate compass, and a marked 360 degree circle can be used to pin point the exact bearing that the signal is coming from. Bibliography from the three articles above can be found at the bottom of this page.

Loop Antennas Another Look

The last 30 years have brought about much refinement in the design of loop antennas. Starting from the basic box loop described by Ray Moore, major developments over this time are; The NRC 4ft Alt-azimuth loop, the Space Magnet, Sanserino Loop, Palomar, Mckay Dymek, Radio West, Quantum, Lankford, Kiwa, and RSM 105, and 103. As time has progressed, so has the design of Receiving Equipment, from the R390A, HQ-180, and SX-122 and Zenith Trans-Oceanic to the Sony 2010, Drake SW-8, Drake R8-B, and the AOR7030 Plus. Antenna needs have changed, with today's broadband front ends, and synthesizer phase noise a concern, a high performance loop, or other means of pre-selection is more important than ever.

We will show a slightly different twist on the same basic loop antennas of the past, with a couple of refinements, as well as construction details of our antennas.
To explain our antennas we want to start with the design criteria necessary to improve the modern communications receiver, as well as consumer grade radios such as, the Super Radio III, the Radio Shack Optimus, and most other portable short wave/broadcast receivers.

Important loop criteria have been explained before in the pages of DX News, and the NRC Antenna Manuals, however, a review is in order. It is our opinion that there are 4 basic parameters that loop performance should be based upon; 1). The loops signal to noise ratio. 2). The electrical Balance. 3). The selectivity or "Q" of the loop.

4). The mechanical rigidity/integrity of the coil assembly, and Alt-azimuth mechanism.
Signal to Noise Ratio

Most efforts during the last 30 years have dealt with making loops smaller, to allow them to be used by the DXer who has limited space. S/N ratio has suffered as a result. The use of direct-coupled balanced FET amplifiers, and smaller, and smaller loop coils means that the bulk of the work in the system is being done by the amplifier. If you capture a very tiny signal, and add some amplifier noise to it, you have degraded what signal that you have to the point that you may bury a signal slightly above the noise floor. A rule of thumb would be to use no more amplification than is necessary. It is better to make the coil larger to enhance the capture area, and insure that what amplification is used is as low gain, and low noise as possible.

The small loops are probably OK for most uses, but when you want to extract the last decibel out of the ether, a larger loop that is properly designed will be best.

Electrical Balance

The electrical balance of the antenna insures that the current at the termination of one end of the loop tank coil is of equal magnitude and opposite polarity to that at the other termination of the loop coil. (A is equal and opposite B) When properly balanced the deepest possible null will be obtained, with the loop. Please note that balance is quite difficult to attain.

Anything connected to the tank coil (or other metal brought physically near it) other than the resonating capacitor, can throw this balance (equal and opposite) off. This distorts the theoretical figure 8 pattern of the loop. If a link turn is used to couple the loop to the receiver, this link and the transmission line must be balanced, or coupled to an unbalanced line (Coax Cable) using a Balun. The link coil should be balanced, as well as the main tank coil. Using a balanced FET amplifier on the tank coil will throw off the balance if care is not to insure that the FET’s are not exactly matched in their gain and transconductance. Not to mention that an amplifier not properly balanced, and running at excessive gain will be prone to create intermod products which degrade further the performance of the system. If a loop antenna seems to have a problem with hand capacitance it is a pretty good bet that it is not properly balanced. Refer to Nelson’s article for detailed hints on how to attain balance.

Selectivity

The "Q" or quality factor of the tank coil will determine its selectivity at resonance (the tuned frequency). If the "Q" of the tank coil is loaded (reduced by the effect of a load on the coil), the "Q" will decrease, and the selectivity of the loop will decrease, or broaden. In the late 60’s Nelson devised the balanced FET amplifier as a way to minimize the loading of the tank coil. This allowed for selectivity that was so sharp that a loading potentiometer was added across the tank coil to reduce the "Q" so that the loop could be more easily tuned. Prior to this, loops were of the transformer variety, with the signal being coupled to the receiver via a link turn, wound amongst, but not attached to the windings of the main tank coil. This process did not take into full account transformer theory, as the loop is now a transformer due to the link coupling. The main drawback of the early designs is that they did not use the coefficient of coupling when designing the loops. Moving the winding away, somewhat from the main winding allows for less loading. Maximum energy transfer from the tank to the link would occur at "critical coupling". The load impedance also affects the loading, and should be matched to the impedance of the link turn, as well. As stated before the link should be balanced.

A balun, and matching transformer should be used with a modern receiver with a 50 ohm coaxial input. The distance that the link turn is from the primary tank coil greatly affects the performance of the loop. The "Q" can be greatly improved, as well as the S/N ratio if the link turn is placed at the critical coupling point from the main primary tank winding. This distance from the main winding can be approximately determined prior to winding the link turn using a pocket radio. Tune the pocket radio into a station that is within the tuning range of the loop. Start out with the pocket radio placed facing the plane of the loop (see fig 2) right against the loop winding, rotate the loop capacitor for a peak (maximum signal) on the pocket radio. Now move the pocket radio ½" from the winding and re-peak the loop. Observe how sharply that the loop tunes.

Move the pocket radio away from the loop in ½" increments. Observe how sharply the loop peaks on the pocket radio, as well as the signal strength at each point. The loop should peak more sharply, and increase its gain as the radio is moved away. The point of critical coupling is attained when the signal is at maximum, the sharpness may still increase somewhat, but the gain will fall off more rapidly as the radio is moved away. Note the critical coupling point, and wind the link coil this distance from the main winding. This process can also be used when passively coupling the loop to a radio using a ferrite antenna, or when using a device such as a Select-A-Tenna, or a shotgun loop , or "Q" stick with a radio with a built in loop.

Mechanical Integrity

Another consideration when building a loop is the mechanical design. This is often overlooked, and can affect the loop balance if the mechanics are sloppy. There are two different types of loop coil designs, The solenoid or box wound, and the spiral or pancake wound. Each type has several advantages, design trade offs, and dis-advantages. The box loop has a higher gain for the same diameter, but is more difficult to balance.

With this type of loop there is a trade off between the inter-electrode capacitance and the length to diameter ratio. Spreaders can be used to cut down on the inter-electrode capacitance, and to maintain coil rigidity. Note that the better the length to diameter ratio of the tank coil, the nulling ability is enhanced and balancing is easier. The spiral loop has the advantage of almost perfect length to diameter ratio, as well as being easier to balance. The main drawback of the spiral is its lower gain than the box loop. Also, if an amplifier is used, it is much more difficult to tap the tank coil at its center. An amplifier can be used more practically with the spiral by attaching it following the balun and matching transformer.

This way the amplifier is isolated from the loop, and the undesirable unbalancing effects can be avoided. Note that an amplifier should be used only when necessary, and should be as low in gain as to improve signal strength on very weak signals, where not using it would yield them unreadable. It is important that the loop antenna be well constructed mechanically to insure that the wires do not flop around, to distort the balance, as well as to prohibit the need for re-winding. We have switched from wood to PVC in our designs, with a minimum of metallic objects near the tank, and link coils. Note that metallic objects within the near pick up field of the loop will induce a voltage into the coil unevenly and throw it out of balance.