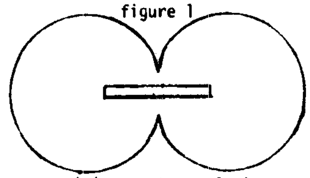
WHY A LOOP ANTENNA?

by Phil Bytheway

There are many reasons for choosing a loop antenna. Loop antennas are bi-directional, which allows you to point the antenna in the direction you want to receive in. More importantly, it allows you to null out stations that you don't want to hear. A loop antenna has two such nulls, ideally 180° apart (figure 1). Even with nulls not exactly 180° apart, the null will give the loop user a general idea of the direction that the signal is coming from, although of course, there will be two possible directions 180° apart. Good quality loops have quite accurate direction finding qualities.

figure 1



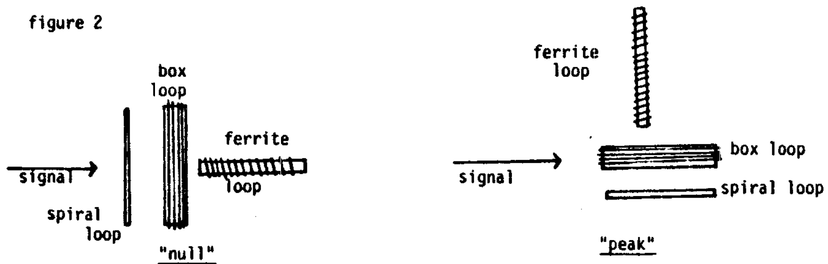
receiving pattern of air core loop antenna

Background noise is lower with a loop. This is due to the fact that the loop antenna responds to the magnetic field of the propagating radio wave, as opposed to the electro-static field of the wave. The high noise level one normally hears on a longwire is caused by its response to the electro-static field. The magnetic field is not as strong as the electro-static field however, and an unamplified loop's signal output is often less than a longwire's, though the signal to noise ratio is better.

The loop's size can be very important when one is living in an apartment, mobile home etc., and can be the sole factor in determining the type of loop antenna one uses. Some loops are less than a couple of feet long and only a foot or so high (those constructed with a ferrite core); air core loops can be four feet square or even more. Your available space may decide what type of loop you use then. Note however, that a loop antenna used inside a metal sheathed or roofed house, mobile home or apartment building will not perform well, particularly when nulling.

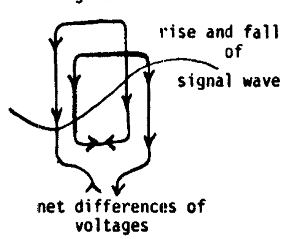
The loop is just a big tuned circuit, that is carefully tuned to the frequency one is trying to hear. The electro-magnetic radio waves induce a current in the windings of the loop, but only those waves at the resonant frequency of the tuned circuit are amplified to a useable signal level. If the signal arrives perpendicular to the plane of the windings (figure 2), current is induced in both sides of the antenna. These

figure 2



currents are equal, but in opposite directions in the coil. They cancel each other out, thus causing the null of the loop. As can be expected this effect occurs with radio waves from both directions, so the loop has two nulls. If the signal arrives in the plane of the windings, equal and opposite currents are again induced in the windings. But in this case, there is a time (phase) difference between the induction in one side versus the other (figure 3). This time difference makes the loop antenna work. The difference is increased by the number of turns, as well as the action of the tuned circuit, to form a signal. That signal is then fed into the receiver, either directly, or by the use of an inductive turn wrapped around the tuned circuit coil. This inductive turn acts like a transformer amplifying the current in the tuned circuit before passing it into the receiver. It is at this point that an amplifier is sometimes used to further increase the signal before it goes to the receiver antenna terminals. The amplifier is either directly coupled to the tuned loop winding or takes its input from an inductive pick-up loop. Several types of amplifiers can be used, but most seem to use an FET input.

figure 3



An FET preamp has lower self noise than a bi-polar transistor type preamp (such as the Space Magnet has), and can make a better amplifier since noise is a DXer's worst enemy. A typical amplifier consists of two stages, the input, which amplifies the signal, and a driver at the output of the amp that isolates the amplifier and provides a low impedance to the radio. However, Jim Hagan describes a balanced FET preamplifier which uses a toroid balun output rather than a second stage of amplification in "An FET Loop Preamplifier with Coaxial Output" (NRC reprint A17). This works well on air-core or large ferrite loops.

Two configurations of amplifier are used. First is the single ended amp which has one input and a ground. Second is the push-pull or differential amp which has two inputs with a ground "half way" between the inputs (i.e. the loop coil is grounded at a center tap). The advantage of the differential amp is that it amplifies the difference between the two inputs and attenuates the similarities. Ideally equal and opposite signals are available at the ends of the loop's tuned circuit or of the pick-up coil. But the electrical noise (picked up by the wire in the loop acting like an antenna) is ideally the same in the two leads. Thus the differential amplifier magnifies the signal and attenuates the noise. It is also true that nulls are deeper and broader with a well-balanced differential amplifier since the signal is equal at the ends of the loop when the loop is turned to null a signal. Any "antenna effect" on the leads between the loop's tuned coil and the amplifier is cancelled out in a differential amp.

Both the single ended and the differential amp are suited for Direct Coupled Loops (DCL's) where the tuned circuit of the loop is connected directly to the amplifier input and there is no pick-up winding. Several schematics are available for loop amps (see IRCA reprints A8, A10, A17 and others) and all work well under the circumstances they were designed for. It is possible to connect an amplifier between a pick-up winding and the receiver (as in the Space Magnet or the 2' loop described in the NRC Antenna Reference Manual). If you use a broadband amp in this case, you run the risk of some shortwave bleedthrough in your signal. The preamp I use on my air core loop with one-turn pick-up winding has a nice constant frequency response through 5-6 mHz and I often get bleedthrough when I'm tuned to a frequency where nothing else is coming in.

Loops can be used up to about 4-5 mHz, depending on design. At this point the natural resistance of the wire and capacitance between windings determine the upper frequency limit of the loop. External capacitance will only serve to lower the tuning range.

There are two different types of air-core loop antennae. The box loop, with the plane of windings perpendicular to the cross arms, and the spiral loop, with the windings in the same plane as the cross arms. The box loop has greater inductance per length of wire than a spiral. However, the distributed capacitance of the spiral loop's windings is lower, which allows a broader tuning range for the loop's tuning capacitor.

Ferrite-core loop antennae are much smaller than air-core loops in general and consist of wire wound around one or more cylindrical ferrite rods. This winding forms a tuned circuit which resonates at the frequency of interest when paralleled with a variable capacitor. By rotating the rod about its center, signals can be nulled and peaked just as with an air core loop. Although the actual winding takes up much less space than an air core loop does, signal pickup is not that much diminished due to properties of the ferrite core. For more on ferrite antenna theory and construction, see IRCA reprints A9 and A10 both by J.A. Worcester and NRC reprint A24 by Jim Hagan.

Winding an air-core loop: Build the air-core loop out of wood, or some other non-metallic substance. Any substance, especially metal, will bend the lines of magnetic flux that go through the loop, and possibly skew up the nulls so that they are not 180° apart. Try to build the loop as geometrically perfect as possible, because symmetry also affects the nulls. Basically, any shape for a wood frame will do, square, wedge or even circular (the ideal shape). Size is also not too important, however between one and four feet on a side is the recommended range (see Table 1 as a guide). Smaller loops have better nulls, but larger loops have higher gain because the distance the waves have to travel across the loop is longer (difference is larger). The lack of gain on smaller loops can be compensated for with a good amplifier. So, a compromise must be made, though often space considerations dictate the size of the loop.

Table 1
--turns required for box loops using a variable capacitor with maximum capacity of 365 pF

length of loop's side in inches	14x14	16x16	18x18	20x20	25x25	30x30	35x35
spacing between turns							
1/4"	22	20	18	17	14	12	11
1/2"	--	--	23	20	16	14	12
3/4"	--	--	--	25	19	16	13

For the broadcast band, you will need about 120 feet of wire (or more) to wind the main winding, but it's always better to have more than necessary. Also required is two 365 pF variable capacitors or a 365 pF variable capacitor and a fixed capacitor of 200 to 300 pF (the second variable capacitor on a junk radio tuning capacitor will do nicely for this, if you can find one). As long as I am mentioning this, if you do look for a junk radio to get a capacitor, then try to find one with a vernier tuner on it, it will make it easier to "fine tune" your loop. Also, I might recommend using two separate variable capacitors over a single variable with two gangs.

Build the frame and make sure that the spacing on the windings is the same on all arms and that each winding is in the same plane on all but one side (preferably the bottom) for transition between turns. Do not use a vertical side of the loop for the transition as this will really mess up the nulls. Spacing between turns should be at least ¼". The greater the spacing the smaller the resulting inductance. Capacitance between turns is greater with smaller spacing. The trade-off point for most designs is between ¼ and ½ inch.

For the loop winding, use the largest diameter wire available. This cuts down on the total resistance of the system, which can affect the tuning frequency and the Q of the loop. 12 to 18 gauge is suggested. Stranded wire is recommended over solid due to its flexibility and ease of soldering. It also helps in construction of a geometrically perfect loop. Ever try to get 12 gauge solid wire straight? Insulated wire is better, as well as a good insulating material such as formica or bakelite to build the wire supports in the case of a box loop. This cuts down on losses in the loop.

Allow for enough turns to use up all of the 120 feet of wire. When the main winding is complete connect both ends to the variable capacitor, one lead to the frame of the capacitor and the other to the fixed plates. Next, add a one turn pick-up winding and connect the ends to your receiver. Then tune to a station near the top of the band. Adjust the capacitor until the station peaks (i.e. gets louder). You have now tuned the antenna to the frequency of the station. If you have adjusted the capacitor all the way open (i.e. unmeshed, which is the lowest value) and you have not peaked the station, try tuning to a station about mid-band (1000 kHz or so) and peak the antenna. If still no peak, try the lower band (600 kHz or so). If still no peak, then there are probably too many turns in the coil. Try taking off a winding, by unwrapping a single turn, but not cutting the wire, just cut through the insulation and reconnect it to the capacitor at that point. Try again to peak a station at the low end of the band. Repeat this process until the low band station is peaked. If you take off more than half the turns, the antenna probably tunes too high a range. Try more wire. This is not likely to happen; the reverse is more likely. When a station can be peaked at the lower end of the band, the loop is within a turn or two of being complete. Go back to the upper band station. Continue the peaking and unwrapping process until you can peak the upper band station. When this occurs, your antenna will probably be able to tune the range 800-1000 kHz to 1600 kHz+. To be able to tune the frequencies below 900, the second variable or fixed capacitor is used. Use a switch to connect and disconnect the second capacitor when necessary and wire it up so that the capacitors will be in parallel (parallel capacitances add). With this set-up (see figure 4) you should be able to tune the entire broadcast band. There should be some overlap between bands (switch open and closed). If there is no overlap (a dead spot) a smaller second capacitor is necessary. Once everything is working, cut off the excess wire, mount the capacitors outside the loop (they're metal, remember?) as close as possible without being inside the loop. I mounted mine in a 3 x 5 card box (adds shielding) with some holes drilled in the top for the wires to come out. Be sure to make good solder connections to the capacitors and switch.

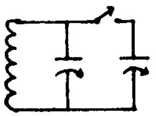


figure 4

Now you have to figure out a way to mount the antenna so that you can turn and tilt it. Building a stand similar to the one described in the "Wedge" loop plan (IRCA reprint A13) is my best suggestion. You can also use a Christmas tree holder and an old broom handle to which one of the cross braces of the loop has been bolted to so that it can tilt. Another idea, but somewhat on the expensive side is to purchase a microphone stand or something similar with a heavy weight on the bottom, and mount your antenna to it, substituting a wooden pole (non-metallic) for the final extension if you can. There is also the possibility of mounting the loop on your ceiling. Find a joist and attach the support "upside down" putting a nail through the dowel to keep the antenna from falling out.

Once the antenna is built and mounted it is then connected to the radio. It is important to keep the lead in as short as possible to avoid losses. Also ground any longwire input you may have in order to obtain best results with the loop. The output of the amplifier (if used) or the single turn inductive pick up is connected to the ground and antenna terminals of the radio. In the case of a spiral loop, the inside wire of the pick-up winding should be connected to the antenna input and the outside wire to ground. If your radio doesn't have antenna connections, several options are suggested. I'll start with the easiest. Wrap a couple of turns of wire around the radio as if adding turns to the radio's internal loop antenna. Or, even better, open up the set and wrap a couple of turns around the internal loop antenna itself bringing both ends outside the set either by finding a convenient hole or by drilling one (as close as possible to the turns). Hold down the turns on the internal loop antenna with nail polish, melted wax or whatever. In both the above cases attach both ends of the wire to the loop's pick-up winding or amplifier output. The longwire coupler described on page 49 of the **TG** should also work using the loop's output in place of the longwire and ground connections, but it means one more variable capacitor to tune.