Small HF Magnetic Loop Project

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For years I've wondered about small magnetic loop antennas. But somehow, they never really made sense to me. And most descriptions left me in the dark for some reason. Then recently a video by OH8STN (https://www.youtube.com/watch?v=Dw1rz0CVn90&feature=youtu.be) caught my attention and made sense. So, I decided to try to make one.

What is a Small Magnetic Loop Antenna?

Simply stated, for use on frequencies between about 9 to 30 mhz, The antenna consists of a circle of wire about three feet in diameter (ten feet in circumference) with the two ends connected across a variable capacitor forming a series resonant circuit. This resonant loop's circumference must be less than 1/10th of a wavelength at the desired frequency to be considered a small magnetic loop. The variable capacitor is selected to resonate with the inductance of the resonant loop over the desired

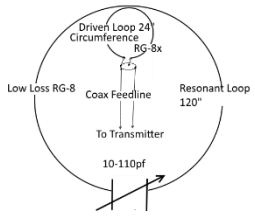

Figure 1 Antenna Diagram

Figure 2 My completed antenna

Figure 3 How the driven loop is positioned

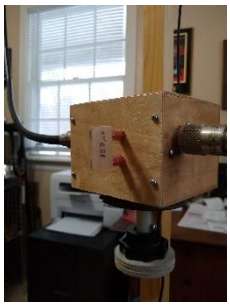

Figure 4 Capacitor Box Assembly

frequency range. Refer to Figure 1. The capacitor can be placed either at the top or the bottom of the resonant loop. I chose the bottom for ease of construction and tuning.

A simple way to connect the antenna to your transmitter is with a "driven loop" having a circumference of about 1/5th the circumference of the resonant loop, about 24 inches for a 10 ft. resonant loop circumference illustrated in Figure 1. Connect one end of the driven loop to the center conductor of the coax feedline and the other end to the feedline shield.

The driven loop is typically placed opposite from the capacitor. Since my capacitor is at the bottom of the resonant loop, I placed my driven loop at the top. A few inches of the driven loop should be adjacent to but not in electrical contact with the resonant loop. The coax insulation provides adequate separation. Figures 2 through 4 show my completed antenna. That's it!

Small magnetic loops are typically used standing vertically. They can be any height above the floor or ground. All my contacts, at five watts, were made with the antenna atop my camera tripod just a few feet off the floor and within arm's reach of my radio.

Small magnetic loops are directional, favoring the plane of the loop with nulls broadside.

Why would you want a magnetic loop?

My first CW QSO with my magnetic loop was on December 18, at 16:52z with NM1I, Butch, in Massachusetts using my Xiegu X5105 transceiver at five watts on 14.033mhz. He gave me a 339 and he was 559! The antenna was just breadboarded, sitting on a two-foot high stool up in our second-floor bedroom. See Figure 5. After having spent several days studying and breadboarding it, I badly needed motivation to keep working on it. The excitement of that contact provided the motivation I needed!

Figure 5 Breadboarded setup for my first contact in our second story bedroom.

I have since had 10 more QSOs with it. Three SSB and two CW on 40 meters. Three CW contacts each on 30 meters and 20 meters. All were at five-watts using my Xiegu x5105. For all but that first one the antenna was mounted on my camera tripod four feet off the floor of my ground level ham shack, shown in Figure 2.

For comparison, just after checking into MidCars on January 8th around 11:00am on 7.258 and getting a 55 signal report using the loop and my 5-watt x5105, I powered up my IC7000 and at 50 watts using my G5RV checked in again. Steve, N8TUW, the control operator both times gave me a 59 report this time. Distance was 360 miles. Just to double check I went back to the loop and x5105 with the same report as before.

The ground or floor level operation is the most remarkable part of the magnetic loop to me. Almost all my HF contacts throughout my 60 years in ham radio have been with outside antennas! How can this thing work standing on the floor right beside me?!

So, why would you want a magnetic loop? For me the initial reason was curiosity. Would something that small, used at ground level actually work? I'm now convinced that the answer is yes! How well is always a subjective question with any antenna. But it works well enough to totally surprise me. Mind you, I have not taken down all my other antennas yet!

But it has once again given me the thrill of a "first contact".

Where to start

Start by deciding on your desired frequency range. A 3-foot diameter resonant loop is reasonable for 20, 18 and 15 meters and it can be used down to 40 meters and up to ten meters. I recommend the calculator at http://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx to see how the length of the resonant loop affects the antenna's performance.

Next, decide what you will use to make the resonant loop itself? I used a 106-inch piece of low loss RG-8 sized coax with PL-259 connectors on both ends because I had it available. Other options to consider are ½ or ¾ inch or larger copper pipe, or even aluminum flat stock about 1/8 x 1 inch or larger. The larger the cross-section of the material you use, the higher the efficiency according to the calculator mentioned in the previous paragraph.

Next decide on a variable capacitor. The bandwidth of a small magnetic loop is very narrow as figure 6 shows. A variable capacitor is essential. When choosing a variable capacitor there are some things to consider in addition to capacitance.

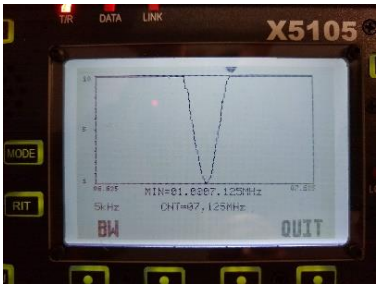

Figure 6 SWR bandwidth on 40 meters

At 5 watts, RF voltage across the capacitor is about 650 Vrms. At 100 watts, the voltage rises to 2,900 Vrms! Potential arcing across the plates of the capacitor is a concern. So wider plate separation is needed at higher operating power levels. In some cases, you may even need a vacuum sealed capacitor. I am only running 5 watts, so the plate separation of a standard variable capacitors seems to work fine.

Capacitance range of the variable capacitor will affect usability. Figure 7 shows the breadboarded capacitor setup I used for that first 20-meter QSO. That capacitor, out of a retired MFJ antenna tuner, has a range of 15-340pf.

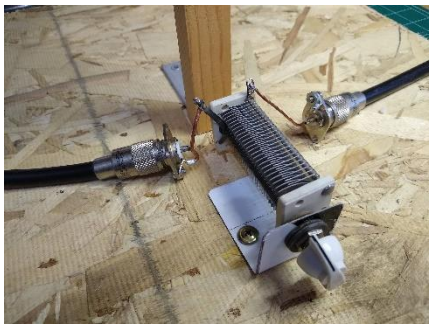
Figure 7 Breadboarded capacitor for first contact

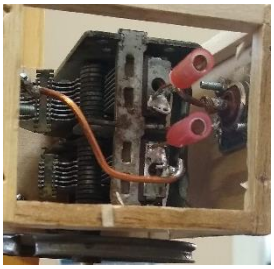
Figure 8 Broadcast Capacitor

The one I am using on my final antenna design shown in Figure 8 is from an old broadcast radio with narrow plate separation with a range of 8-118 pf. With my loop configuration it tunes the resonant loop on 30, 20 18, 15, 12 and 10 meters. And by adding a 156pf fixed capacitor in parallel with the variable capacitor it will also tune 40 meters. See Figure 9.

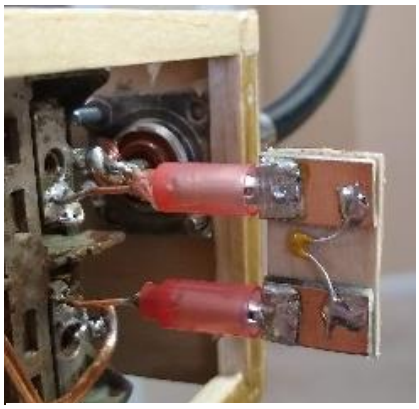
Figure 9 156pf capacitor assembly plugged into jacks shown in Figure 8

Another consideration, when selecting a variable capacitor is rate of capacitance change. Since the antenna's bandwidth is very narrow, a capacitor like the 15-340pf one shown in Figure 7 which I used with my breadboarded antenna is impractical. A very small movement of the rotor changes the resonant frequency a lot making finding your frequency tricky. A reduction or gear drive would help considerably.

Some hams connect a small-range variable capacitor, 2-50pf or so, in parallel with their main capacitor to use as a Vernier. You get close to your desired frequency with the main capacitor, then tweak it with the Vernier. I tried that and decided I could live without it because the narrower range of the 8-118pf variable capacitor on my final antenna is much less sensitive.

Related to rate of capacitance change, is tuning knob size. The larger the tuning knob the easier it is to make very small changes. My two-inch knob described later works well with my capacitor.

Hand capacitance is a potential problem so you may need to attach a plastic extension shaft between your capacitor and tuning knob to keep your hand away from the capacitor when adjusting the resonant frequency.

Finally, regarding the capacitor, a significant source of loss in the resonant loop can be the wiper contacts of your variable capacitor! A simple solution, if you have a dual section variable capacitor, is to connect one end of your resonant loop to one stator section and the other end to the second stator section. The common rotor then connects the two sections in series capacitively. No moving contacts are in the RF current path eliminating all contact loss! See Figure 10.

Figure 10 Capacitor Sections Connected in Series

Lastly, decide how you are going to build the antenna? The main fabrication challenges are making the two loops and mounting and connecting the resonant loop to the capacitor. Making the Resonant loop itself was simple in my case because I already had that piece of RG-8 coax with PL-259s. If you use copper pipe or aluminum strap you will need to bend it into a circle or octagon. The calculator mentioned above (http://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx) gives measurements for an Octagonal loop. You will also need to figure out how to connect the ends of your loop to the variable capacitor as losslessly as possible. Direct soldered Connections are preferable.

If you use a piece of coax for the resonant loop, you'll need to solder the shield and center conductor together at both ends so it functions like a single large conductor. If your coax does not have connectors, simply remove some insulation and solder the shield and center conductor together on each end before connecting to the variable capacitor.

Since my RG-8 coax had PL-259 connectors on both ends, I decided to connect the shield and center conductor together by soldering heavy wire between the mounting flange and the center pin on the back side of both chassis mount SO-239 connectors. See Figure 11.

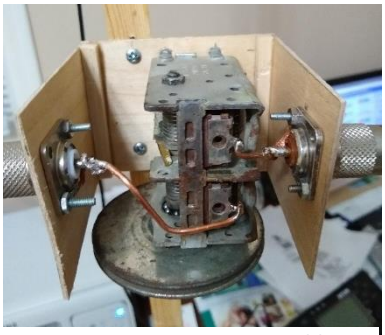

Figure 11 Capacitor Box Assembly

To house and mount my variable capacitor to the mast and connect the resonant loop, I fabricated a small wooden box assembly using thin plywood and balsa materials from my RC plane building hobby. See Figure 11. A plastic box would be a good option. If you use a metal enclosure, the two SO-239s and capacitor must all be isolated from each other and the metal box. My wooden box, as would a plastic enclosure, made that easy.

Figure 12 Driven loop connections to feedline

For my driven loop, I used a 21-inch piece of RG-8x with the center conductor and shield soldered together at both ends. I then connected each end respectively to the ground and center pin of a BNC jack to which the feedline is attached. I fabricated a small bracket of aluminum to which I mounted the BNC jack and two machine screws for the solder lugs on the ends of my driven loop. See Figure 12. I insulated the mounting screw for end of the driven loop that connected to the BNC center pin from the bracket with a couple nylon washers.

Figure 13 Notch at top of mast for loops

For the mast I cut a one-inch strip, 40-inches long from a 1x6 pine board. I then cut a notch in the top end of the mast about ½"wide and ¾" deep to allow both loops to fit into the notch. That allows me to simply hang both loops on the mast. See Figure 13.

Figure 14 Capacitor Box Assembly mounted six inches from the bottom of the mast

I mounted the capacitor box assembly about six inches from the bottom of the mast with wood screws as shown in Figure 14.

Figure 15 Nylon coupling and knob assembly

A nylon coupling, short plastic shaft and knob on the variable capacitor shaft eliminate hand capacitance effects while tuning.

To make a larger knob, I sandwiched two 2-inch self-sticking felt furniture pads together and then stuck them to the face of the knob which provides an easy grip and makes tuning easier. See Figure 15.

Figure 16 L-bracket for mounting to the tripod

To connect the mast to my camera tripod I attached an L-bracket to the mast with wood screws with a ¼-20 nut slightly embedded into the lower end of the mast, held in place by the L-bracket foot. The nut accepts the ¼-20 camera mounting screw on the tripod which holds the bracket snugly in place. See figure 16. Your tripod may require a different way of attaching the mast. My camera tripod is not rugged but works and easily allows me to rotate the antenna.

To assemble the antenna once the mast is on the tripod, I top of both the resonant and driven loops into the slot in the top of the mast. Then I screw the PL-259 connectors on the ends of the resonant loop to the two SO-239 jacks on the sides of the box stabilizing it securely.

Finally I just attach the BNC terminated coax feedline from my transceiver to the BNC jack on bottom of the driven loop and let it hang suspended along the mast from the BNC connector as shown in Figure 3. I use RG-143 coax to keep things light weight.

Wrap up

In doing my initial research and as the project progressed I found the calculator at http://www.66pacific.com/calculators/small-transmitting-loop-antenna-calculator.aspx indispensable. It provides good ballpark physical measurements and values. I also found the YouTube video by OH8STN (https://www.youtube.com/watch?v=Dw1rz0CVn90&feature=youtu.be) very helpful, as well as an article by KF5CZO at http://kf5czo.blogspot.com/2012/02/diy-magnetic-loop-antenna-part-1.html. Another helpful resource is AA5TB's article at http://aa5tb.com/loop.html. Finally, thanks to Jerry, N9AC, Carl, AF9L and Gary, KD9KHI, friends who live nearby, for their constructive comments and editing.

My conclusion is that a simple, junk box DIY three-foot diameter magnetic loop is a practical, interesting, useful and enjoyable antenna. It's probably not a replacement for your base station dipole, G5RV, vertical, or whatever you use. But it can get you on the air in situations where other options are not at hand. And I get a real thrill every time I make a contact with this thing sitting right beside me using 5 watts. My intuition says, it shouldn't work! But it does! So, don't be afraid to try making one.

If you want to see all the gory details of my build, go to https://www.huyettm.net/magnet-loop.html.