Helically Loaded Magnetic Loop Antenna

Object of the design:

There are many designs and information available on the net concerning **"Magnetic Loop Antennas".**

Even though these antennas are a fraction of the size of a full size resonant antenna, size of the lower frequency loop can still be quite large for a limited sized property. The object of my design is to compact the size of a magnetic loop while trying to maintain the efficiency of the loop.

Theory of Design:

Anyone that has delved into the theory of magnetic loops knows that smaller size loops result in very poor efficiency at lower frequencies. A magnetic loop for the 80 meter band should be 15 ft diameter to produce efficiency of 88%. Using a 3" diameter copper pipe at a 15 ft diameter will only produce a 7Khz band width. This band width requires very precise tuning.

By implementing a helically wound design a 6ft diameter 80 meter text book loop seems to emulate a 10 to 15 ft diameter loop of a single conductor. The 80 meter bandwidth of my 6 ft loop is 11Khz. The loop construction technique provides for light weight and cost as compared to a 15 ft loop constructed from copper tubing. This

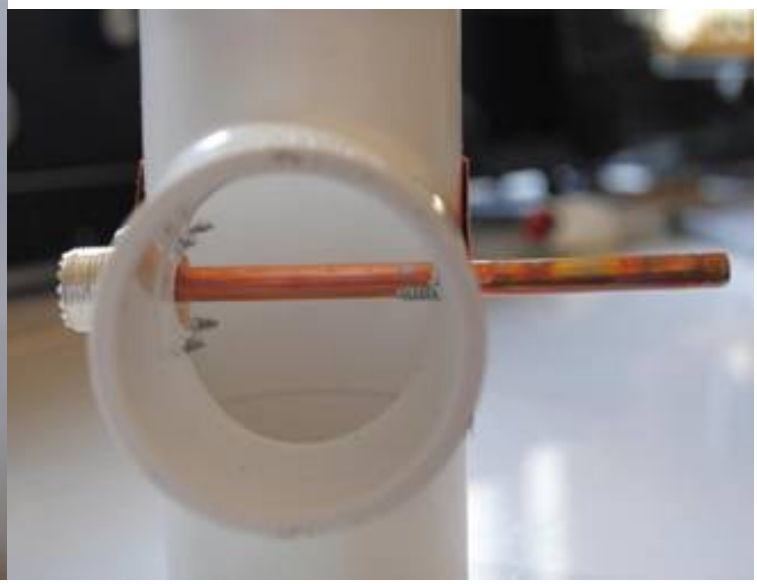
design has been accomplished by using just enough copper to take advantage of “Skin Effect”. This allows the use of a thin flat copper conductor which provides more surface area then a heavy copper pipe while still providing a large surface area of RF skin depth. At the same time the radiation resistance is raised considerably while only raising the IR losses slightly. The ratio of Radiation Resistance to IR losses equals the efficiency. The use of PVC tubing and flat soft copper strap provides a sturdy substrate in which to wrap the soft copper strap while increasing inductance for the same circumference as a substantially larger loop. The result is a two part gain; the same length of copper conductor that is required for a 10 ft diameter loop equates to similar performance wound on a 6 ft diameter substrate; thus reducing the size, weight and cost while still retaining the performance. These miniature loops for bands as low as 80 meters have now become such a small footprint that they can be employed in an HOA situation even if hidden between foliage. There are still a few factors that I have not calculated yet. The use of loading and the distributed capacitance somewhat adds a mysterious factor to this design. I am still working out all the details. The apparent efficiency and the large increase in Band Width tell the story. My actual “on the air testing” has depicted better results than I could have imagined. So far my “seat of the pants measurements” has shown a great increase in the tightness of the doughnut pattern shape. The approximate 4 degree very sharp null I am seeing to near E field noise seems much tighter then my previous single conductor loops. I have also noticed from many signal reports that I am experiencing as much as 3 to 4 S-units increase/ decrease in signal strength by rotating the antenna with distant stations. This seems to be more apparent depending on the angle of radiation being utilized at the time of contact. There may possibly be more horizontal radiation off the side then a normal single conductor loop; this is just theory for explanation at this point. The reason that I am theorizing the polarization is due to the fact that I have seen stations get much stronger broadside while I other stations get much stronger in the plane of the loop. Text book magnetic loop theory states stronger in the plane of the loop. This is definitely the case for ground wave stations; I have tested this in depth with great repeatability. I can get a 3 to 4 S unit change at 20 miles on the 20 meter band, the signal will just about completely null broadside to the loop.

Details of building this design:

The Hi-Res photos that I am attaching to this article will depict more than can be described, thus I will not go into great detail.

Starting with the PVC octagon frame, calculate your PVC parts by the size of the loop desired for the particular frequency range. View my photos carefully to observe how to mount the SO-239 connector; do this before gluing any frame parts.

Use a hard temper piece of copper flashing for the underlay of the SO-239 connector. Soldering this connector as the photo shows is important. The photo also depicts how the center feed from the SO-239 was routed thru the PVC- T. Finish this part carefully before any gluing. Use a short length of ¼ inch copper tubing to follow thru the PVC T for stability of the connection. If this connection breaks after gluing the frame you will be in trouble! Fill the short length of tubing with solder then heat it a push it over the center conductor of the SO-239 and heat generously. The other exiting end out of the PVC T will then be supported by the T itself, this makes for a very strong connection point.



Use cleaner and good glue and glue the frame together, use ingenuity when assembling the frame as to what parts to glue first. Once the part is glued and it isn't

right it will be very difficult to correct.

Make sure to use both good quality PVC cleaner and Cement for good bond which will provide stability of the frame. The frame will need about 3 coats of high quality Krylon spray paint. I use flat black as it hides well, Krylon makes a spray paint for plastics; this is the one that I recommend. If you do not paint the frame the PVC will deteriorate fast especially in the western state where I am located. The next generation of prototype will use a plastic protective paint on the substrate and a clear lacquer coating over the copper for corrosive protection.

Now it's time to wrap the frame, this part is a bit tricky the first time you do it. The rule that used to build both prototype loops was adding 37.5 % of conductor length to the amount of conductor required for a single turn loop. Credit is given here to **"AA5TB"** the work on a great loop calculator. AA5TB calculator has been very useful to speed up calculations, I have compared it to hand calculations, it is very exact; just search the net for his Excel program. Plug in all the factors for the loop that you want to build and follow my rule for length of conductor. Use the width of the copper strap X2 in place of the circumference (diameter X 3.14) the formula requires diameter. Divide the calculated length of the conductor in half, and mark the center of the length. Start the wrapping at the marked center at the SO-239, pay close attention to the pitch of the material. Again some ingenuity on calculating the wrap spacing is necessary here. Make sure that the two ends of the material come out even at the capacitor/tuner feed point. If care is not taken here you will have an unbalanced loop. Once the loop is wrapped and if it came out even, then temporarily tape the ends in place while you solder the center of the flashing very carefully to the so-239 supporting foil.

Capacitor & Drive Motor Assy:

The tuning capacitor is one of the most critical devices in this build project. Choosing to use anything but a good quality vacuum variable capacitor will result in substandard performance compared to the results claimed in this prototype antenna. First issue is power handling, my loops handle SSB full legal limit (1500wts), and are rarely run at more than 1Kw. To keep the Q high and power capability high use a vacuum cap otherwise the results will probably be disappointing. Humidity will also play a role in affecting your antenna by using an air capacitor. I am using a 12 volt gear reduction motor with a forward and reverse controller arrangement. The down side is the long times required to change bands. The reductions need to be slow for precise tuning, thus a single speed geared motor is not the best solution. My next prototypes will utilize a stepper motor control system which is currently in development. Utilizing a stepper motor control in conjunction with a PIC or other small processor board the speed can be controlled enabling quick band changes, and then use a system of fine tuning buttons to move about the band of operation.

Tuning unit mounted in the operating position.

Great care must be taken with all connections; every milli-ohm gets multiplied in the main conductor will be subtracted from the total radiated power. This results in lower antenna efficiency. All overlapping joints in were tinned on the underside, and then quickly heated with a torch. After cooling they were all soldered using a very hot iron all around the copper edges. Try not to leave any sharp edges, there can be 15 KV at the area around the capacitor connection; some corona arching could happen at sharp points.

The Gamma Match:

Several different matching techniques have been tried, most worked although

negligible difference was noticed using the simple gamma match. The gamma match also seems to be the flattest match across the entire tuning range. Once tuned to the center of the tuning range of the loop design the match appears to hold a flat match of < 1.2 to 1 @ 50 ohms across the range. It will be the farthest off at the lowest band. It takes a bit of experimentation to get it perfect. Both loops are 1:1 @ 50 ohms except on the lowest designed band; there it may be 1.2 or 1.3 which is negligible.

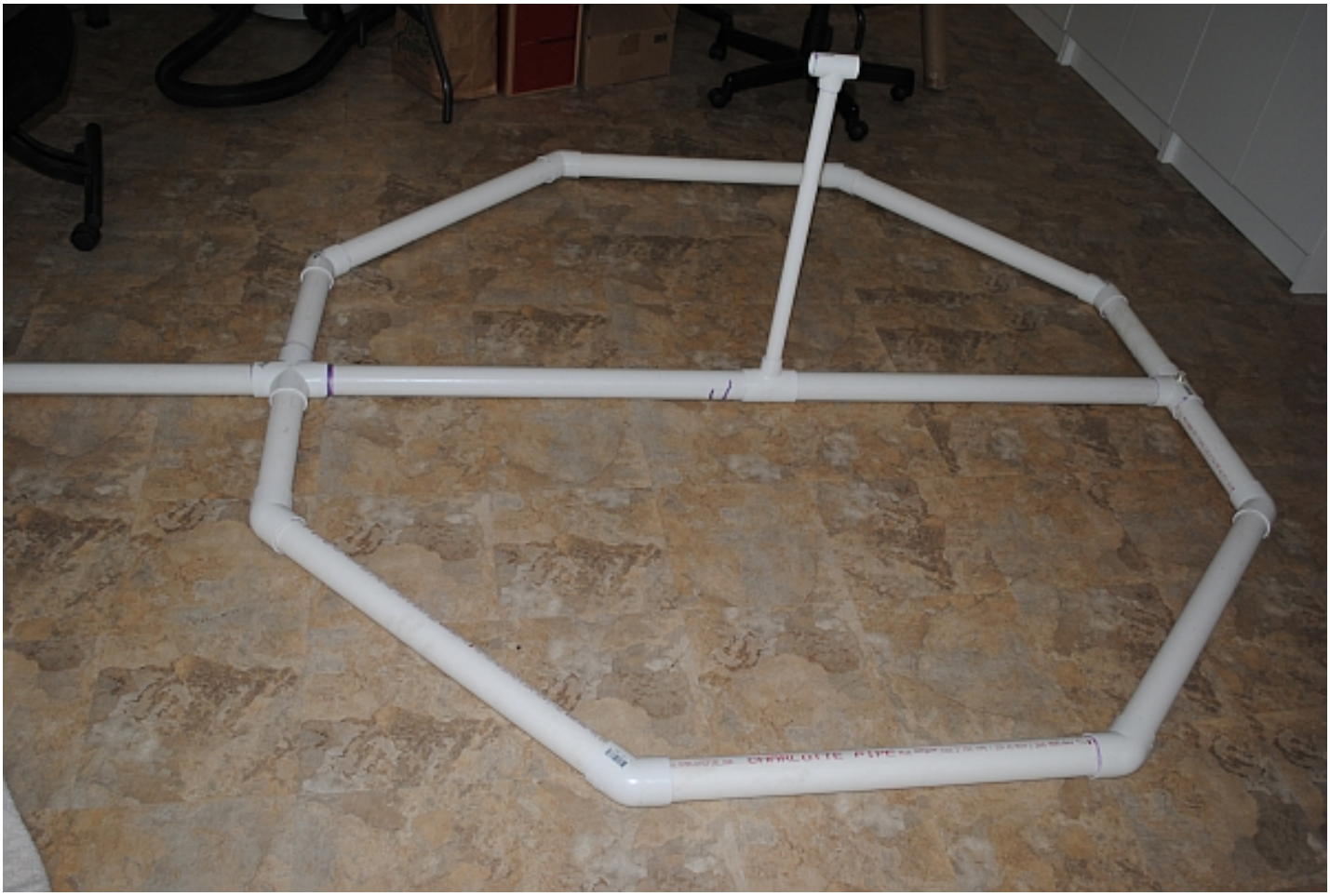
If you tune your loop in the horizontal position, do not solder it in place until you mount it in the operating position complete vertical plane. Just use a SS hose clamp fastener to get the match, when you are satisfied then solder it to the foil and clamp over it to keep it secure. The 80/40 meter match proved to be twice as long until I mounted it in the vertical operating position.

Match was 1:1 @ 50 ohms here, DO NOT SOLDER YET!

Rear view of gamma match in operating position, indicating how the SO-239 connection exits from the rear of the PVC T

Front view of gamma match soldered in place; 1:1 @ 50 ohms

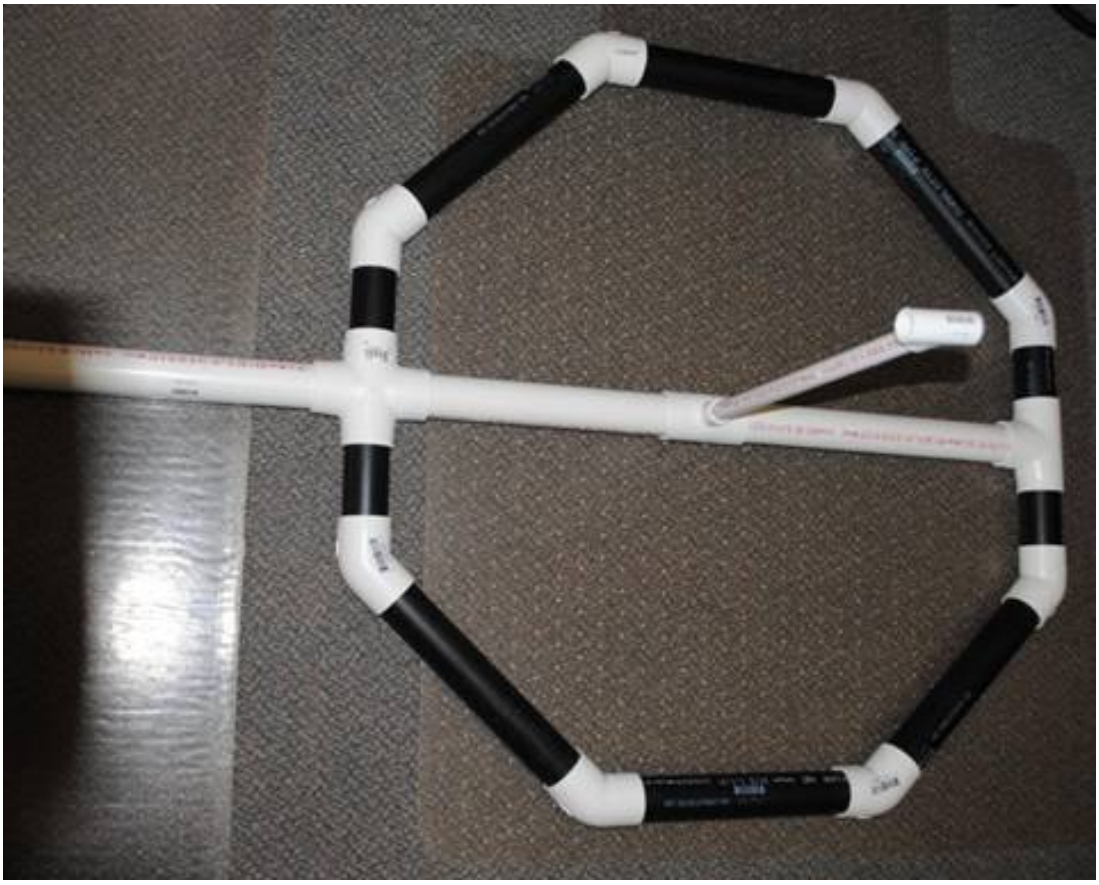
More photos of construction in progress



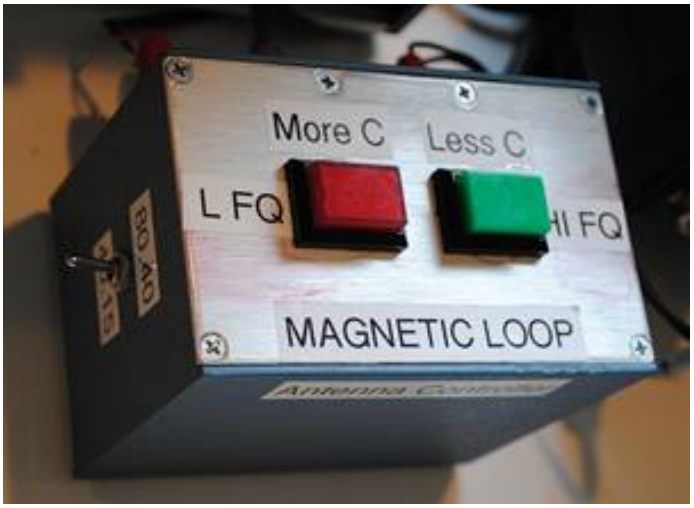
Gamma Match –

20 thru 10 meter loop

20 thru 10 meter loop under construction, this one will be painted after finished




1-1/2"
WWW.CHARLOTTEPIPE
32



Loop Controller, controls both loops with side switch

Finished 20 thru 10 meter loop ..... Just needs paint

Parts list

Copper foil/flashing: **3 inches wide X .008 thick (8 mils), Soft anneal.**

Less than 8 mils will cause heat loss resulting in poor efficiency. Efficiency is the ratio of Radiation Resistance to IR losses. Material that has a large RF Skin area is required while still thick enough to handle VERY LARGE circulating currents. Unfortunately this is hard to find and very expensive in small quantities. I have found that suppliers do not want to deal in the lengths required. I have had to purchase large quantities of this material to get cost effective. Please email me if you need options for the copper flashing.

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PVC: **2 inch schedule 40 PVC has approx 2.25 inch OD.** This size is required for the 80/30 meter version. The diameter is required to achieve the necessary inductance of the overall loop diameter.

Vacuum Capacitor: At least a range of 10 pf to 250.

If you use the loop formula it will indicate that you need more "C" but the helical winding brings that capacitor value down. **To be safe I would purchase 10/300pf version.** A 10 to 500 pf version could be utilized in case you might want a larger cap for future development. More precise control will be realized with the 10/300pf using my helical wound design. The ratio of capacitance to the gear ratio of capacitance to turns will smooth out fine tuning. **The voltage rating should be 15 KV @ at least 40 to 50 amps.** Many of the Vacuum Capacitors especially surplus units are drastically under rated. Some are capable of double the posted rating. Check this out with the supplier. 15 kV is possible across this capacitor running 1KW. If a 25 KV version can be located, it would be the best choice. The SSB or CW modes and respective duty cycles actually allow the use of smaller KV values. If you plan on running key down, AM or high power digital modes you may want to reduce your power output to 500 watts continuous.

Tuner Mounting Board: An inexpensive easy to purchase material is a cutting board from Walmart. About 7 to 8 dollars can buy a durable cutting board that is a very good insulator (White/opaque) in color. It can easily be cut down to size to mount the motor/drive system and capacitor.

Capacitor Clamps: Use some ingenuity here depending on the type of Vacuum cap that you acquire. As can be seen in my photos electrical conduit clamps are used on one unit. Care must be taken that the clamps are very tight and making a very positive connection; the use of copper flashing in between the clamps and the cap just to make

sure.

Drive System: In viewing my photos it can be seen that a geared 12 volt DC motor, reversible. If this your choice a means of keeping track of position in the range of the capacitor is necessary, if care is not implemented here you will either jam the cap to one end or unscrew the shaft at the other end depending on the cap construction. Utilizing ingenuity/design limit switches can be employed in the control circuit. There are Magnetic loop sites on the net which have accomplished this method. I just keep track of the band of operation, I have never dead ended the system yet but that is me; this is not the recommended way to travel. This was my prototype version; I am currently working on stepper motor controls for fast and precise tuning. Keep in touch with my web site and I will post updates.

SO 239: Pay attention to my instruction and photos on how to mount the SO-239, once the PVC is glued together it will be difficult to repair.

Radiating the Cows! Hi Hi.....

The author/ Designer Rich K8NDS

Thank You for reading the article.

I hope that you have as much fun with these stealth antennas as I have had. It is a way for the HOA restricted Amateur operator to come very close to the performance of full size antennas.

Please look me up if you want to see these antennas in action, I think you will be quite surprised at the functionality of these small antennas. Many on the bands have heard these already and have stated how good the signals were..... in amazement!

You can find me whenever I am active on the bands by visiting QRZ.com and look up K8NDS

Then just click on "MY QSX" link

It will take you to my page where you can see what frequency that I am talking/listening on. Many have already done this. You can also view your own signal

strength there while you are transmitting.