The Plastic Fantastic: a Magnetic Loop costing around $54 for 40 metres

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Introduction

As previous articles in *AR* will show, I have long had an interest in magnetic loops. However, transmitting loops have a number of disadvantages, not the least of which follows:

a. Very low radiation resistance. In comparison to the nominal 72 ohms of a dipole, magnetic loops have radiation resistances of typically between 10 - 80 milliohms making them very sensitive to losses in the loop conductor, tuning capacitor and any joints in the system. For efficiency, losses must be kept in the milliohm range meaning that the loop conductor should have a large diameter, be an excellent RF conductor and have a very smooth surface finish. For reasonable efficiency, the loop circumference should also lie between 10-20% of the operating wavelength.

   Because the operating Q of this resonant system is so high (typically 500 – 1500), the circulating currents are huge. With 100 watts of input to the loop, circulating currents may be 30 – 60 amps. This leads to very high voltages across the tuning capacitor at resonance (3 – 6 kV at 100 watts) and substantial heating effects in loss resistances. Unlike the dipole, the SWR bandwidth is very low and the antenna in this article is just 15 kHz wide.

b. Because the circulating currents are so huge, standard variable capacitors with their wiping contacts to the rotor cannot be used. Losses in these contacts will ruin the antenna efficiency and generate enough heat to certainly damage such contacts and maybe even weld them. Special and expensive capacitors are thus required, with large plate separations for the high operating voltages. Split stator variable capacitors are one possibility, where the current enters the capacitor via one set of static plates and passes to the other set of static plates via the moving plates and shaft. Vacuum variable capacitors are also very useful. However, such special forms of capacitor also have disadvantages. To

Photo 1: The completed magnetic loop.

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completely cover a particular amateur band (say 7 – 7.3 MHz), a capacitance change of around just 8 % is required. This makes tuning very twitchy because of the very narrow SWR bandwidth of the loop. A split stator capacitor must only move through 15 degrees total to cover the total band while a vacuum variable only has to move through around two turns of its 32 possible turns. These simple facts make it obvious that normally a magnetic loop is optimally a monoband device with most of its tuning capacitance probably being in fixed form with a small “band-spreading” variable capacitor to tune across the band. Either that or the drive to the tuning capacitor must include a high ratio gear box.

General

So, all this was in the back of my mind when Hans VK5YX gave me a short sample of plastic pipe used for the standard household reticulation of gas and which he believed would be a good material for loop construction. This is interesting stuff, made by a number of manufacturers and available at Bunnings under the trade name *“Gastite”*. It comes in 16, 20 and 25 mm diameters, in 1.2 metre straight lengths and in 6 and 20 metre rolls of around 500 mm diameter. It consists of three layers; an outer layer of clay filled yellow high density polyethylene (HDPE or PEX) which is UV proof, a 0.3 mm thick layer of aluminium (to protect the enclosed gas against nearby lightning strikes) and a 1.4 mm thick inner layer of extremely high quality HDPE. These three layers are held together with some form of thin diabolically good glue having extreme tenacity.

Skin depth in aluminium at 1.6 MHz is around 52 microns meaning that the 0.3 mm aluminium layer has six skin depths of thickness at this frequency. So, this pipe is perfect for RF conduction from 160 metres to well beyond the very top of the HF band.

But aluminium………. The sample sat on my workbench while I pondered how best to make a very low resistance connection to this thin layer. Hans had indicated that he was going to use the pipe as the loop conductor and somehow join it to a vacuum variable capacitor to make a multi-band loop. Being the sort of guy he is, doubtless this will occur and will work very well indeed. It may even end in an *AR* article.

However, in a light bulb moment I suddenly saw how to make a cheap mono band antenna. If I could just find a piece of copper pipe to fit inside the plastic pipe, I had a very high quality variable capacitor. And indeed, standard 0.75 inch diameter copper water pipe fits beautifully into the 25 mm dia. plastic pipe with around 0.4 mm clearance. The capacitance of the two pipes works out at 624 pF per metre. Some work with a magnetic loop calculator indicated that a loop of around 5.2 metres perimeter (6 metres less a guess at the length of the capacitors) would require around 117 pF to tune it to 7 MHz and that the self -capacitance of the loop would be around 14 pF. So, two 206 pF capacitors in series (a trombone capacitor) would be required giving a capacitor length of around 330 mm.

And there it was: an aluminium loop with no physical connection between the loop conductor and tuning capacitor. It would be

Photo 2: Stripping the end of the plastic pipe.

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Photo 3: The trombone construction.

ultraviolet proof, easy to waterproof, easy to build and the precious smooth surface of the loop conductor would remain perfect for many years without having to polish it, plate it and/or powder coat it.

Making the loop

The first thing is to find a 6 metre long coil of gas pipe at Bunnings which has the two ends as nearly straight as possible. Ratting through their stock will save much effort in trying to straighten out the pipe ends over the two 360 mm lengths required to accommodate the trombone capacitor. Also buy one length of their straight 1.2 metre long 0.75 inch diameter copper pipe.

The plastic pipe is straightened to its required cardioid shape by hand. Note that the aluminium sheath has already been considerably work hardened by coiling the pipe for sale. Further working of the aluminium layer should be minimized to avoid further work hardening, possible cracking and rise of its RF resistance.

Before you do anything cut 500 mm off one end of the 1.2 metre length of copper pipe. Carefully round and smooth the four ends of the copper pipes and their outside surfaces so there are no burrs.

Slide one of these smooth pipes into the plastic pipe and proceed to straighten out at least 360 mm. Do this slowly in small lengths, advancing the copper pipe as you go, to keep the shape of the plastic pipe circular. Repeat for the other end of the plastic pipe using the other piece of copper. Continue any straightening until the copper pipe slides smoothly within the plastic. Leave the copper pipe inside the plastic pipe for the next operation.

To avoid flash-over between the aluminium layer and the trombone capacitor inner, both ends of the plastic pipe must be stripped back of both the yellow plastic and aluminium layers for about 10 mm. Warm the end of the pipe to around 70 C (an uncomfortable hand temperature) with hot air gun and cut three quarters the way through the depth of the outer layer with either a sharp knife or a pipe cutter, right around the circumference of the pipe. Then make a 45 degree cut from this circular cut to the very end of the pipe. Warm the pipe again to slightly loosen the hold of the infernal glue and strip off the plastic by grabbing the V end of this cut with pliers and rolling off the outer plastic. Repeat the same process with the aluminium layer being very careful not to damage the inner layer of high grade HDPE.

Leaving the two copper pipes in position, hand straighten the remaining plastic pipe so that most of its length forms a circular shape. The two straight lengths of pipe forming the capacitor are connected to the main loop circle by two 90 degree bends. These 90 degree bends should be left at the same radius as came on the original roll to avoid further work hardening.

Make up the trombone capacitor inner, which is fabricated from two 385 mm lengths of copper pipe, two 90 degree copper elbows and a short length of pipe to join the copper elbows together at the capacitor bottom. Everything is soft soldered together with a gas torch or hot air gun, after all parts have been brought to a clean shiny super smooth surface with steel wool. The two tubes must be closely parallel in two planes for the trombone to work properly and some careful jigging with timber and clamps before soldering will be necessary.

My loop was mounted on a cross made from two 1.8 metre lengths of 42 x 19 mm pine. To retain the loop on the cross, I made up some very simple clamps from this same timber. I drilled centrally through the 19 mm thickness of this timber with a 25 mm spade bit, and then drilled a further two 4 mm holes for mounting screws on either side of

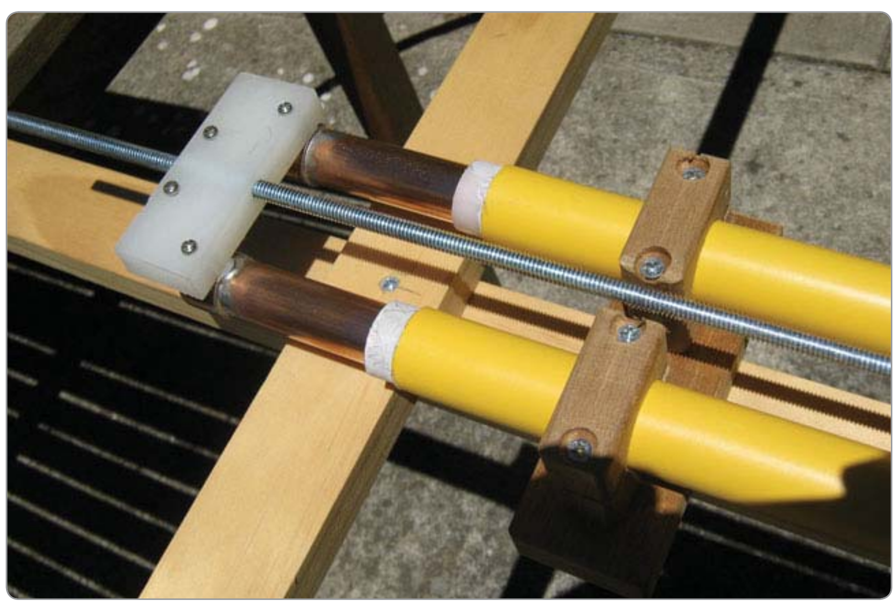

Photo 4: Close up of the timber clamps.

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Photo 5: The copper wire driving loop.

the 25 mm hole through the 42 mm timber width. This fabrication was then cut into two halves on a table saw to make the clamp. This kept the loop conductor circular while providing a very good grip indeed.

The main loop was excited into resonance with a small driving loop of 330 mm diameter placed at the bottom of the main loop. I just used very heavy copper wire (around 4 mm diameter), but the driving loop can be fabricated in a considerable number of ways. RG8 and RG213 can be used to form Faraday shielded driving loops which have noise pickup advantages in bad locations – see the net for the variants but particularly the excellent paper by Leigh VK5KLT on the Adelaide Hills Amateur Radio Society website (*www.ahars.com.au*)

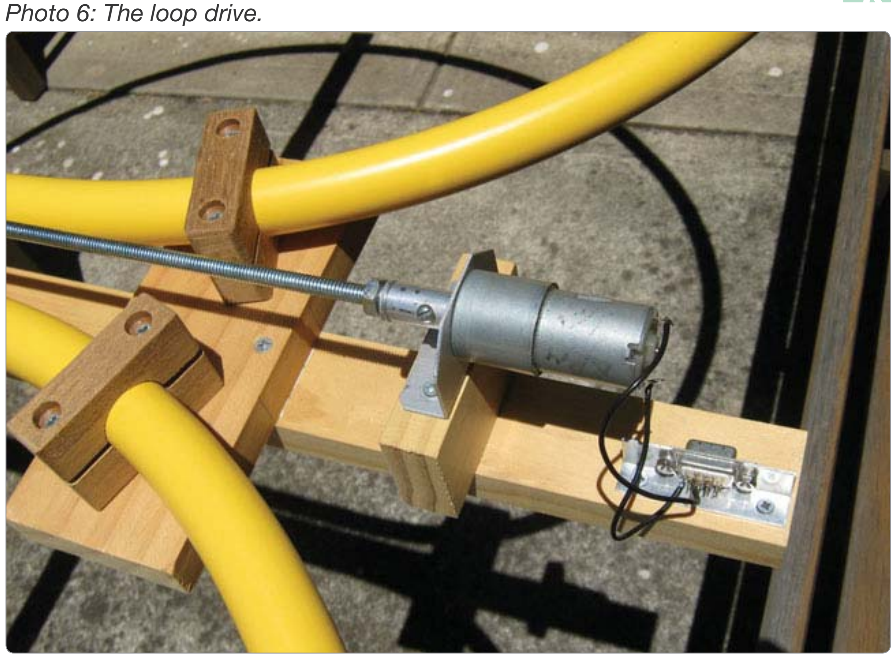
An SWR of very close to the perfect 1:1.00 can be obtained by adjusting how much the coupling loop overlaps the main loop conductor or by squashing its circular shape. About 5% of the coupling loop diameter on my antenna overlapped outside the main loop conductor and the SWR was less than 1.02 across all of 40 metres.

The operating height of the loop is selected so that the bottom of the loop is at least as high as the nearest tin fence. So, 1.8 metres or more with large heights offering very little extra. The field intensities around such a loop are much higher than would be found around a dipole and caution should be exercised. There are calculators around which give safe working distances. When the loop is operating at 100 watts, I personally would not go closer than say 5 metres, even for very short times. In short, do your RF safety homework, as required by the ACMA.

Finally comes the question of loop drive. Overall travel of the trombone capacitor to cover the 300 kHz bandwidth of the 40 metre band is some 30 mm. This gives some 10 kHz per mm. If a screw thread of around 1 mm pitch is used to drive the trombone cap (Bunnings 6 mm diameter X 1 mm, or ¼ ” BSW 24 TPI threaded rod) , this means that each one degree of rotation of the screw thread corresponds to around 28 Hz of frequency change. This gives tuning which is stunningly less critical than the much more expensive vacuum variable or split stator capacitor. If a stepper motor is used with 200 steps/rev., each step corresponds to 50 Hz. I used one of the small geared motors to be found at Jaycar, but these have some end float in the shaft which must be carefully shimmed to avoid tuning hysteresis. A stepper motor with a ball race mounted rotor is a much better proposition but is more complex to drive. I can provide details of the geared motor drive if required, but I leave this area of construction to the true experimenter. Last, the trombone capacitor can be simply water proofed by providing two skirts made of duct tape or similar at the two ends of the loop.

Have fun…..these are a great DX antenna.

Photo 6: The loop drive.



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