Charles Riley's

antenna workshop

A small transmitting loop for 10MHz – and the adventures behind it!

Charles Riley G4JQX describes the ideas behind a small transmitting loop for 10MHz – a WARC band that shouldn't be ignored!

Let's take a look at the project's concept – electrically small loops, that's to say a loop that is less than 0.1 wavelength long, have been around for many years – but not many people build them. The usual reason for not doing so, is that loops are "difficult" and have high voltage potentials making construction very specialised. This is unfortunate, as with some ingenuity small loops can be excellent performers on the short wave bands.

The main problem is trying to find solutions to some of the constructional problems that loops present without getting involved in complex engineering challenges and needing to make considerable financial outlays.

Electrically small loop antennas are very simple and very effective – the loop is essentially a parallel tuned circuit – with an inductor (the loop) acting as a radiator and a capacitor is used to tune the loop. The best known version is the 'Army Loop' originally designed for US Army deployment and introduced to the Amateur Radio world by **Lew McCoy W1ICP** in 1968. Various versions have also been introduced through the years – the **Ted Hart W5QJR**, "high efficiency" loop in 1986 amongst others – and there's a portable version available today from a commercial supplier.

Electrically small loops work by increasing the magnetic field component of the radiated signal, rather than the electric field utilised by a more conventional antenna. The theory is complex – but doesn't really matter – the fact is, magnetic loops work very well indeed and are used throughout the world, especially in rugged military applications where small size is paramount.

The key concept to grasp is that in order to utilise the magnetic field we need to concentrate the radiated magnetic field by forming a loop. As this is done the inductance of the loop is increased and must be tuned by some form of capacitor as in a normal tuned circuit. If the magnetic field is not formed in this way, then the electric field dominates and the antenna will behave more like a dipole (or more correctly, a doublet).

My ex-colleague and great friend, who is now retired, **Chris Clarke G0AQL**, has a real knack of making something out of nothing. His experience as a Royal Navy submariner probably has a lot to do with it – you don't find many shops on a submarine and when something breaks its down to your ingenuity and practical resourcefulness! Years ago, when we worked together, Chris was always the first person to find practical solutions to engineering problems – and so it turned out to be with the challenge of a loop antenna.

On our regular 70MHz (4m) and E-mail chats, we had been discussing antennas for the 10MHz (30m) band. In fact, due to its limited frequency span, the band always seemed to be an ideal choice for an equally limited bandwidth loop antenna and with the band always being full of surprises, it was a good band to experiment with!

Biggest Problem

The biggest problem with loop antennas is that at the tuning point very high voltages occur (perhaps 10kV or more at 100W) and large circulating currents occur in the inductor itself. These parameters frightens people away from constructing loops, which is a shame and Chris was determined to find a way of creating a 10MHz pocket-sized loop design that was accessible to anyone, with everyday resources.

Finding a simple practical way of insulating the antenna construction, was a topic under discussion one night during our regular chat on 70MHz. However, the discovery by Chris of a high voltage insulating material whilst doing the food shopping the next day – in the form of a nylon chopping board at the local Sainsbury's supermarket for £1.99 (!) – led to a practical loop construction project coming to life. Within a couple of weeks some significant constructional challenges were overcome and reduced to simple solutions.

The loop antenna was soon on the air at full maximum legal power. This article describes Chris's solutions in the same way that they evolved during our nightly QSOs and follow up E-mails – and we hope they will inspire others to build one of these remarkable antennas from simple components available around us.

The Loop

Early discussion between us about the loop material itself didn't reveal anything particularly new. Loop antennas are typically characterised by low radiation resistance, so losses have to be kept as low as possible. Electrically small dipole configuration antennas are usually brought to resonance by loading coils – and these have inherent losses in their usage. Loops avoid this problem by not having traps, but do feature an adjustable capacitor for tuning the inductor (loop).

Low loss loop material inevitably means using relatively heavy material – so whatever material was chosen for the loop it had to be physically connected to the variable capacitor somehow. And our discussion centred around this issue.

Chris did what many loop builders have done in the past – and headed for the plumbers' section of the local building equipment suppliers. Fortunately, 22mm diameter copper tube is easy to get hold of, and is relatively inexpensive (although commodity prices have increased recently). He then used a very modern plastic coupling for the insulator at the top of the loop where the variable capacitor would be connected across. The rest of the fittings were the

Fig. 1: General arrangement of the loop – with the balun acting as weight for stability.

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conventional 'soldered on' type of water pipe couplers.

The loop can be of any size – it's a tuned circuit so the only variables are the loop inductor and the capacitor, the ratio of which varies with the usual tuned circuit formula. Chris made his loop about two metres in diameter – simply by finding which standard copper pipe stock lengths meant the least waste – it's cheaper this way. Incidentally, all the informationassociated with loop antennas – for those wanting to do the maths – are contained in the *ARRL Antenna Handbook* (available from the **PW Book Store**) but nothing is critical.

Copper straps were then soldered on to the pipes to connect to the variable capacitor as shown in the photo illustrations. The Sainsbury's chopping board is the main constructional support item as it has a very high dielectric withstand!

The 22mm pipe size is the best to use – it keeps losses low in the loop and 135° couplers are easily available. The 15mm size tubing could be used but with a loss of *Q* and probably less physical strength in the finished loop.

The support plates (chopping boards!) from the local Sainsbury's store are remarkably good insulators and can be cut to virtually any shape with a jigsaw. They are made from some form of nylon material – but are excellent for this job and easy to use.

Chris rapidly built the loop – and with his usual constructional far sight, developed a balun which later became a counterweight for the loop stand. I then received and E-mail from Chris, where he updated me and said that we were 'almost there' and just needed the vacuum capacitor, which he'd be getting soon.

The Vacuum Capacitor

Vacuum capacitors can be difficult to obtain, although they do appear at rallies and surplus stores. The key is to maintain a good look out. They do appear on eBay – although prices can be high if the seller knows what he has got (many don't so look at photographs carefully). They can also be obtained by buying scrap/surplus equipment for a few pounds that may have one buried within it. The key is to keep looking – one will appear from somewhere!

Some good Russian devices have also been appearing on the surplus market and it's also possible to get them directly from Russia as well. A search on the Internet may yield some good results. As its name suggest, the vacuum variable capacitor consists of two copper concentric sleeves in an evacuated valve type enclosure.

The vacuum then acts as the dielectric and enables much higher voltages to be tolerated between the two sleeves. One sleeve (there are other designs as well) is then moved away from the other by rotating a coupler which drives an internal screw thread mechanism. I've never understood how the vacuum seal integrity is maintained – it's some form of metal seal similar to a valve base – but they do work well. If you are buying one check the integrity of the unit carefully – and if at all possible, see if it can be flash tested at several thousand volts. (A vacuum variable capacitor is incredibly stable under high power).

Note: It's possible to use open frame capacitors in this application, but you will need to restrict power levels if it's a small capacitor – this will not be much of an issue at QRP power levels. The best versions are probably split stator or butterfly types, which are often found in ex PMR equipment.

Chris had already promised me that he'll turn his hand to making a suitable capacitor in the next few months he just needs a bit of inspiration again from the local shops and we will make the design available. He always collects things – and had managed to obtain a couple of vacuum variable capacitors from various rallies over the years and one was soon sorted out and fitted – the value was believed to be around 10,000pf. This is rather excessive, but would allow the loop to be tuned over other bands as well – so it was fitted.

Chris sent me a photo and we discussed the merits of the nylon insulator on the capacitor adjustment thread. Although probably adequate at low power, neither of us fancied adjusting this at high power when the voltages in this area might be considerable! So, Chris started to set his mind to working out how to motorise it and was in two minds about doing it as it would bring a lot of complexity into the loop.

Loop Antenna Matching

To make the loop antenna complete, a radio frequency (r.f.) feed system is required and this must match the output of the transceiver directly to the antenna. A conventional a.t.u. cannot be used as this would bring the transceiver coaxial cable and a.t.u. into the 'loop' circuit and it would not function correctly (it might tune, but not much would be radiated!).

We had a good discussion about matching the feed to the loop. I'm not a fan of delta matching and could not see how to apply it to a loop. Even if we could find a way, Chris and I struggled to see how this could be adjusted sensibly with the large voltages and circulating currents in the loop.

We opted for the Faraday loop match (more correctly known as a 'Faraday shield loop'), which is simply a single turn loop, used to couple energy into the loop. There's plenty in the usual antenna books on designing a match – but it's simply a loop made out of coaxial cable. The basic theory and practice says that the feed loop has a diameter 1/5 that of the larger loop and can be constructed using coaxial cable, but has to be physically strong enough to support itself. The coupling loop is formed in the following way: from the coaxial cable that will connect the antenna to the transceiver, a loop of approximately 1/5 diameter of the main transmitting loop, needs to be created. Dimensions are not at all critical and 1/5 diameter is just a guide. From the end of the loop, 200mm or so of the coaxial cable's sleeve is removed to expose the shield. Where the loop starts, 30mm or so of the sleeve jacket is removed to also expose the shield and the shield at the end of the coaxial cable is soldered to the exposed

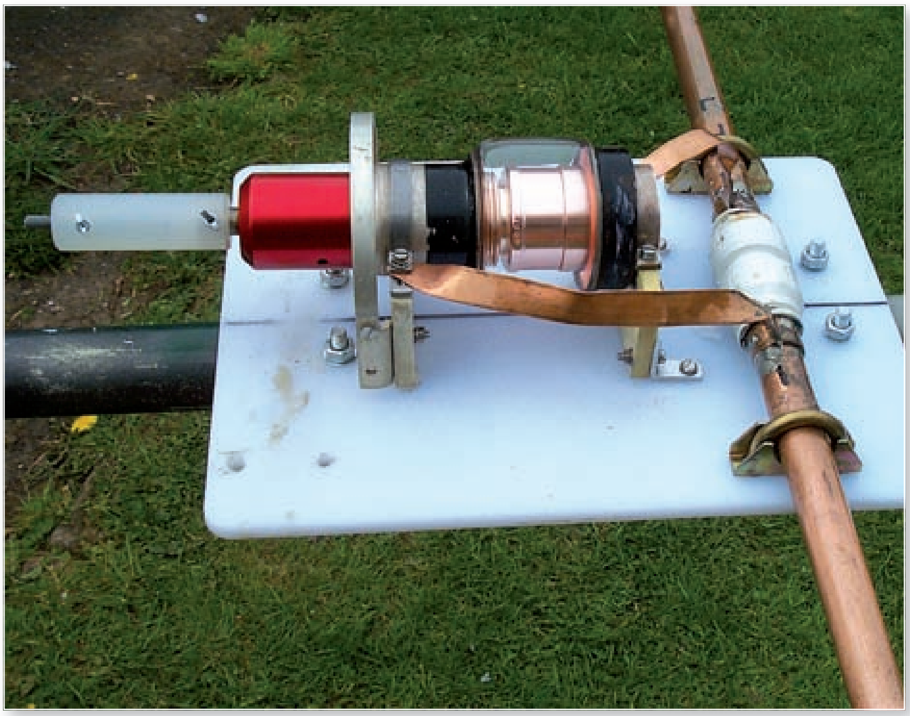

Fig. 2: Note especially the thick copper strapping from the loop to variable capacitor.

Fig. 3: The Faraday coupling loop (top right) – this should be positioned opposite the vacuum variable capacitor but it is not unduly critical.

shield at the start of the loop – the loop is then created.

Half-way round from the start of the loop, the coaxial cable is cut completely through. 20mm or so of the inner conductor is exposed and the shield cut away. On the other part of the cut cable, only the shield is exposed. The exposed shield is then soldered to the exposed inner conductor formed earlier. The coupling loop is then completed. All the joints are then sealed with self amalgamating tape.

The loop is now rigid it is fitted into the main transmitting loop. Chris used a short piece of wood to hold the loop rigid and also to fasten it into the main transmitting loop. He fitted it into the transmitting loop 'corner' - but anywhere on the loop opposite the vacuum tuning capacitor seems to work well.

Motorising The Capacitor

It then became clear to both of us that the loop could be made to work on other bands, so the capacitor had to be motorised. It wasn't good enough to adjust the loop at low power on 10MHz alone – what was needed was a tuning mechanism for the other bands.

A look on the internet came up with a Meccano circuit site **http://www.internationalmeccanomen.org.uk** and this had some circuits dedicated to motor switching – and also gave some advice on circuit topics. Chris soon finished the drive with the help of some Meccano gears and some metal work bits raided from an old bench clamp vice.

Chris E-mailed me the following evening to tell me he'd made good progress with the loop but had to play around with the motor drive but had got it going okay in the end. He told me the loop was complete and commissioned successfully. He had problems at first but soon resolved, as he had the centre core and screen transposed in the wrong halves of the loop (*PW* readers can bear this in mind!).

Next, Chris conducted trials up to 400W with no problem and also achieved a very low s.w.r. without an antenna tuning unit – so he was very pleased, especially as there was no flash-over but this wasn't really surprising as we had used the vacuum capacitor (there was nearly 10kV at the capacitor). He also reported that signals over to Japan and towards East over to USA were significantly stronger than when using a dipole – with a good reduction in noise.

Interestingly, Chris also mentioned that, " We'll probably not need to motorise it for 30m use only and body capacitance does not seem to be a problem. The analyser results should that 1.2:1 s.w.r. was achievable!"

Chris had also waterproofed the unit with a flowerpot! He then tested the loop on 3.5, 5, 7, 10 and 14MHz with good s.w.r. readings on all bands. The next job Chris had to do was to drill holes in his shack wall to take the control cable!

Fig 4: The 10MHz loop came about due to the active help of my very capable friend and co-writer Chris Clarke G0AQL, pictured here in a brief moment away from his workbench!

The loop became known as the 'beast' in our conversations and following Chris's salvaging in a neighbour's skip, now had a stand made from a old halogen lamp. The balun became ballast for the tripod stand!

Chris is an ex-military man, so most of his equipment ends up with a coat of Nato standard paint and always gets a serial number! So, after tidying up the control systems and completing the waterproofing – we were ready to go!

Tuning Easy!

Tuning the loop is easy – the *Q* of the loop is very high, so even if a MFJ or similar antenna analyser is not available – it can be done by listening to the noise peak when tuning the capacitor. The peak **is very sharp**, and it's not easily missed as you pass through it when tuning the capacitor, but it does takes a bit of finding exactly – so a slow speed reduction drive is required whether or not it's being tuned manually or electrically.

When transmitting, the s.w.r. is adjusted for minimum in the usual manner. However, for this antenna the coupling loop is adjusted to give the best results. The Faraday coupling loop can be adjusted either by rotation or by physically adjusting its position with the loop (it is, after all, just a large one turn inductor coupling to another inductor and the usual approach of stretching/squeezing a p.c.b. mounted inductor works the same way).

Note: The Faraday loop is matching the 50Ω unbalanced transceiver output to the loop and the loop itself is tuned using the variable capacitor.

Varnishing Recommended

For best results to loop should be varnished to preserve its *Q* in different weather conditions . But please be aware that varnish will 'creep' over time – so keep it well away from any capacitors or non soldered/brazed connections, as it will creep and become an excellent insulator at a critical point. Really excellent protection can be obtained by using a clear twin-pack epoxy resin (pop into your local chandlers or wood working store and you'll find some).

The loop gives fantastic service from Chris's suburban QTH and he has literally worked the world with it sitting on the patio as shown in the photographs. Height is not important to a loop, and it has an exceptional ability to reject local interference due to its narrow bandwidth and immunity to electric field radiated noise. They work very well in lofts!

However, a word of warning is required if you build one yourself – be very careful where you site it. The voltages on parts of the loop are very high and it ideally needs to be fenced off if there is any possibility of accidental contact – but don't let this put you off – some simple materials and good constructional practise can give you an excellent antenna where space or height is limited.

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