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# The G4ILO Wonder Loop



The G4ILO Wonder Loop is an inexpensive, easy to make magnetic loop antenna that covers five HF bands, 40m through 15m. It is designed for portability, and can be assembled or disassembled in about a minute. When disassembled the antenna easily fits in a suitcase or backpack.

The Wonder Loop is the perfect antenna for picnic table or hotel room operation, or for home station use where outside antennas are not permitted and attic antennas not possible. It needs no supporting mast, and no counterpoises or ground connections are required. Tuning is quick and easy.

Performance is within an S-point or two of a dipole and better than many of the antennas often used in temporary or compromise locations. In good conditions the Wonder Loop should genuinely be capable of worldwide communication using low power, particularly if CW or PSK31 is used. In its first couple of days of testing the G4ILO Wonder Loop sent a 2 watt signal all the way from northern England to Western Australia. Interested? Then read on!



## Design objectives

The idea for the Wonder Loop first came to me after I had tested small portable whip antennas such as the ATX Walkabout, Miracle Whip and Wonder Wand. These antennas are small and very portable, but you pay for this with a considerable penalty in efficiency. My experience with the MFJ magnetic loop led me to be very impressed with this type of antenna, and I wondered whether a better type of "miracle" antenna could be made using the magnetic loop principle. So began my first experiments with what evolved into the Wonder Loop.

I soon learned that making a magnetic loop the size of a Miracle Whip would be impractical. The efficiency of a magnetic loop drops steeply as the size of the loop decreases, and you quickly reach the point at which efficiency is so poor that the telescopic whip radiates a better signal. Also, the voltages present across the tuning capacitor, even at QRP power levels, are high enough that a good air-spaced variable capacitor needs to be used, increasing the size and weight of the antenna.

So I modified my objectives to create a QRP magnetic loop that, while bulkier than a Miracle Whip, would blow it away in terms of performance yet still be easily portable and usable in all the same situations except walkabout operation. And so the G4ILO Wonder Loop was born.

Since many amateurs these days are going into business and selling their creations I must make clear at this point that **the Wonder Loop is not a commercial antenna**. You cannot buy one, and **I will not make one for you**. You have to build it yourself. If you really cannot do that then I recommend that you look at the MFJ magnetic loop tuners or the portable magnetic loops made by G4TPH.

I should also point out that the Wonder Loop is not a design you can slavishly copy. You will need to adapt it to suit the parts - and particularly the tuning capacitor - that you can buy. You can probably (in fact, almost certainly) improve on my design in several respects. The main purpose of this article is to show that a magnetic loop is a very easy antenna to make and gives great results even when used indoors. It's something every ham should try, because it's a gas getting reports using an

antenna you made yourself and which is sitting on the kitchen table. The Wonder Loop really is a wonder antenna!

## Loop principles

A magnetic loop (sometimes known as a small transmitting loop or STL) is one of the easiest antennas there is to make. You don't need great DIY or engineering skills - believe me, if you did, I'd never be able to make one! The magnetic loop's performance isn't dependent on cutting lengths of wire or aluminium to precise lengths, nor does it need an expensive ATU to match it to the rig. A tuner is part of the design.

A magnetic loop is nothing more than a loop of wire or other conducting material connected across the terminals of a variable capacitor. The capacitor resonates the loop to the frequency you require. To get RF into and out of the loop a coupling loop one fifth the diameter of the main loop is made, with its ends connected to the braid and centre of the coaxial feeder. The coupling loop is insulated, and placed so that the mid-point (opposite the feedpoint) is next to the mid-point of the main loop, opposite the tuning capacitor. You end up with a loop within a loop, one of which is fed with RF, the other tuned, as you can see in the top photo. And that's basically all there is to it!

There are other ways of coupling power to a magnetic loop besides the method I use. Some people use a toroidal transformer, others a gamma match. In its manual loop tuners MFJ uses a method developed by the US Army, which employs an additional variable capacitor. That adds cost, but it has the advantage that both feeding and tuning occur at the same point in the loop, which can be inside the tuner case. However, my simple coupling loop uses something that every amateur has, a piece of wire. MFJ uses this method in its remotely tuned loops such as the one in my attic. So that's what I decided to use for the Wonder Loop.

## Loop construction

Although the basic design of a magnetic loop is very simple, there are considerations that mean you can't make an effective small transmitting loop from just any old capacitor and any old piece of wire. The higher the current that circulates in the loop, the more efficient it is, so the resistance in the loop should be as low as possible. For this to be achieved the conducting material used for the main loop needs to be something stouter than ordinary antenna wire.

Many builders use copper pipe for the loop main element. However, the thought that you must buy expensive copper pipe and be able to solder it together into a square or octagon shape probably puts off a lot of people from trying to make a magnetic loop antenna. It is not necessary, especially if the loop will only be used at low power.

The main loop of the G4ILO Wonder Loop is made from a length of RG-213 coaxial cable. The braid of this coax is heavy enough to have a low resistance and easily able to handle power levels of a few tens of watts. Having compared the performance of my antenna directly with a professionally built MFJ magnetic loop which has a solid aluminium radiating element I believe that any difference in performance resulting from the use of coaxial cable rather than solid tubing is insignificant.

## Tuning capacitor

The other thing that tends to give the idea that magnetic loops are difficult and expensive to make is the notion that you need a hard to obtain and costly high voltage tuning capacitor. Certainly this is a real problem if you want to build a magnetic loop you can use at high power. But if you will only be using low power a suitable capacitor will be much easier to obtain and a lot cheaper to buy.

Even with QRP a couple of hundred volts can develop across the capacitor plates. An ordinary broadcast radio tuning capacitor with vanes you can't easily slip a postcard between is only good for true QRP power levels - 5 watts maximum. If you can slip a card between the vanes then the capacitor should be able to handle 10 watts with no problems. An air gap of 1mm equates to a breakdown voltage of about 1KV, which can be encountered when as little as 20 watts is used. So if you want to use 100 watts you should be looking for a capacitor with at least a 2mm air gap or else a vacuum variable capacitor.

Many magnetic loop constructors state that you need a special type of capacitor such as a split stator or butterfly capacitor. Again, this is really only important at high power. The most easily obtainable and least expensive variable capacitors have one terminal and set of vanes connected to the chassis, and the other set of vanes mounted on the shaft which is insulated from the chassis. To get current from the insulated fixed terminal to the moving vanes a contact or brush is used. This contact is not designed to carry high currents. Moreover, especially if the capacitor is old (ex-equipment) the contact point may not be very clean, creating a resistance that will limit the current and affect the efficiency of the antenna.

A butterfly or split stator capacitor offers the lowest resistance between the two terminals, because the current flows only through the vanes which are directly connected to the terminals. No moving

contacts are present in the path. Another advantage is that the vanes are all insulated from the body of the capacitor. With an ordinary tuning capacitor the chassis is common with one set of vanes and becomes part of the antenna.

Despite this, the cost savings resulting from using an ordinary tuning capacitor make this an attractive choice when building a QRP magnetic loop antenna. Because the chassis of the capacitor is connected to the loop, you must use a plastic case and ensure that any mounting screws accessible on the outside are covered. You should also use as large a tuning knob as possible to minimize hand capacitance effects when tuning the antenna.

If the capacitor is new or in good condition then the resistance introduced by having a movable contact in the current path should be negligible. In my experience, comparing my Wonder Loop to the MFJ magnetic loop, I do not consider that it is significant enough to make a noticeable difference under normal operating conditions at low power levels.

If you buy a used capacitor and you think the brush contacts are dirty try cleaning them before using it. If you do this using volatile switch cleaner, make sure that it is thoroughly dried out before boxing it up and using it. One loop constructor caused a small explosion after he tried using too much power and the resulting spark ignited fumes from the switch cleaner that were trapped inside the case!

One other characteristic of the ideal tuning capacitor for a magnetic loop that has no bearing on the efficiency of the antenna but is certainly nice to have is a reduction drive. The tuning of a magnetic loop is very sharp, and if the entire range of the capacitor is covered in one 180 degree rotation of the tuning knob then setting it to the point that gives the perfect match is going to need more than a steady hand. Butterfly capacitors cover their range in only 90 degrees of rotation, which is even worse! If your capacitor does not have a built-in reduction drive then an external one would be a good investment.

For further information, MFJ has a good article on manual loop tuner considerations.

## Building the Wonder Loop

Exactly how you go about building your magnetic loop will depend on the parts you have to hand, or are able to purchase, and particularly the tuning capacitor. Therefore I am only going to give a general outline of construction. You should be prepared to adapt this to your own circumstances and requirements.

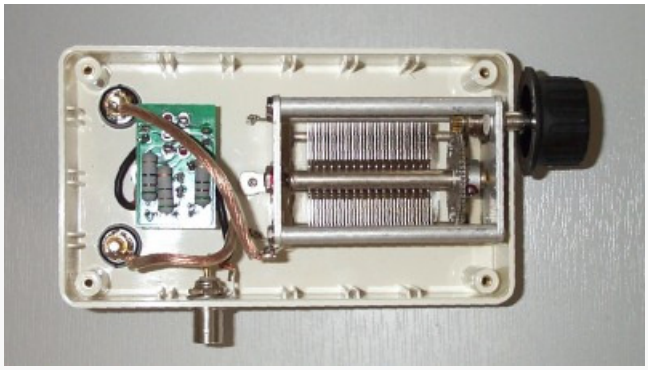
I used a 250pF tuning capacitor which was a one-off, purchased on eBay. A smaller value tuning capacitor may cover a smaller tuning range (dependent on the minimum value). This will require a larger loop to cover lower frequencies. However, the larger loop will be more efficient, so this is not necessarily a disadvantage.

### Parts list

- 250pF single gang variable capacitor with reduction drive
- Plastic case
- Self adhesive feet
- 2 x 4mm gold plated binding posts for the main loop connections
- 2 x 4mm gold plated spade terminals for the main loop connections
- 250cm length RG-213 coaxial cable for main loop element
- RCA (phono) plug and socket for coupling loop input connection
- BNC socket for coupling loop output connection
- 50cm insulated wire for coupling loop
- Length of RG-174 mini coaxial cable for coupling loop
- N7VE SWR Indicator Kit or similar (see below)
- 2m white uPVC electrical conduit, for fabricating loop support mast
- White plastic cup hooks
- Self adhesive Velcro (hook and eye fabric fastener, from XYL's sewing box)
- Large plastic tuning knob
- White car number plate fixing bolt covers (to cover tuning capacitor fixing screws)
- Bolt for photographic tripod mount (optional)

### Assembly

The parts to make the loop tuner are assembled as shown in the photograph.



The tuning capacitor is fixed to the case, and the two terminals connected using stout wire to the two 4mm binding posts to which the ends of the main loop will be connected when the loop is in use. Because one of the capacitor terminals is common to the frame of the capacitor, the frame and mounting screws are part of the antenna. The screw heads should be covered to avoid the risk of touching them whilst the antenna is being used.

The RCA socket for the downlead from the coupling loop is mounted between the two 4mm binding posts. The output BNC connector for the cable to the transceiver should ideally be mounted at the front, to preserve symmetry, because the cable exiting from the side of the case could in theory affect the tuning or radiation pattern of the loop. There wasn't the room in my case to put it at the front, however, and in practise it doesn't seem to have had any adverse effect.


It is optional - though I found it convenient - to take the output from the coupling loop into the tuner and then route it to a BNC socket so I could use any of my existing patch leads to connect the antenna to the transceiver. In my initial experiments the coupling loop was connected directly to a couple of metres of RG-174 miniature coaxial cable and taken straight to the transceiver.

Routing the coupling loop into the tuner box is necessary if you decide to incorporate an SWR indicator, but this again is optional. If you will only be using the antenna with a transceiver that has its own SWR metering then you may consider it unnecessary, although it does make life easier on the finals by presenting the transceiver with a 50 ohm load during tune-up. If you will be using the antenna with home-built QRP rigs with no SWR indication then the indicator becomes invaluable. The N7VE version is easily sensitive enough to show a match when tuning with rigs of 1 watt output or less, such as the MFJ Cub.

I used the N7VE design which is available as a kit from QRP Kits. Subsequently I became aware of several alternative circuits if you search for "resistive SWR bridge" such as this one from the G-QRP Club or the even simpler circuit shown here. I can't vouch for how well these other circuits work, but use of either of them would have saved me some money.

## Loop construction

The frequency coverage of your loop will depend on the tuning capacitor you have purchased. Therefore it may be worthwhile making a quick lash-up first using longer lengths of cable than those specified, testing the frequency coverage by listening for a noise peak on various bands in your receiver and trimming the cable until the desired bands are covered. Any dimensions given in this article assume that you are making your Wonder Loop using the same tuning capacitor that I used, which is rather unlikely.

Note that the design of the Wonder Loop lends itself to being used with different sized loops for different bands. A larger loop should be able to cover 80m with reasonable efficiency, and would probably provide improved performance on 40m and 30m. For reasons of space I haven't tried this myself yet, but may do in the future.

To make the coupling loop, strip the end of a short length of RG-174 miniature coaxial cable and attach a loop made of insulated wire, one side to the centre conductor, the other to the braid. The loop will be one fifth of the diameter, and hence use one fifth of the length of the wire in the main loop. However, the size is not critical. In fact due to a mistake in mental arithmetic I originally made the coupling loop much bigger than it should be and still managed to get a good SWR and make contacts.

Attach an RCA plug to the other end of the coax. The loop will hook over the top of the support which, since the main loop is 78cm in diameter, will be 78cm above the top of the case. Ideally, the length of the coax should be such that when the coupling loop is in place and the plug is plugged into the socket on the tuner, the coax is pulled taut against the support mast. However, during the testing stage you may want to try squashing the coupling loop into an oval or elongating it into an egg shape to get the best SWR on all bands, so it's worth making the cable a bit longer to give you room for experiment.

To make the main loop strip the insulation from 5cm at each end of the length of RG-213 coaxial cable and then pull the braid away from the centre conductor. Cut off the last 4cm of centre conductor and insulate the stub with tape. Twist the braid together and solder it to the 4mm spade terminals, then wrap the braid in insulation so only the ends of the terminals are exposed. Mark the centre of the cable that forms the loop with a strip of tape - this will be the point it is suspended from the loop support and marking it will help you to get the loop symmetrical.

## Loop support

The support for the loop is made from white uPVC electrical trunking. This stuff has a square section and is made in two parts, which snap together. The front part is flat, apart from the grooves at each side which snap onto the back part. By glueing front and back sections together so that they are offset, you can create a mast that breaks down into two sections and snaps together.

A short length of front section is screwed to the back of the tuner and the mast slots into this to hold it vertical. The construction is probably clearer if you look at the photograph of the antenna disassembled. Click on the photo to see a larger version. This is just about strong enough but an alternative, more rugged method would be to use a couple of bolts held captive with nuts, and then use wingnuts to secure the mast to the base.

The total length of the mast in my case is 76cm plus the depth of the tuner base.

A plastic cup hook glued to the top of the support is used to hold the main loop and the coupling loop at the top position. The coupling loop also needs to be fixed to the support at the point where it is connected to the short coaxial cable. I used a small piece of copper clad PCB to make the connection between wire loop and cable, and then put some self adhesive Velcro on the back of this and some matching fabric at the corresponding position on the mast.

RG-213 cable does not have sufficient stiffness to hold a circular shape when supported just at the top and connected to the 4mm binding posts. Rather than use a central wide cross-piece as in the loops you can buy from MFJ for use with its own loop tuners I chose to make a top support. I took a length of the front part of the uPVC trunking and glued cup hooks at each end. This sits on top of the support as can be seen in the very first photograph and lifts the cable up at each side so that it assumes a more circular shape. This is not the most elegant support arrangement and I am sure that others can find ways to improve on it.

## Using the antenna

As can be seen from the photograph above, the entire antenna breaks down into a small and robust tuner box, two small coils of cable and a couple of lengths of plastic that clip together to form the mast support. The whole thing can easily be fitted into a holiday suitcase or backpack.

Self adhesive rubber feet are fixed to the base of the tuner box to allow it to be sited on any flat surface. I also found a bolt in my junk box that fitted a standard camera tripod mount so I filed a hexagonal hole in the plastic base and fixed that in place and strengthened the surrounding area using a large mass of Araldite adhesive. The tripod mount has been very useful since desk space in

my shack is limited. It would also be useful for portable operation when no table is available to put the tuner on as the loop should be at least a metre above ground to avoid ground losses.

Erecting the antenna is a simple matter of clipping the support mast together, clipping that to the tuner, hooking the coupling loop over the hook and plugging it in to the tuner, draping the main loop over the support and securing the ends to the binding posts, then clipping the support piece over the top of the loop to hold it circular. This takes no more than a minute.

Then connect the transceiver, tune for maximum noise in the receiver, flip the SWR indicator switch to Tune, apply RF and fine-tune the tuning control until the LED extinguishes. Flip the indicator switch back to Operate (I have lost count of the number of times I forgot to do that and got poor reports!) and you're good to go. It really is very quick and easy compared to adjusting tuning coils, fiddling with counterpoise lengths, guying portable masts or trying to catapult wires over tree branches. And the results are as good, sometimes even better. I just love this little antenna!

If you can't get a perfect SWR (1.1:1 is normally achievable, but anything better than 1.5:1 is just fine) then try moving the antenna. Nearby objects can and will affect magnetic loops on some frequencies more than others. If you can't get the SWR below 1.5:1 even with the antenna in the clear, try changing the shape and position of the coupling loop. Squashing it up to a rugby ball shape often helps. Or you could try making it larger. The two loops should touch at the point where they are held by the hook on the support mast.

The magnetic loop is nearly omnidirectional but there is a sharp null axially through the centre of it. This can be used to null out sources of noise or interference, a feature I have made considerable use of while testing it here on 20m!

When using the antenna on a tabletop, position it so the tuning knob is towards you. That way, you will be sitting in the null and minimising your RF exposure. Since the antenna is only intended for QRP, your exposure is going to be far less than it is with a 5W 2m handie held right in front of your face, anyway. But it is as well to stay on the safe side.

The tuning is very sharp, and even with a reduction drive you'll need sensitive fingers to hit that 1:1 spot. If you QSY more than a couple of KHz on 40m then you'll need to readjust the tuning. On higher frequencies you get a bit more latitude. This is a characteristic of magnetic loops and what makes them so efficient. Do not be tempted to use the ATU in your transceiver (if it has one) to take the effort out of retuning. It might keep your transmitter's PA happy but the loop won't be working at maximum efficiency.

## Performance

I spent quite a lot of time trying to get some objective measures of the performance of the Wonder Loop. Due to the poor propagation conditions at the time of writing this has only been possible on 20m, 30m and 40m.

First, I used WSPR, Weak Signal Propagation Reporter. The value of this is that it allows me to get accurate reception reports from stations around the world, automatically. By switching between the Wonder Loop and my MFJ magnetic loop in my attic (which itself performs very similar to my attic dipole) I could get a rough comparison of how the antenna performs.

On the whole, the Wonder Loop performed slightly poorer than my attic antennas, but only by an S-point or so. In some cases (from certain parts of Italy for example) the Wonder loop received consistently higher signal strength reports than the MFJ! This happened too often to be simply a coincidence caused by QSB, which itself often accounted for more than the difference between the two antennas.

No DX has been worked so far, but single-hop contacts as far away as Scandinavia and Eastern Europe are quite easy to make using as little as 1W of CW or 5W of PSK31. I have even had stations standing by to call me after a contact is finished, and replying to CQ calls! This just does not normally happen with QRP unless you are using an antenna that is reasonably effective.

Making contacts using SSB has been a lot more difficult, but this is normal using QRP when conditions are poor and there are no sunspots.



## Conclusion

The G4ILO Wonder Loop is an easy antenna to build and delivers an impressive performance. I have had a lot of fun making and testing it. If I was to live in an apartment or other situation where no other antenna was possible then it would still enable me to pursue the hobby with a lot of interest.

The size, portability and ease of deployment of the Wonder Loop make it an ideal antenna for holidays, business trips and even portable outings. It will permit and encourage you to get on the air in circumstances when you can't, or don't have time to, erect another type of antenna, and will require little or no compromise to be made compared to other temporary antennas when it comes to performance.