Magnetic Loop Antenna for 80-20 m

INTRODUCTION

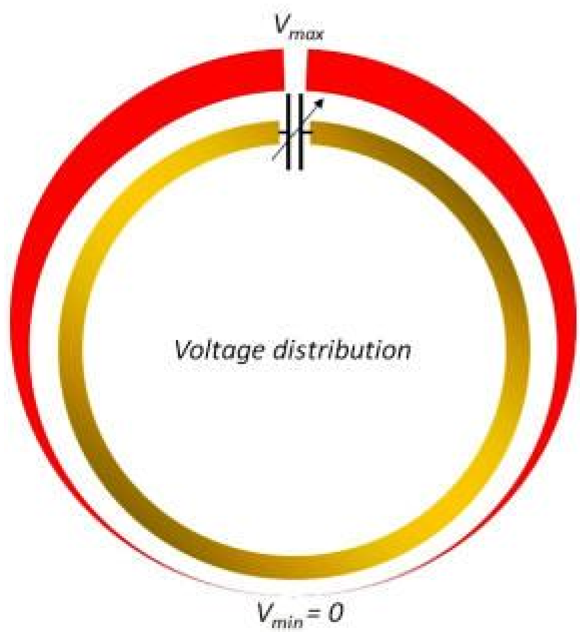
I wanted a **small transmitting loop** (STL) antenna that covers at least the 80 and 40 meter bands. Why?

1. I want to do 80 mtrs DX, but I have no room for a decent 80 m wire-antenna. I have had success with short, loaded vertical antennas with a single elevated radial (much better than a bunch of radials on or in the ground), see here and here. But I cannot install those permanently at my QTH.
2. Below 10 MHz, our apartment building generates a massive amount of QRM (S9++), probably due to the huge, dirty switched power supply of the central ventilation system. An STL tends to be less sensitive to picking up electrical noise in the near-field (< 1 λ). which is why this type of antenna is also referred to a "magnetic loop antenna".
3. STLs have a radiation pattern with directivity. They are also small enough to rotate with a small motor, or TV-antenna rotor.
4. Less conspicuous (to my friends of the home-owners association "police") than a wire antenna strung along the outside of the building.
5. Don't want to have to mess with radials, counterpoises, RF-grounds, etc. Loops are inherently symmetrical, like dipoles.
6. Can be installed close to the ground (vertically oriented), without significantly losing efficiency. Yes, higher is better.

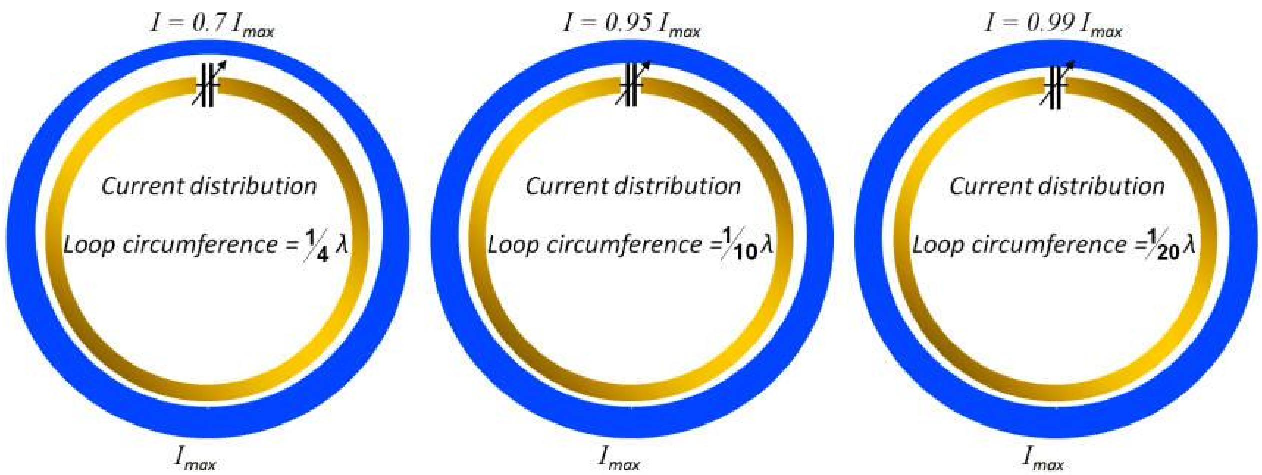
A loop is generally considered "small", if its circumference is less than 10% of the operating wavelength. In my case "small" would be a circumference of less than 8 mtrs, e.g., a circular loop with a diameter less than 2.5 mtrs (≈ 8.2 ft).

To be more precise, it is a **small *resonant* loop**. To obtain resonance, we need to combine inductive and capacitive reactance. The loop is the equivalent of a single winding of a coil, so it has a self-inductance. Resonance is obtained by connecting a capacitor across the ends of the opened loop. The capacitance has to be appropriate for the desired resonance frequency, as in all (parallel) resonant circuits. Note that the loop-winding not only has inductance, but also stray capacitance. So, even without the additional capacitor, the loop has a resonance frequency. It is the maximum resonance frequency that can be obtained wit the loop.

One important aspect to keep in mind, is the voltage and the current distribution along the loop - at resonance. As shown in the figure below, the voltage is highest at the capacitor, and zero at the point diametrically opposed (in a perfectly symmetrical loop + capacitor + capacitor connections). In some coupling methods, the braid of the coax feedline is actually connected to that neutral point.



The current is highest at the point opposite the capacitor. and lowest at the capacitor. Ben Edginton, G0CWT, has nicely illustrated this with a video clip on his website. Note that the minimum current is not zero! Unlike the voltage distribution, the current distribution depends on the size of the loop (circumference), as a fraction of the wavelength. For a small transmitting loop (circumference < 0.1 λ), the current distribution is nearly constant around the loop. Both the voltage and the current distribution are symmetrical.



Clearly, the impedance (ratio of voltage and current) also varies around the loop; from highest at the capacitor, to lowest at the opposite point. So, for instance, there are two 50 ohm points, offset from the point opposite the capacitor (one on each side). This is used coupling methods such as Gamma Match and Delta Match.

Just to get a feel, I have calculated the characteristics for a loop with a circumference of 5 m (that is: 1.6 m diameter, ≈ 5.2 ft), made of copper tubing with a 16 mm outside diameter. This is a standard item at the local building supply store (straight or rolled up):

Resonance frequency	Capacitance	Efficiency	Bandwidth	Capacitor voltage	Q
3350 kHz	503 pF (max)	4 %	3.6 kHz	2.9 kV	931
3580 kHz	440 pF	5 %	3.8 kHz	3.1 kV	953
7040 kHz	104 pF	36 %	7.8 kHz	4.2 kV	905
14800 kHz	14 pF (min)	88 %	61 kHz	3.1 kV	241

Calculated antenna characteristics for the given copper loop (KI6GD calculator)

Resonance frequency	Capacitance	Efficiency	Bandwidth	Capacitor voltage	Q
3300 kHz	500 pF (max)	4 %	3.6 kHz	3.0 kV	986
3580 kHz	424 pF	5 %	3.5 kHz	3.3 kV	1015
7040 kHz	110 pF	36 %	7.3 kHz	4.5 kV	963

14800 kHz	14 pF (min)	88 %	58 kHz	3.3 kV	256

Calculated antenna characteristics for the given copper loop (AA5TB calculator)

The tables show that the calculated / predicted efficiency for 80 mtrs is rather low (no surprise), but my other antennas for 80 mtr are (very) short verticals. I do not know what their efficiency is, but I am sure that it is very low as well. In the end, what counts is performance at my location, for the available space, for the prevailing conditions (proximity to the building, QRM levels, etc), and with respect to other antennas that I can install there.

The tables also show that this loop should be tunable from 80-20 mtrs with a 15-500 pF variable capacitor.

I have not looked into the assumptions that the calculators make, regarding installation height (free space?), coupling method, etc. As in all high-Q resonant circuits, calculated and actual performance is highly dependent on the losses in all components (loop, capacitor) and all interconnections. Losses in the single-digit milli-ohm range may be significant! In general, doubling the diameter of the tubing will reduce the (inductor) losses by 50%.

Mike Underhill, G3LHZ, has a very controversial view on the efficiency estimates obtained with traditional models. I recommend reading this:

- "Small Loop Antenna Efficiency", May 2006
- "All sorts of small antennas – they are better than you think – heuristics shows why!", February 2008

The tables above are for a circular loop. The values for an octagonal loop are very similar: for the same circumference, an octagon has nearly the same area as a circle. For those who like (or need) formulas, this is shown below.

For a **circle** with radius *R* and diameter *D*:

$$Circumference = 2 \cdot \pi \cdot R = \pi \cdot D$$

$$Area = \pi \cdot R^2 = \frac{\pi}{4} \cdot D^2$$

For an **octagon** with side *L*:

$$Circumference = 8 \cdot L$$

$$Area = \left(2 + \sqrt{2}\right) \cdot L^2$$

After some basic manipulations, we can derive that for equal circumferences:

$$Area_{circle} = \frac{16}{\pi \cdot \left(2 + \sqrt{2}\right)} \cdot Area_{octagon} \approx 1.055 \cdot Area_{octagon}$$

q.e.d.

The height of an octagon (i.e., distance between parallel sides, not the largest distance between corners of the octagon):

$$H = \left(1 + \sqrt{2}\right) \cdot L \approx 2.4 \cdot L$$

Note that if you make an octagon with eight sections of length *L*, you will require elbow pieces to join these sections. This increases *H*. In my case by 5-6 cm (±2").