Introduction to

MLA

THE BASICS

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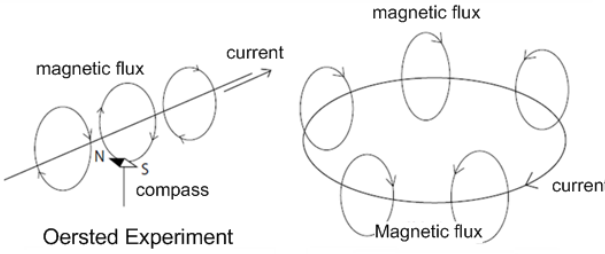
Ver. 2 2021. 4. 26

★MLA - Origin of the Name

MLA (Magnetic Loop Antenna) is often called "magnetic field type loop antenna", as if to imply "antenna that only generates a magnetic field". Rather, the name implies its operating principle of "inducing magnetic field" intentionally to emit electromagnetic waves (radio waves).

* Magnetic field: The state of the space where magnetism works

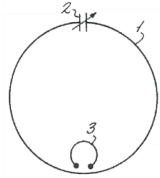
From Maxwell's electromagnetic equation, it is self-evident that "a changing magnetic field produces an electric field, and the changing electric field, in turn, produces a magnetic field". In other words, if you force a strong resonance current in a loop substantially shorter than its wavelength, a magnetic field is generated in the vicinity, and a strong electric field is generated after 90 degrees of its propagation.



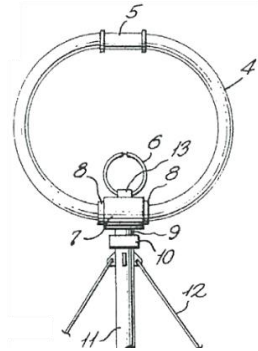
★Operating Principle

When a resonance occurs between L (inductance) of a loop and C (capacitance) of a capacitor, large current flows in the loop and a strong magnetic field (rings of magnetic flux) is radiated.

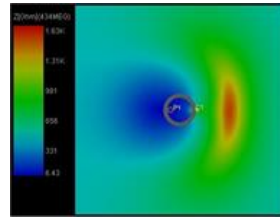
On the other hand, the electric field in the capacitor is pushed out to the space beyond it, and "electromagnetic waves (radio waves)" are radiated along with the magnetic field. The figure shows the structure of US patent US3588905 filed in 1967.



Legends: 1 – L, 2 – C,
3 – coupling coil,
5 – Vacuum Capacitor
Right: Deployment example



H-field is strong around the main loop, and E-field around the capacitor at the right edge. Outside of that, it shows 377Ω everywhere (the impedance of free space)



★What is Resonance?

In the RLC series circuit as shown in the figure in which R (resistor) is added to L (coil) and C (capacitor), reactance X is

$$X = \omega L - \frac{1}{\omega C}$$

The frequency f_0 ($\omega_0 = 2\pi f_0$) at which X becomes zero

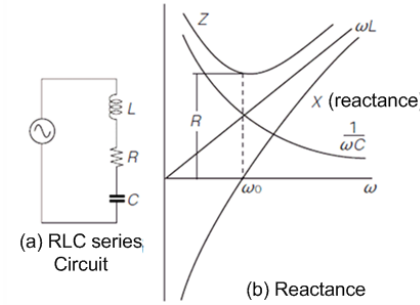
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

The state in which L (inductive reactance) and C (capacitive reactance) connected in series cancel each other out is called series resonance, or simply resonance. The frequency f_0 in the above equation is called the resonant frequency.

The magnitude of impedance is $Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$

At the resonant state, it becomes the minimum as shown in the figure, and the maximum current flows when Z becomes equal to R.

* MLA operates at series resonance by L of the main loop and C of the capacitor, and the value of R is generally very small.



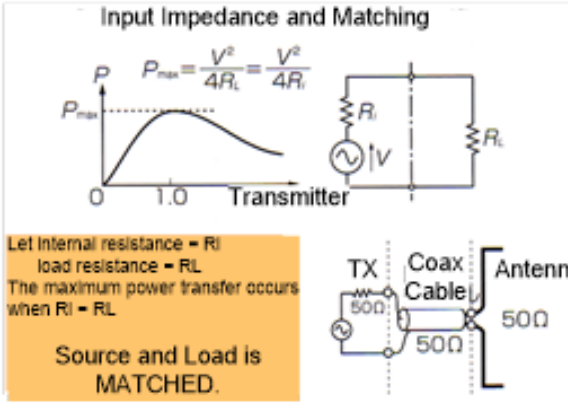
★ The Matching is Important

It is desirable to radiate the power supplied to the MLA to the space with minimum losses.

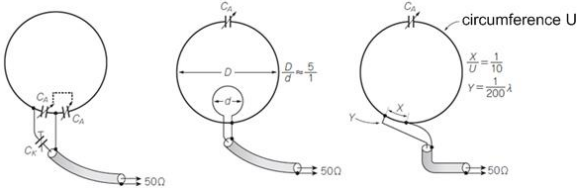
To that end, it is necessary to reduce the power reflected and returned at the feed point to zero. As shown in the figure, we mean to match the impedance R looking into the MLA (antenna) to 50Ω.

As is well known, a dipole antenna is 73Ω, and it becomes 50Ω when both edges are bent down.

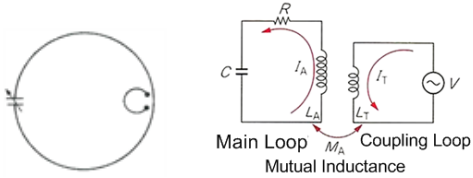
When an MLA resonates, on the other hand, large current flows in the main loop, and the value of R becomes extremely small (often less than 1Ω). Several means to match the impedance were devised so that it would look like 50Ω from the transmitter.



★Types of Matching



In the early days of MLA, the Patterson method that uses two types of variable capacitors and /or the gamma match methods were used. Currently, the method of electromagnetically coupling a small loop is more popular (the center in the above figure).



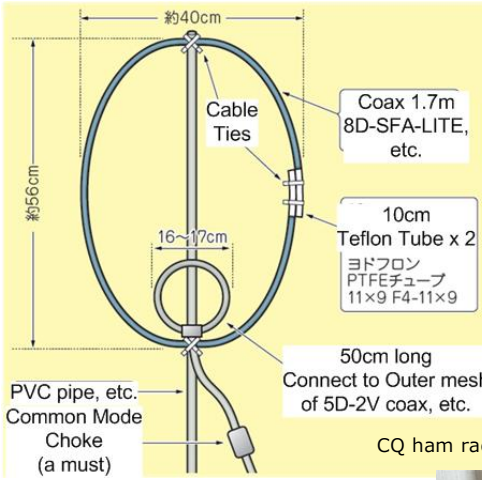
In the equivalent circuit on the right, the ratio of the self-inductance L_T of the coupling loop and the mutual inductance M_A between the main loop and the coupling loop is adjusted to 50Ω. Resolving this circuit for the input impedance R_{in} at resonance, the equation below is obtained to adjust the Radiation Resistance R to 50Ω. $R_{in} = R\left(\frac{L_T}{M_A}\right)^2$

* L_T is adjusted by loop length and M_A is adjusted by positioning.

Radiation Resistance: Radiated power divided by the square of the current at the feed point.

★Let's Try Making One!

While MLA products becoming widely available, it is also fun to QSO with a home brew antenna. Let's make an MLA for 50MHz using a coaxial cable.



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The resonant frequency can be finely adjusted by the position of the clip. It's Okay to be circular instead of elliptical.

The coupling loop can be a single wire, though it tends to get it a little bigger.

★Beware of Main Loop Current

MLA has a large resonance current flow and the voltage across the capacitor is extremely high. Hence the products in the market tends to be for QRP operations. When operating higher power, it is essential to devise a safety measure to avoid touching the element. It is also advised to keep safe distance from radiation safety point of view.

A note is posted on the the MLA48 homepage. Since MLA has extremely low radiation resistance, a large current flows in the main loop during resonance, and a high voltage is applied to the capacitor.

For example, when the resistance R of the input impedance is 0.1Ω and the transmission power P is 50W, the current

$I = \sqrt{(P / R)} \sim 22A$.

It follows that, the voltage across -j200Ω capacitor is 22 x 200 = 4.4kV.

* Do not touch the capacitors during operation!

Electric field unit: [V / m],

magnetic field unit: [A / m]

(Example):

	2m	3m
E (x)	12.5	4
H (x)	0.2	0.08
E (y)	40	17.2
H (y)	0.1	0.03

E (x) is the absolute value in the X direction

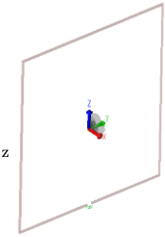
ICNIR regulations (general public):

27.5 [V / m] 0.073 [A / m]

Radio protection guidelines of Ministry of Internal Affairs and Communications:

as f [MHz] 824 / f [V / m] 2.18 / f [A / m] at 3 to 30MHz

* Note that the value depends on the frequency.

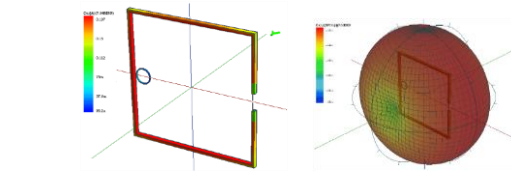


★Radiation Direction and Settings

When the loop surface is placed perpendicular to the ground, MLA emits vertically polarized waves (the direction of the electric field is perpendicular to the ground). The radiation pattern in free space is "fat donut shape (hi)".

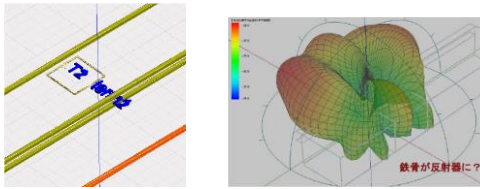
* Example of 1m square MLA at 7MHz, even for a square loop, radiation is to all directions …

When making a direct contact to a horizontal dipole, the horizontal installation of MLA works better.



When MLA is installed on the balcony of a steel bar reinforced concrete building, RF current is induced in metals such as handrails and steel frames. When it flows through the entire building, a magnetic field is re-generated and the EM radiation can occur in a complex pattern.

* The electromagnetic field simulator S-NAP Wireless Suite is used for this analysis.



★Improving the Radiation Efficiency

It is said the MLA does not pick up noise. Others say that "Of course, because the radiation efficiency is low." True, MLA with a wavelength of 1/10 or less can have a radiation efficiency of 10% or less, but that is not the main reason for the low noise.

Electric charges are easily distributed on the metal edges of iron fences, metal railings, etc., and the tip of the monopole (GP) is an electric field noise probe (hi).

On the other hand, MLA picks up magnetic field in its vicinity. While it can pick up a strong noise current that happens to flow around, it resists strongly against electric field type noise concentrated on the metal ends.

Equation to calculate radiation efficiency η:

$\eta\ [\%] = 100 \times R_{rad} / (R_{rad} + R_{loss})$

where R_{rad} is the radiation resistance (mentioned above), and

R_{loss} is the loss such as conductor resistance.

Since R_{rad} is small in MLA,

for example, when 0.1Ω,

even if R_{loss} is 1Ω, η is 9%.

周波数[MHz]	7	14	21	28
同調容量[pF]	183.8	41.5	15.3	6.2
指向性利得Gd[dBi]	1.83	1.75	1.64	1.57
絶対利得Ga[dBi]	-5.58	0.31	1.22	1.4
放射効率η[%]	**18.2**	**71.8**	**90.9**	**96.1**

The academic definition is a "micro loop" whose loop length (or diameter) is 1/10 or less of the wavelength, but we at MLA48 thinks ~ 1/5 is practical (see the figure above).

For a 1m square MLA, in our EM field simulation, η is 60 to 70% at 14MHz

* The point is to reduce R_{loss} Since R_{rad} is extremely small below 1/10 wavelength, the contact resistance of each connection should be minimized.

★Homebrewing Tips

Coupling Loop dimensions

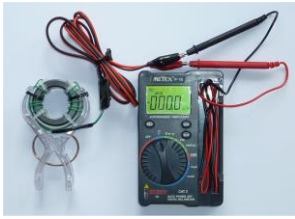
It is commonly said the proper diameter of the coupling loop is about 1/5 of the diameter of the main loop. If the main loop becomes larger, it also needs to be made larger. It would be OK to make it larger and adjust the degree of coupling by elongating and/or rotating it.

Capacitor Can Heat Up

If you build your own capacitor by sandwiching insulating material as a spacer, the electric field will be concentrated there. Since plastics act as dielectric, they will generate heat for QRO operations if they are brought into close contact. Polycarbonate does not get too hot, but ABS does, and may carbonize over time.

Suppressing Common Mode Current

The MLA is a balanced antenna, and a common mode choke such as a float balun near the feed point is a must. The current returning to the outside of the outer conductor of the coaxial cable causes RFI (radio interference), and the transmitter may be damaged in high power op.



It would be good if you use an RF current meter like the one designed by JF1DMQ Yamamura-san.

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