Desktop MLA

By Tak Asami / W6SI
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This text is a re-write version of what I wrote to enter the Desktop MLA antenna in the 2024 QST Antenna Design Competition, sponsored by ARRL. The credit goes to the original inventor of the antenna, Hajime Nakajima (JR1OAO).
This is not a direct copy of the original manuscript, as the copy / distribution right belongs to ARRL. But the publication is expected to be shortened edition, I decided to re-write it with more and recent details added to share with the small loop enthusiasts.
Therefore while this document has the same title and the subject covered, it is considered a separate, independent writing.

I would also like to express my gratitude to Nakajima and the rest of the MLA48 group for their cooperation in creating materials, simulations, and test data, and to state that I am honored to have been able to participate in this project.

What is Desktop MLA?

Installing shortwave antennas is a serious challenge these days. An antenna installation is subject to various constraints, making the set-up of an even the simplest antenna to operate on HF frequencies for many hams.

This article introduces a small, flexible loop antenna that covers all HF bands and can be placed on a small table. While it may look like a toy, it's a highly practical, all-band antenna with excellent performance and practical utility.

The antenna consists of a base unit in a plastic case and a 1m diameter loop antenna element made of LMR-400 coaxial cable supported by a PVC mast. The loop element can be replaced with different sizes/loop diameters to suit various bands and efficiencies.

Key features include:

- Supports multiple configurations covering the 80-10m amateur bands
- Supports over 100W of transmit power
- Ensures reliable and stable operation even in environments with limited antenna space and portable operations

- Built-in matching system supports remote manual control and automated tuning
- Avoided using costly and heavy parts (such as Vacuum Capacitors) to keep it affordable

Small loop antennas (often referred as “magnetic loop antennas”) are not new. However, building them can be challenging. They are typically limited to low output powers of around 5-10W, due to required high-voltage tolerance for relatively large capacitors. Their low radiation efficiency and narrow usable SWR bandwidth turned off many experimenters.

Many thought they are impractical. Lack of practical products isn’t helping.

Photo 1 Example oif Desktop MLA Installation

The Desktop MLA solves most of these problems. It is not an one-off experiment. The inventor himself has built several units and shared with multiple individuals, demonstrating their reproducibility, ease of use, and excellent performance. (Photo 1: Example of desktop MLA installation) Many users have reported excellent operability. With the exception of a custom-made variable capacitor, no hard-to-obtain parts or complex manufacturing techniques are used, making it a viable option for DIY builders / experimenters.

Please note that none of the materials presented here is commercially available for purchase at this time. The intent of the paper is to show such implementation is possible and actually built. To encourage those willing to guide through how they can do it.

Basic Structure

The circuit diagram below (Figure 1) shows the assembly and wiring of this antenna.

The capacitor, small DC motor, and position-sensing VR are housed in a base unit (a plastic case 22 cm wide, 22 cm deep, and 11 cm high). A loop element, i.e., a loop of coaxial cable, is attached to the top. This is supported by a 32 mm PVC pipe slightly over 1 m high (depending on the size of the element used).

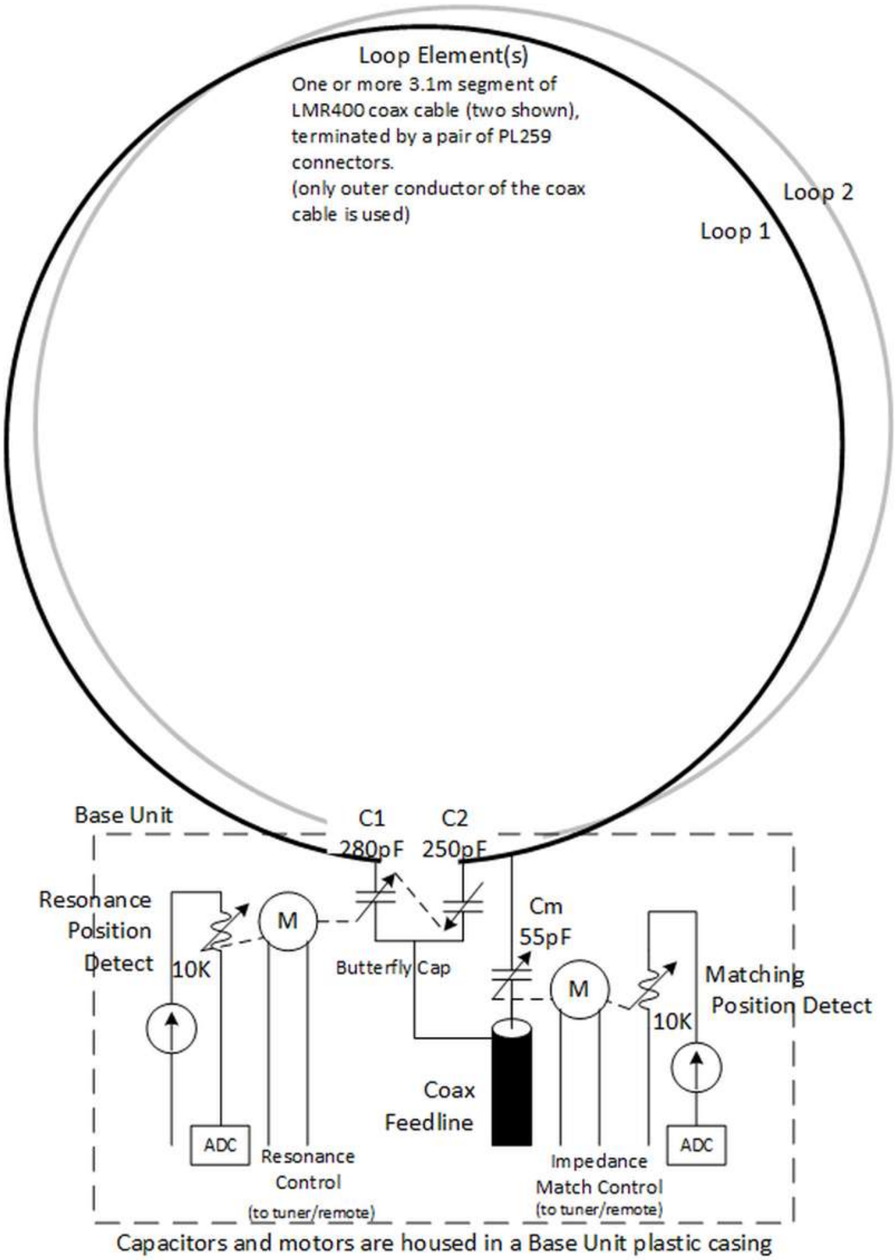


Figure 1 Simplified Schematic Diagram of Desktop MLA

Loop Configuration

The loop element can be easily modified to suit operational requirements. Photo 2 shows a

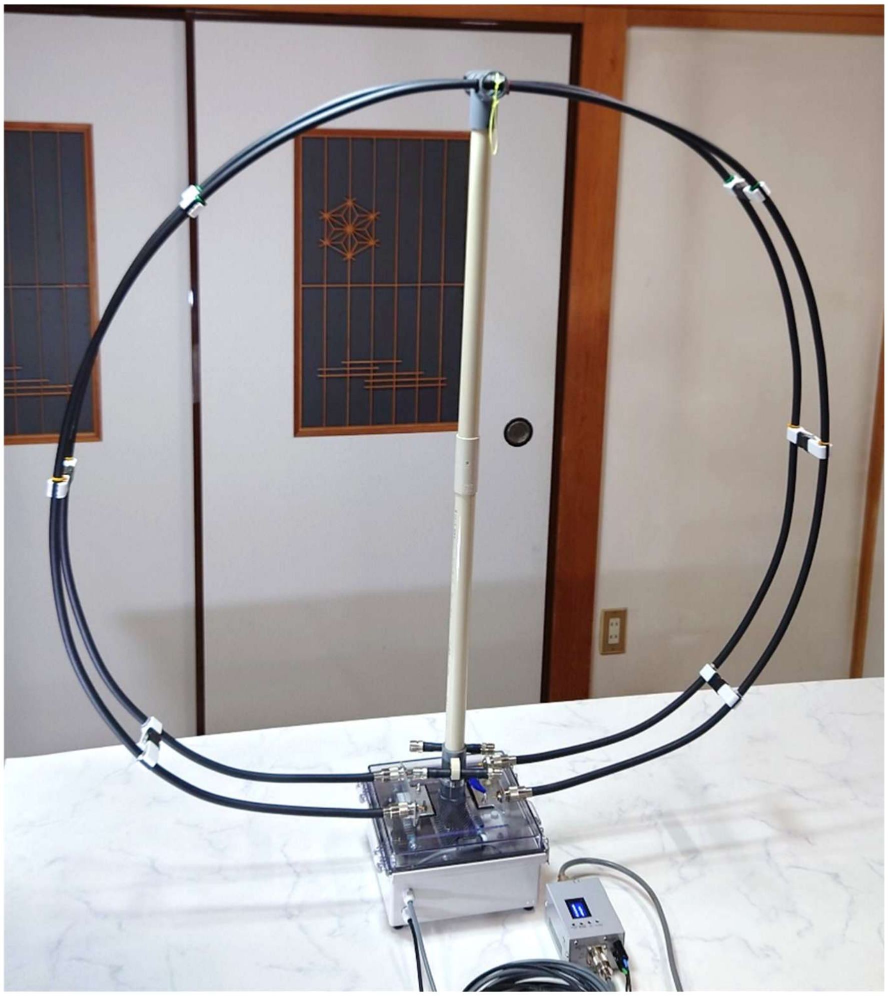
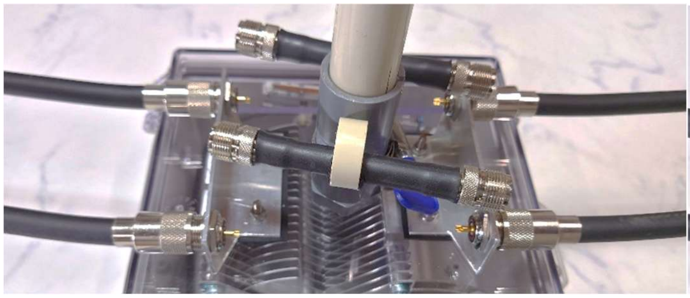
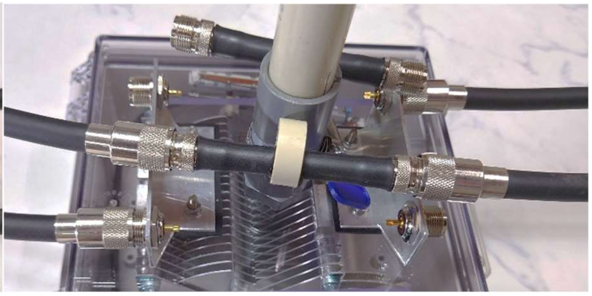


Photo 2 Dual loop, 1m diameter configuration of Desktop MLA

Two loops side-by-side. Depending on how it is hooked up on the base unit, it can be:
(left) Two parallel single loops for 20m to 15m bands, or
(right) One series two-turn loop for 40m and 30m bands

standard configuration with two 1m diameter coaxial loops connected in parallel to the base unit, a common configuration for bands from 20m to 15m. Using parallel elements is known to improve radiation efficiency compared to a single loop.

The configuration in Photo 2, as it is designed, cannot support high bands (12m, 10m bands and above) because the minimum capacitance of the tuning variable capacitor is too large. To support high bands, a shorter loop element is used, as shown in Photo 3. This configuration is sufficient for bands up to 6m.

To support lower bands, you only need to increase the element length. This can be achieved by using a longer coaxial element or by connecting two or more loops in series to double the effective length (i.e., double or triple winding). The top of the base unit has two L-shaped brackets, each with two M-type coaxial connectors. As shown in the bottom of Photo 2, various loop configurations can be created.

Photo 4 shows how a three-turn configuration with a longer element and the same diameter can be used to improve efficiency in the low bands. Single or multiple turns, there is a practical limit on how large the loop can be made, as keeping the loop structure can become challenging. An example of an antenna with a larger diameter is shown later in the "Actual Operation" section.

Photo 3 Two loop, 30cm diameter configuration for 6m band

As it is shown here, using different coaxial elements, connected differently allows you to easily cover a variety of circumstances.

A point to be made here, is that applying an optimum configuration for a given operation band is the most advisable. Early in my development project, I tried to find a single loop antenna that covers all bands. After much study and experiments, I learned there is an optimum range for given frequency in terms of size, performance and usability. This flexibility of

Desktop MLA makes it ideal for the optimum utility by enabling configuration changes simply.

Photo 4 Single Three-turn loop configuration for 80m band

Configuration change does not require any tools. The feed point is readily reachable at the table top, or not-so-high tripod. Because the loop antenna in vertical orientation (with respect to ground), it is pretty much ground independent and does not require height to radiate effectively. This is another distinguished feature of this antenna.

Note the loop element utilizes only outside conductor of the cable. Inner conductor is not connected. I use LMR400 cable because of its thick solid inner conductor keeps loop shape self-supportive and does not require horizontal support at the middle.

When two or more elements are used in parallel, the distance between the elements is optimal if kept between 50mm and 80mm. Closer or further tend to affect the radiation efficiency negatively. The cable management and top support makes use of 3-d printed custom brackets. For two loop elements, six cable spacers and a top support part is needed.

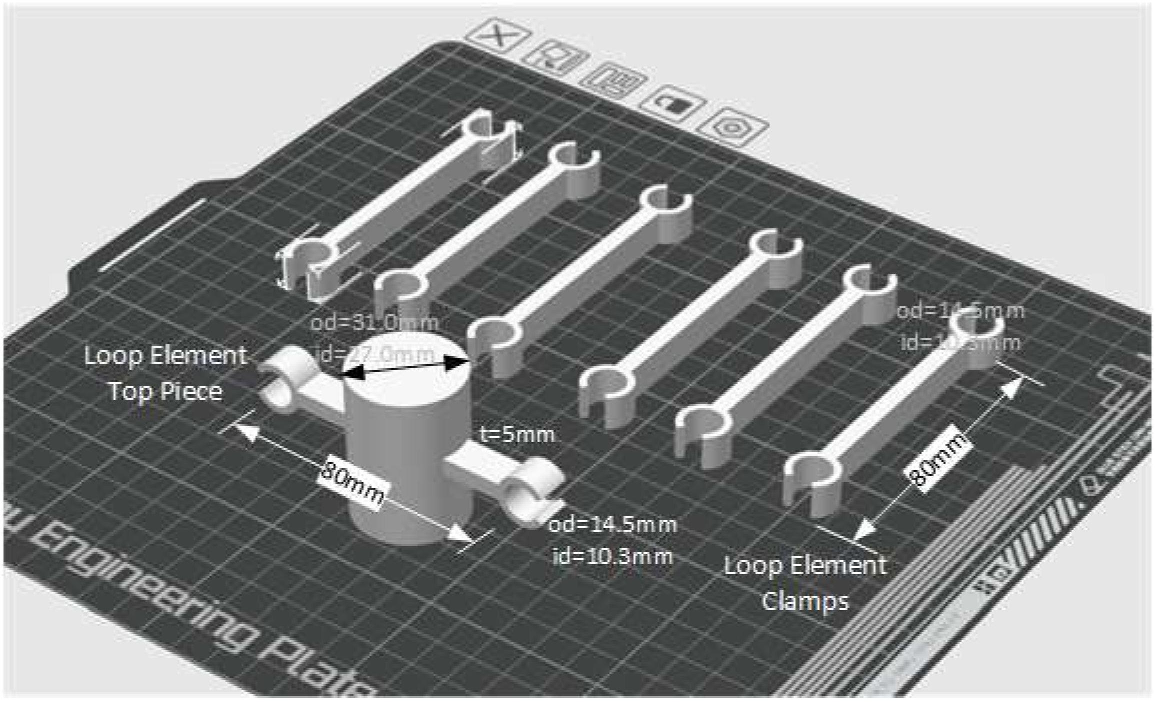
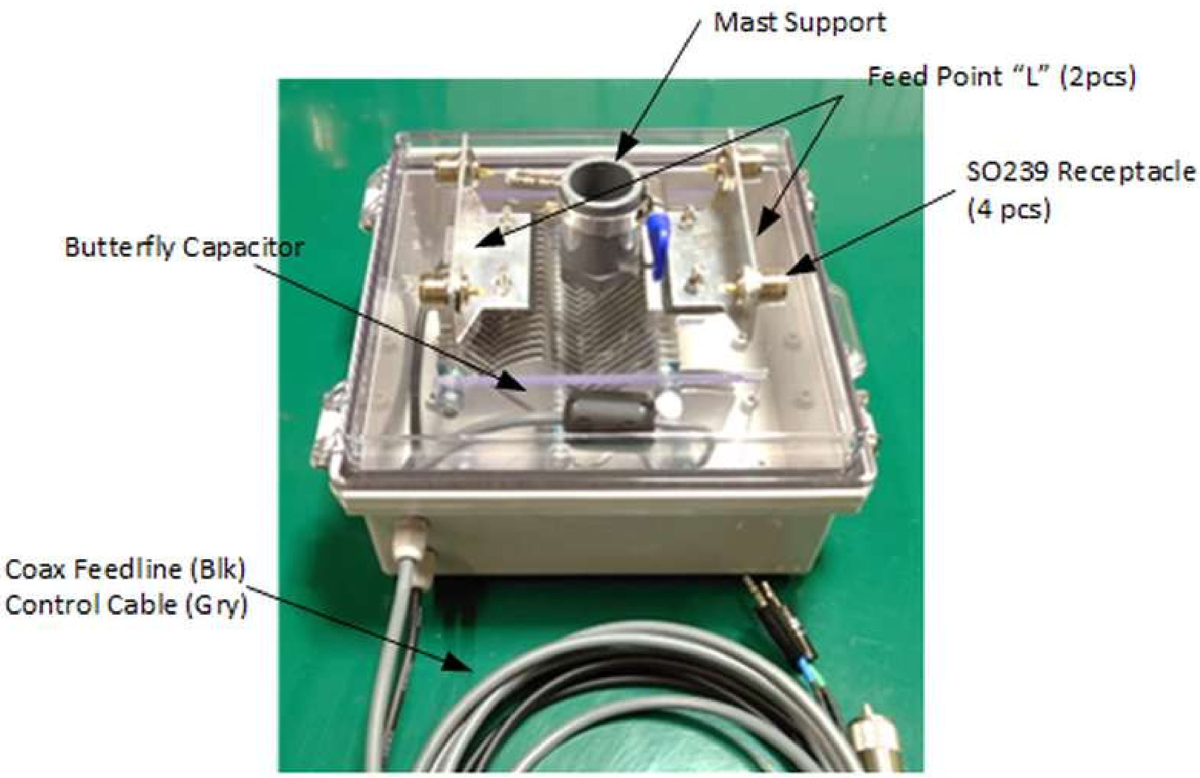


Photo 5 3d Printed Element Clamps

The Base Unit

The base unit houses tuning element for the system.
The matching technique used here is referred by Mr. Nakajima as "C-Coupled". It is derived from original Patterson match. Notice it does not use a small coupling loop typical of MLA implementation. C-Coupled match allows heavy components like the tuning capacitor to



be concentrated at the bottom. This avoids making the loop antenna top heavy, enabling a unit so compact to place on a table top without support. Referring to Figure 1, C1 and C2 are wired in series to resonate the loop to the transmission frequency. Parallel combination of C2 and Cm is used to match the feedline impedance (50Ω) to the radiation impedance of the loop (~0.1Ω). This capacitor is unique in that three capacitors are integrated into a single component. It has two axes of rotation, for C1/C2 and Cm, to perform resonance and impedance match, independently.

CAUTION!!

One of the important points to note is that the outer conductor of the feedline coax is NOT the neutral point (Not at the ground potential). This could cause some common mode

Photo 7 Motirized and Position Detect mechanism

current on the feedline to affect matching and radiation. It is strongly recommended to insert a good common mode filter on the feedline cable.

During transmission, very high RF voltage (~4KV at 100W transmission) develops and large RF current (~10Amp) flows through the loop element, therefore it is not advisable to perform tuning manually, for RF safety's sake.
The unit is equipped with a pair of small DC motors to turn the capacitors remotely.
A remote control with batteries and switch box is easy to build and operate. The motor mechanism also has slider potentiometer synchronized with the rotation, so the capacitor

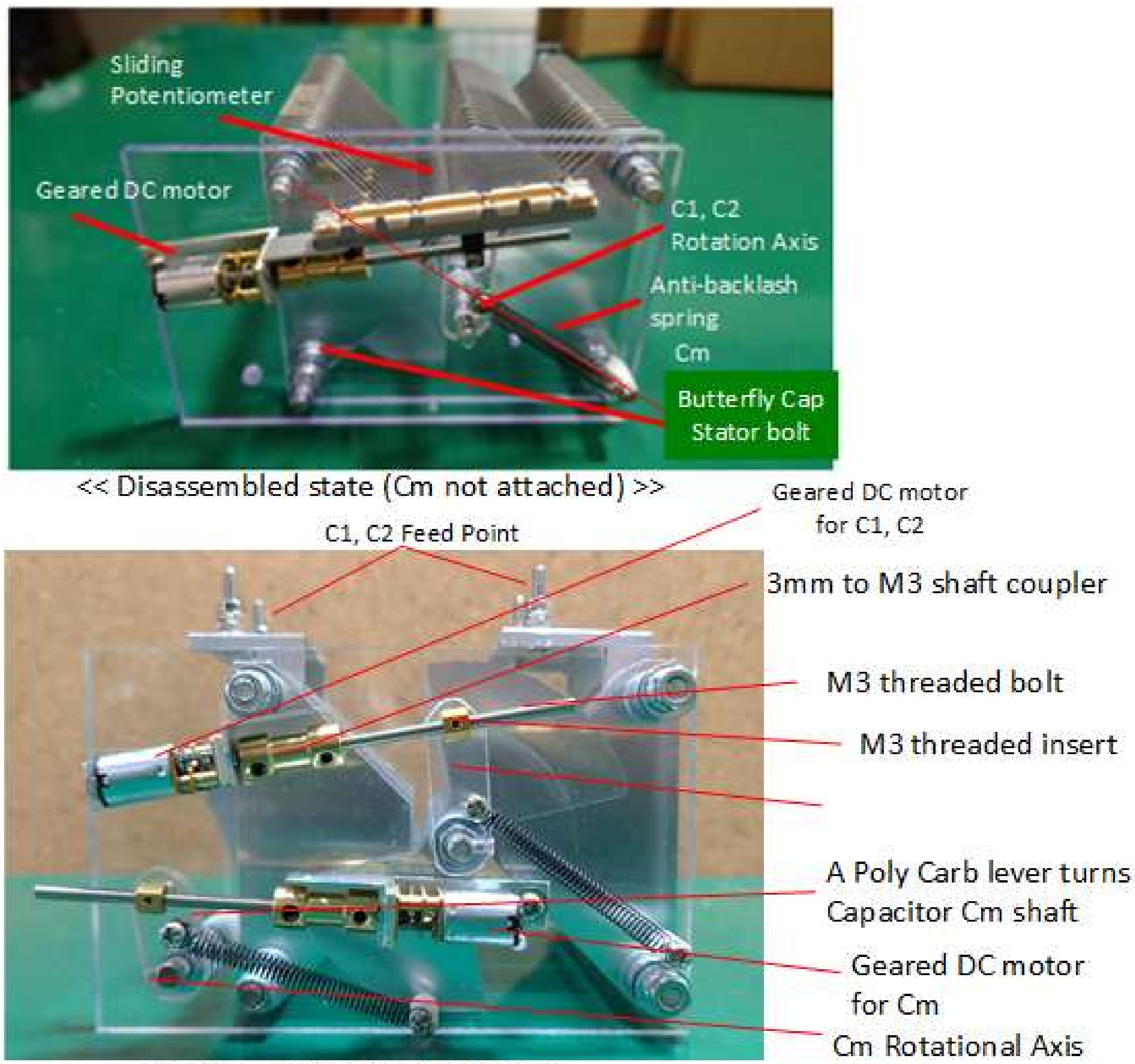


Photo 6 The Base Unit

position can be sensed by measuring the resistance. It is designed to be used with an auto tuner.

Auto Tuning and Manual Remote

Because of the high-Q nature of small loop antenna, the usable bandwidth at a given point is very narrow. The slightest change in transmission frequency calls for re-tuning. It is also subject of temperature / humidity change even without frequency shift. While this is not a big problem for digital mode where you tend to stay in a narrow frequency range, more agile modes such as SSB, CW and RTTY can benefit from automated tuning.

Photo 8 DPAT, the auto tuner for Desktop MLA

Mr. Nakajima, working with another colleague, Mr. Shuichi Hashiba, JA1BQE, built an automatic tuner named "DPAT" (Phto 8). This is a sophisticated system that continuously monitor the RF voltage and current through the feedline coax during transmission, to continuously adjusting the match full time. But that is a different subject and will not be discussed here in detail.

The local group here in California is also developing a similar tuning system; it is still a work in progress but we hope to complete it "soon". We will be announcing it when ready. The point here is the Desktop MLA has built-in motorized mechanism to be integrated with such automated tuning.

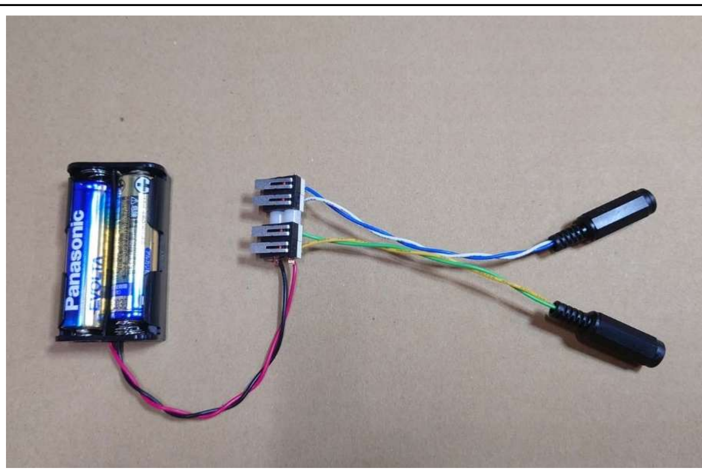


Photo 9 Simplified AA battery based Manual Remote

Without the auto tuner, the mechanism can be utilized by AA-batteries powered switch to facilitate manual tuning. By applying 3V DC to two motors in the base unit, you can turn the variable capacitor to the desired frequency and impedance to match. See Photo 9.

Building the Base Unit

As mentioned above, the base unit houses the resonant and matching capacitors, the internal motor drive mechanism, the element mounting bracket, and the upper mast support.

All signal paths ("L" brackets and capacitors) are made of aluminum. The top panel contains two "L" brackets with two M coaxial connectors. The brackets are bolted directly to the butterfly capacitors on the bottom panel with two M5 screws, shorting the outer mesh of the coaxial cable to the capacitor. The inner conductor contacts are open. A 70 mm long, 32 mm diameter PVC pipe is bolted to the center of the top panel with four M4 screws. (See Photo 6)

The capacitors are actually attached to the top lid with M5 screws and are not fixed to the bottom of the case. The feed coaxial cable and control cables are routed as shown in Figure 1. If an auto-tuner is not being used, the position detection output is not used.

Butterfly Variable Capacitor

One of the key components of the matching system is a butterfly variable capacitor with a third small built-in capacitor. As shown in the circuit diagram (Figure 1), the C matching system consists of three variable capacitors. Two series-connected capacitors, C1 and C2, function as tuning elements. The third, Cm, is an impedance-matching capacitor. By separately controlling antenna resonance and impedance matching, the highest level of matching, near SWR=1.0, is achieved in most cases.

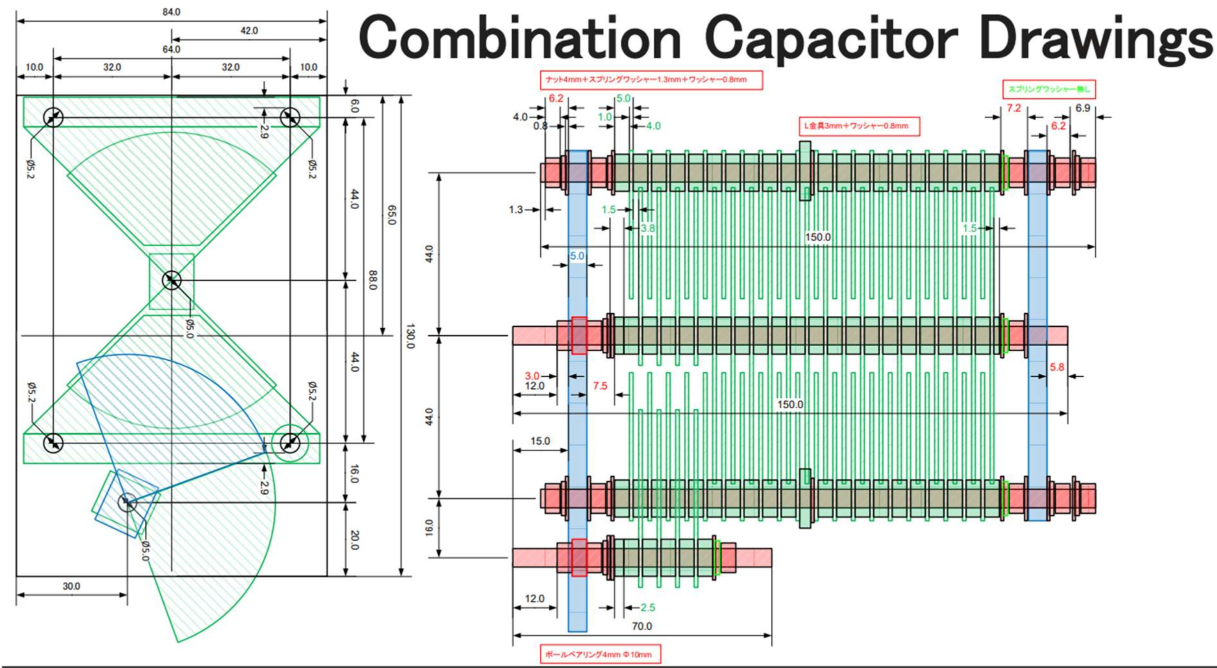


Figure 2 Combination Capacitor Drawing

The three-capacitor unit used in the design is unique to this system and was built by members of the MLA48 project group. Normally, in such cases, two 280pF butterfly variable capacitors (as shown in Figure 2) and another small variable capacitor (55pF) are used. However, Mr. Nakajima improvised a biaxial variable capacitor using unused blades (removing about three rotators on the C2 side to make it 250pF). Though this is not immediately available for everyone, but anyone with an access to this level of tooling is encouraged to try.

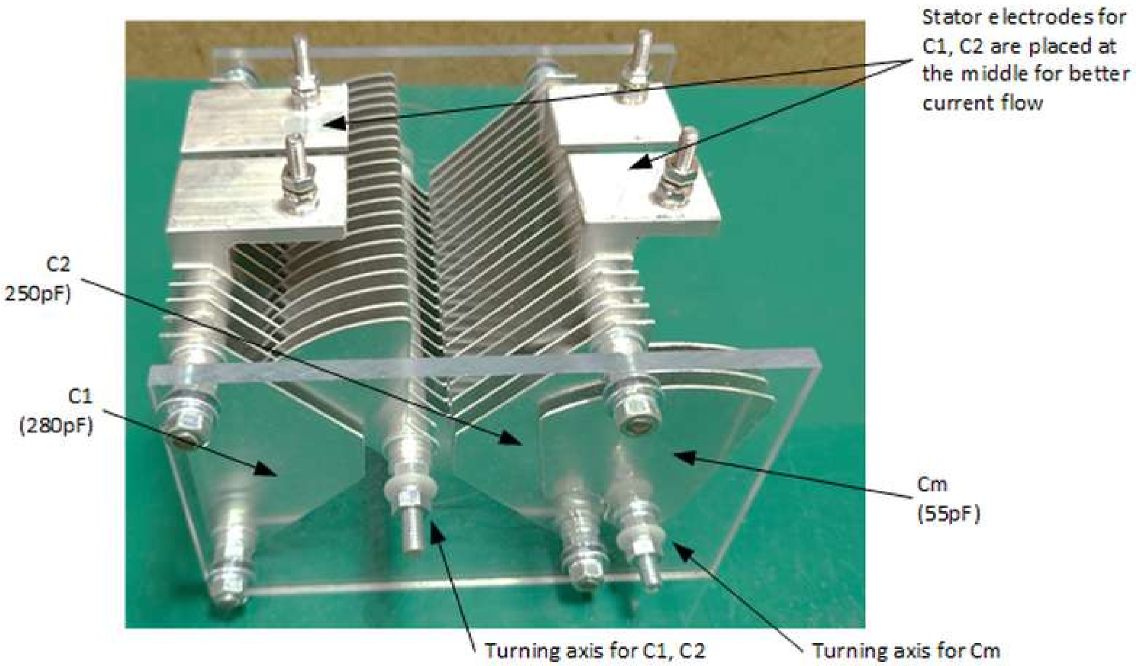


Photo 10 Structure of a Combined Butterfly Capacitor

Making these capacitor blades requires special skills and tools, but if you prefer to build your own, butterfly capacitor kits without integrated Cm are commercially available via eBay and other sources.

The structure of the variable capacitor is shown in detail in Photo 10. You can see the tuning variable capacitors (C1 and C2) and the matching variable capacitor (Cm). C1 and C2 share a common rotating shaft and are rotated by a DC motor. Meanwhile, Cm (consisting of three rotors half the size of a butterfly variable capacitor) is rotated by a separate motor using a similar mechanism, as shown in Photo 7.

High-Voltage Tolerance Required of the Capacitors

One of the reasons most MLA is limited to low power is the high-voltage tolerance required of tuning capacitors. This butterfly-type capacitor has a 1.5mm gap between the stator and rotor blades. The breakdown voltage of air is said to be 3.0kV/mm. Therefore, the estimated DC withstand voltage of C1 and C2 with a 1.5mm clearance is 4.5kV. During 100W transmission, the gap voltage between the loop elements can exceed 4kV. It has also been noted that RF high voltages are "nastier" than DC. That is, RF voltages can zap at voltages lower than 4kV. However, because C1 and C2 are connected in series, only half the voltage, 2kV, appears on the capacitor blades. To provide a margin of over 100% RF "nasty" coverage, the design is usable for a 100-watt transmission.

Simulations and Field Testing

For the project, all simulations of this antenna were performed using S-NAP Wireless Suite® electromagnetic field simulator from MEL Inc., Japan, offered to us by Mr. Ogawa, JA5KVK. This simulator offers a more detailed analysis of near-field interactions than other common simulators such as EZNEC and MMANA. It is necessary to understand the behavior of this type of antenna.

This paper lists the S11 (equivalent to SWR) for impedance matching, and radiation efficiency (please note this is different measure from those "antenna gain") for specific configurations. While the effective SWR bandwidth is very narrow, this is not considered an issue because the antenna is easily adjustable. Please see "Antenna Tuning" above.
When S11 is -30 dB or less, the VSWR is 1.05 or less, which is perfectly matched in all

practical sense. When S11 is -9.5 dB, the VSWR is equivalent to 2.0. This roughly defines the "usable" bandwidth of this antenna.

Simulation Overview (Configuration, Radiation Efficiency, and Actual Construction):

- 7MHz, Single 2-Turn Loop, 1m Diameter — Radiation Efficiency = 13.9%
  (Photo 2, Right)

- 7MHz, Single 2-Turn Loop, 1.3m Diameter — Radiation Efficiency = 23.2%
  (Photo 2, Right)

- 14MHz, Two Parallel Single-Turn Loops, 1m Diameter — Radiation Efficiency = 54.1%
  (Photo 2, Left)

- 21MHz, Two Parallel Single-Turn Loops, 1m Diameter — Radiation Efficiency = 83.65%
  (Photo 2, Left)

- 28MHz, Single 2-Turn Loop, 70cm Diameter — Radiation Efficiency = 76.5%
  (Photo 3, Left)

- 3.5MHz, Single 3-Turn Loop, 1m Diameter — Radiation Efficiency = 2.45%
  (Photo 4)

Each configuration was tuned for an SWR < 1.1 in both the simulation and the actual implementation.

Simulations show that the antenna is completely omnidirectional, except for the hollow top at low frequencies. This means that a vertically oriented loop is suitable for both local and DX communications.

The simulations were performed in free space with the loop plane horizontal. Simulations with ground in this manner may affect the radiation. However, in actual operation, the loop plane is often used perpendicular to the ground, making it less susceptible to ground influences. Therefore, the directional characteristics of this free-space simulation are comparable to those of actual vertical operation.

The simulated radiation efficiency for two 1-m diameter loop antennas ranges from 14% at 7 MHz (one two-turn loop) to 76.5% at 28 MHz (two parallel loops). The longer the loop, the higher the efficiency. This means that the same antenna changes its behavior depending on the frequency. It can go from primarily magnetic to hybrid magnetic-electric type depending on the frequency.

Author's Test Results

Prior to submitting the antenna for the competition, I conducted actual tests using my own desktop MLA. The results were largely consistent with those reported by Mr. Nakajima and Mr. Ogawa's simulation results, demonstrating good repeatability. In summary,

- Two parallel 1-turn loops with a diameter of 1 meter were tuned from 8.9 MHz to 24.2 MHz. Tuning was confirmed on the 30m, 20m, and 15m bands. The 12m and 10m bands were not tested because a 70cm short loop element was unavailable.
- Only one 2-turn loop with a diameter of 1 meter was used and tuned from 4.75 MHz to 9.5 MHz. Tuning was confirmed on the 40m band. Though not actually tested, it should tune to 60m band just fine.

Each amateur band within the tuning range and tested, exhibited low SWR. However, since the tuning was performed manually (due to the extremely hot weather on the day), it was not necessarily "perfectly tuned," although it should have been possible.

With these two configurations, this antenna provides continuous coverage from the 40m to 15m bands. If the loop element diameter is reduced to 70cm, it should be possible to tune on 10m and possibly 6m without any problems.

I have not yet tried the 80m band using a 3-turn loop, mainly due to a lack of cable in stock.

At this point, I should repeat the point I made earlier; while MLA can be tuned to wide range of frequencies, the operating performance may not be desirable at edges. For example, 3 turn, 1m diameter loop simulated above, can tune to 80m band but at 2.5% efficiency, no one can hear you. It is best to adjust the optimum configuration for each operating band. Desktop MLA makes this change of configurations easy.

While we are on the subject of radiation efficiency, I can almost hear some say "look at those low efficiency, this small loop is of no use". In my limited experience, antenna with (feeling, but maybe un-scientific) 25% or better efficiency is very useful and workable. In fact, many non-MLA antenna in use today are actually not much better in practice.

Actual Usage

This section shows various setups used on this antenna for multiple purposes.

For portable setups, since it disassembles easily between the base unit and the loop elements, it is easy to carry and deploys quickly. If there is a picnic table near operation site, base supports like tripods are not necessarily needed.

Permanent or semi-permanent deployment is easily done. Following is the usage pictures of the antenna, sent from actual users. The pictures and name are used with permission from the individuals.

Hiroaki Kogure (JG1UNE) Installed on his Apartment Veranda

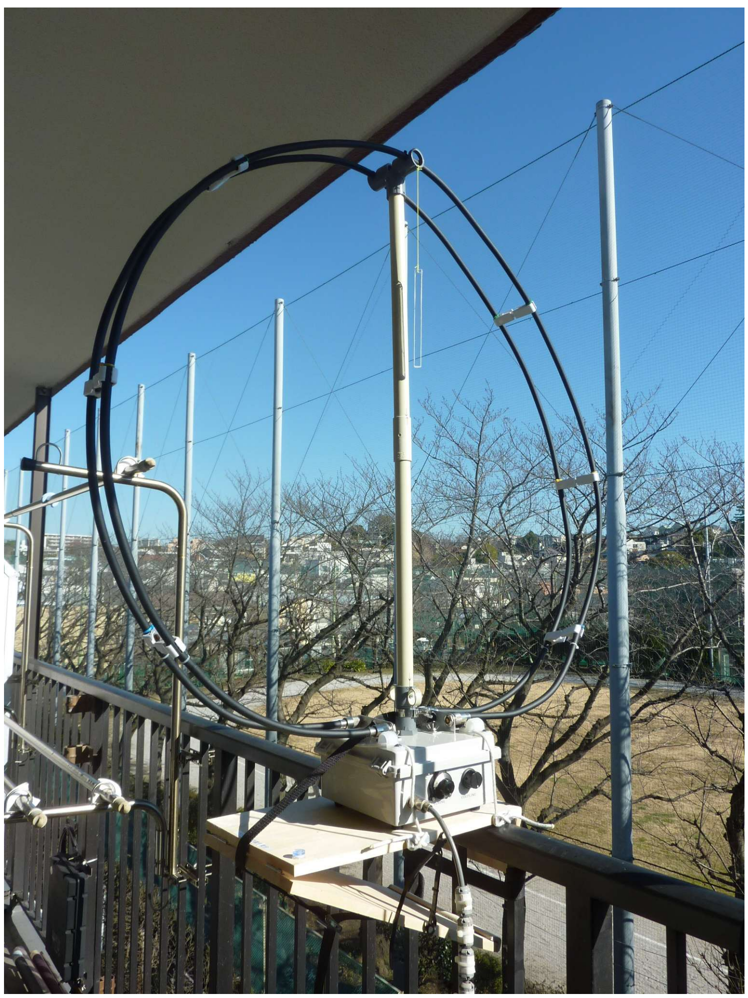


Photo 11 JG1UNE Dr. Kogure's Balcony Installation

Dr. Kogure installed the Desktop MLA on his balcony, using a parallel 1m diameter loop for frequencies from 10 to 21 MHz. He said, "I tried calling CQ on 21 MHz at 80W, and was startled when I was suddenly called by station RK4FF (south of Moscow). While some bands had poor propagation in the afternoon, I was able to communicate with Asia (December 2021)."

Mr. Katsuyoshi (JS1EYR) set up his MLA at veranda in his high rise (11th floor) condo. He is active on 20m and 15m bands. At 30W power, he gets good contacts throughout Japan.

Photo 12 Desktop MLA deployment at JS1EYR (Courtesy of Mr.Katsuyosi Akazawa)

Mr. Yonosuke Harada (JA3UOQ) ‘s DXCC-achieving MLA setting

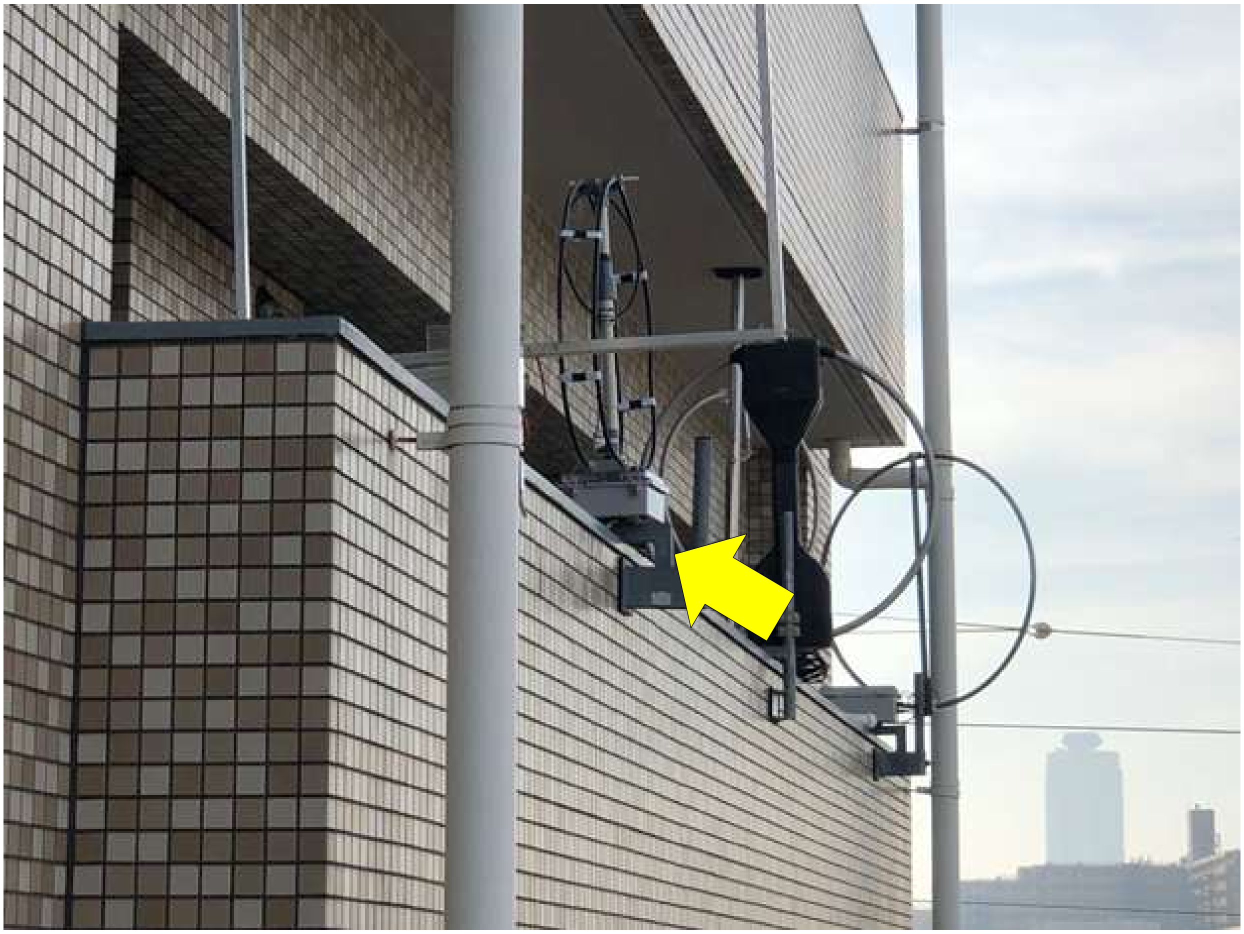


Photo 13 Mr. Harada (JA3UOQ) MLA Antenna Farm

Being one of the most active MLA users, he has arrays of different small loop antennas deployed at home. The desktop MLA is placed at the front (left most, behind a square loop).

He is one of the practitioners of MCB (MLA-Coupled Beam) antenna, that couples two or more small loop antenna to form strong directional pattern and gain. This is a separate subject worthy of discussion.

He has been using small loop antenna since 2016 to challenge DXCC. He achieved it on 2018. He operates 100Watt station using these small antennas. As of May 2022, he has made 10,500 contacts, mostly in digital and CW. All on his array of small loops.

JR1 OAO's own desktop MLA mobile operation

Photo 14 JR1OAO's Mini Van Mobile Set up

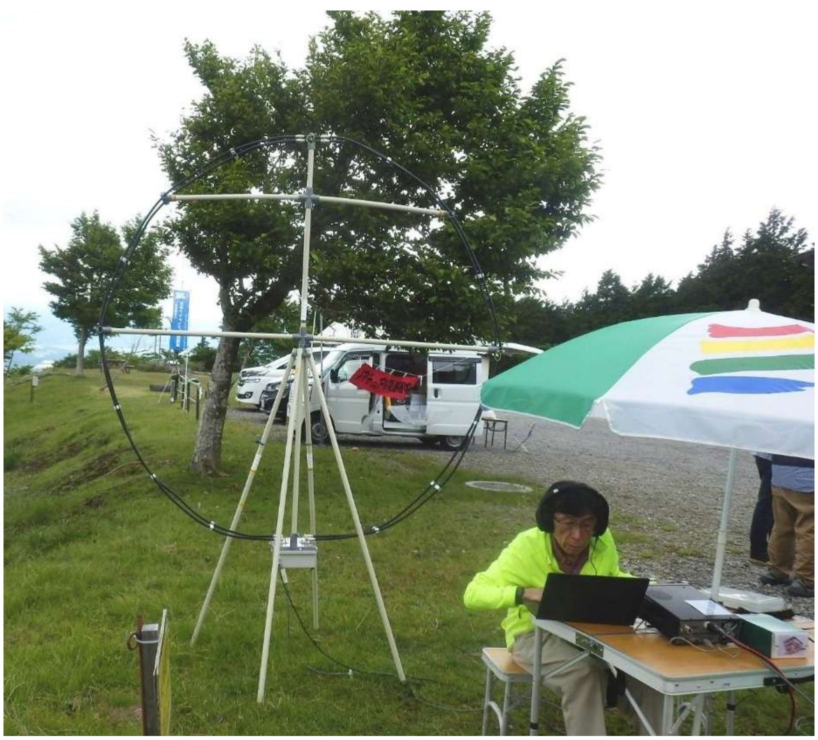
Mr. Hajime Nakajima (JR1OAO), the inventor of the desktop MLA, puts his master piece on the top of his minivan. Placed vertically on the roof provides for a good portable operation experience without the hassle of setting up an antenna with good height.
Works well but it is for strictly stational operation; it is hazardous to drive with the loop erected vertically, and a horizontally mounted antenna does not work well at all.

JH1YMC Club portable operation at Lake Yamanaka

Photo 15 JH1YMC Portable Operation with 2m diameter MLA for 40m band

JR1OAO Mr. Nakajima and fellow JH1YMC (Yokohama Midori Club) members operated on 7 MHz using a Desktop MLA with a 2m diameter element at the remote location near Lake Yamanaka. That was his latest large-loop development, aimed at improving the radiation rate on the low bands.

He said, "When I travel, I carry the PVC pipe and PVC stand in a golf bag and can set it up/take it down in under five minutes. I learned that this PVC stand can support (or "hang") antenna with any diameter." It is amazing that he was able to carry a working 7MHz antenna all the way to a good location at an altitude of about 600m and set it up so easily and quickly.



Mr. Harada, JA3UOQ, who actually operated the antenna, said he was able to QSO with around 10 stations in an hour using 7MHz 50W SSB (not FT8).

My On the Air Impression

It is often stated that small loops are not practical for DX due to low radiation efficiency. Narrow bandwidth makes it hard to use on frequency agile mode like SSB, CW and RTTY. Difficulty supporting high power transmission also limits the DX opportunity.

Desktop MLA is developed to overcome these shortcomings to make this remarkable antenna infinitely practical. Actual usages are presented here as proof.

Final Points:

First of all, the antenna "hears" very well.

Second, the low radiation efficiency is not a killer. As such, it is not much worse than many of the shortened antenna with insufficient height (many of us just don't know that fact). It certainly is not a miracle antenna beating out big beam kilowatt stations. But like any other antennas, operation skills count. In general, if I can hear him, there is a good chance I can work him. Given a good propagation, just a few watts transmission can reach almost everywhere on Earth.

Conclusion

The remarkable antenna, that is easy to deploy, easy to work with, workable performance in very restrictive environment, is presented.
Please note this is not a one-off experiment. But it is very reproducible design, and the inventor JR1OAO encourages anyone who can build this to try and keep improving it.
Through this discussion, I hope to have impressed upon the reader, the usefulness and craftsmanship of the invention.

Annex:

The simulation summary and actual test report are recorded in separate files.
They are found in the same part of my web site, http://w6si.com

"DesktopMLASims.pdf", September 16, 2024

"InitialTuningTestOnDesktopMLA.pdf", April 17, 2024