MFJ Manual Loop Tuner Considerations

Introduction

MFJ manual loop tuners are versatile, high-efficiency loop tuners that can turn any loop conductor into a high-efficiency multi-band transmitting loop antenna system. This paper has been prepared to provide the reader with some loop antenna theory, and loop mounting and antenna considerations as specifically applicable to MFJ manual loop tuners.

MFJ Manual Loop Tuner Products

There are two types of MFJ manual loop tuners. The "QRO series" consist of the MFJ-933, MFJ-935B and MFJ-936B all rated at 150 watts maximum power. The MFJ-932 "QRP" loop tuner is a much smaller, lower powered unit rated at 50 watts maximum.

The MFJ-933B, MFJ-935B, and MFJ-936B utilize the same basic loop tuner circuitry, but there is a difference in size and features. The MFJ-933B and MFJ-935B tuners measure 6 ¼" x 9 ¼" x 5 ¼" and cover 60-10 meters. The MFJ-933B has no internal metering, while the MFJ-935B has an RF current meter for tuning. The MFJ-936B is a physically larger tuner (10 ¼" x 9 ¼" x 5 ¼"), and includes both an internal RF current meter and a SWR/RF Power Meter – and also adds 80 meters to the band coverage.

The MFJ-932 loop tuner has dimensions of just 3" x 4" x 1½", making it a convenient size for portable/camping/QRP operation. No metering is included in this unit.

Some basic loop antenna theory

A small transmitting loop antenna has a conductor length or circumference of less than 1/4 wavelength (λ/4). When properly designed, the small loop can have performance close to, or even exceed that of a full-size antenna depending on mounting location. The small loop radiation pattern is maximum along the plane of the loop, with sharp nulls perpendicular to the plane of the loop. Loop length (circumference) approaching λ/4 and shaped as a circle is the most efficient configuration. A circular loop has about 10% higher gain than the other shapes as gain is directly proportional to the area enclosed by the loop. Small loop antennas also enjoy significant rejection of undesired signals and noise, height above ground is not critical, and no ground or radials are needed.

Unfortunately, the advantages do not come without trade-offs. Tuning is very sharp, bandwidth is very narrow, and efficiency can suffer unless care is taken in the design and set-up of the loop system. As an example, there can be thousands of volts generated across the tuning capacitor due to the high-Q circuit. And radiation resistance is very low because the loop is small compared to a full-size antenna. So very high RF currents will flow in the loop – on the order of 10's of amps at the 100-watt power level.

To mitigate these issues, one must use large-gauge low-loss antenna conductors, minimize all loop connector interfaces, and use wide-spaced air-variable tuning capacitors which have no mechanical wiping contacts in series with the RF signal. See the loop antenna chapter in the ARRL Antenna Book for more detailed information.

Loop Tuner Operating Locations

As the loop antenna is elevated, its efficiency improves. At very low heights, close coupling to the ground can cause detuning and losses due to current induced into a mirror image of the loop below the surface, with resistance of the image loop proportional to soil resistance. Another loss component is due to current flowing in the soil via capacitance between the loop and soil surface.

An operational height equal to half the diameter of the loop antenna is recommended to prevent detuning and excess ground losses. This means that the loop tuner should be at that recommended height, since the MFJ manual loop tuners are connected to the bottom ends of the loop, regardless of the loop antenna configuration. Finally, to minimize ground losses, the loop should be mounted vertically.

For operation on 14 MHz and higher frequencies, ground losses are minimal so it is fine to operate near normal ground level. For the 7 MHz band and lower, ground losses can be more of a problem, so elevated operation (i.e. from a second or higher floor) can result in improved performance.

MFJ Loop Tuner Design Discussion

All MFJ loop tuners use a butterfly loop-tuning capacitor, which has no rotating contacts in series with the high-current RF loop signal. For the 150-watt tuners, MFJ manufactures their own butterfly air-variable tuning capacitors (MFJ-19 and MFJ-21). Number 10 brass screws hold the capacitor assembly together, and two of these screws extend through the case and serve as antenna connectors to essentially make the tuning capacitor part of the antenna. The entire capacitor plate connectors and brass screws on all four sides are paralleled with separate bus wires to further reduce losses. Transmitter matching is accomplished with another air-variable capacitor. So, only high-Q air-variable capacitors are used in the tuner design. Finally, a vernier drive is used with the butterfly tuning capacitor to ease the tuning process.

While the MFJ-932 QRP Loop Tuner is rated at 50 watts maximum power, this doesn't negate the necessity of requiring very low loss components and connections. Like the larger loop tuners, the MFJ-932 uses a more expensive air-variable butterfly tuning capacitor which eliminates any wiping contacts in series with the RF. And transmitter matching into the loop is also accomplished with an air-variable capacitor. So again, only high-Q air variable capacitors are used in the design. No vernier drive is available do to the compact size of this tuner, so tuning is "touchier" than on the larger loop tuners.

Loss Considerations

When coupled to a low-resistance loop conductor such as a copper strap, copper tube, or large gauge copper wire, MFJ loop tuners can provide a high efficiency transmitting loop antenna system. However, particular care must be taken to reduce system losses. The primary causes of loss are due to the antenna conductor itself, and losses due to mechanical interconnect points.

As discussed earlier, the radiation resistance of a small loop antenna is very low. From the ARRL Antenna Book,

$R_{rad} = 3.12x10^{-4}(A/\lambda^2)^2$

Where: A = area of the loop in square meters
λ = wavelength in meters of the operating frequency

So, as an example, a 10-foot loop on 20 meters has a radiation resistance of only about 0.1 ohms! This highlights the necessity of minimizing other system losses.

Another ARRL Antenna Book equation permits calculating the AC loss resistance of various copper conductors.

$R_{AC}(\Omega/ft) = 9.96x10^{-7}(f)^{1/2}/d$

Where: f = frequency in Hz
d = conductor diameter in inches

Again, a few examples highlight the conductor considerations. A 10-gauge copper wire has a diameter of about 0.1 inch. It's AC resistance will be approximately 0.037 Ω/ft on 20 meters, or 0.37 ohms for a 10-foot loop. Therefore, assuming no other system losses, the efficiency of a 10-foot loop on 20 meters will be:

$Eff = R_{rad}/(R_{rad} + R_{AC}) = 0.1/0.47 \cong 0.2$ or 20%. I.e., 80% of your power is lost!

By going to ¼" diameter copper tubing (refrigerator ice-maker tubing), the efficiency will double to about 40%.

The only mechanical interconnect points in the MFJ loop antenna systems are the actual interconnection points where the loop attaches to the loop tuner. Care must be taken to ensure that these two connection points are kept very clean, and that the wing nuts are tightened snugly. Cleaning is particularly important after periods of inactivity to ensure minimal losses due to dirty contacts. But it is good practice to always clean the connectors before attaching the loops.

Antenna Considerations - General

The 150-watt loop tuners will cover about a 1.5-to-1 frequency range (i.e. 28 – 18 or 10 – 7 MHz, etc.) for a given loop length. The MFJ-932 50-watt loop tuner can achieve a 2-to-1 frequency range due to differences in its tuning capacitor range. Exact frequency coverage depends on each individual installation configuration involving choice of loop length, shape of the loop, height above ground level, and operating environment.

Antenna Considerations – Wire Loops

For portable operation, trade-offs in antenna efficiency can be made when true portability is desired. In this case, wire loops may make the most sense, while keeping in mind the

efficiency penalties discussed earlier. Ten gauge wire should be the smallest wire used, as this can be a good trade-off of efficiency versus size, weight, and portability.

Along this vein, the MFJ-933/935B/936B loop tuners have provisions for mounting an assembled CPVC Loop Antenna Cross assembly (MFJ-57B or MFJ-58B Loop Antenna Kit) by inserting the cross into the ¾-inch CPVC receptacle mounted on the cover. The MFJ-57B kit provides operation on 20 and 30 meters using an insulated 10-gauge flexible wire loop strung on the CPVC assembly. The MFJ-58B uses the same CPVC assembly, but provides coverage from 60 meters through 10 meters with four different 10-gauge flexible wire loops. However, only operation from 30-10 meters is supported by the CPVC assembly. The 60/40 meter wire loop is too long (28-ft) for the CPVC assembly. The photos below show the different wire loops mounted on the MFJ-936B loop tuner.


13-ft 10ga 30-20m wire loop & MFJ-936B


7-ft 10ga 20-15m wire loop & MFJ-936B


4-ft 10ga 17-10m wire loop & MFJ-936B

The loop lengths are not the same for the QRO and QRP loop tuners due to differences in the tuning capacitors. Also, MFJ does not currently provide a loop antenna kit for the MFJ-932 QRP loop tuner. However, a CPVC stand-alone assembly can easily be made. You will need the following material:

13-feet of ½" CPVC pipe
Five 3-port ½" CPVC adapters

Four ½" cpvc caps
Four #10 yellow crimp-on connectors
Four ¼" nylon cable clips
20-feet of flexible 10-gauge wire (or 16-feet of ¼" copper tubing)

The drawing below details this CPVC assembly, made with ½" CPVC tubing. It is designed to hold a 10.5-foot wire loop which covers 20-17 meters, and a 6-foot wire loop for covering 15-10 meters, or a 10-foot ¼" copper tubing loop which covers 20-15 meters and a 6-foot copper tube covering 15-10 meters..

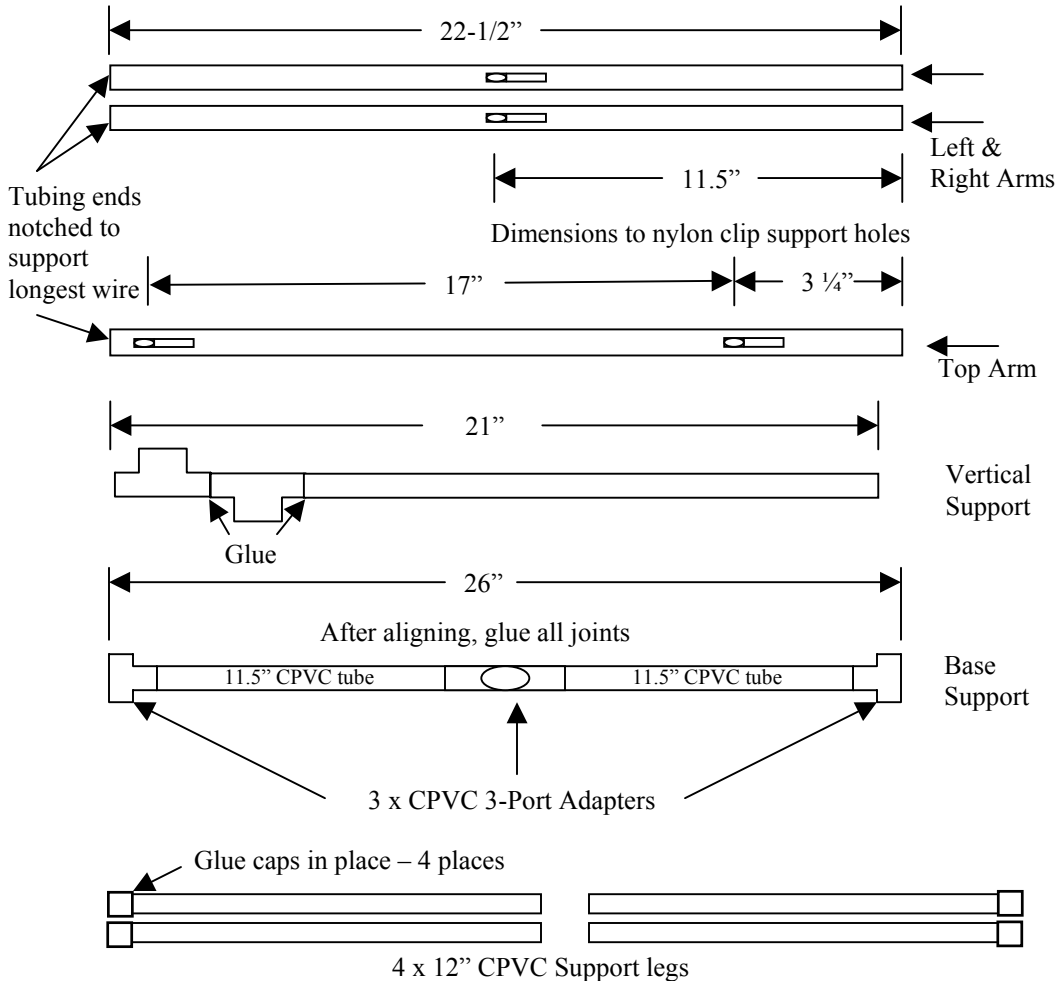
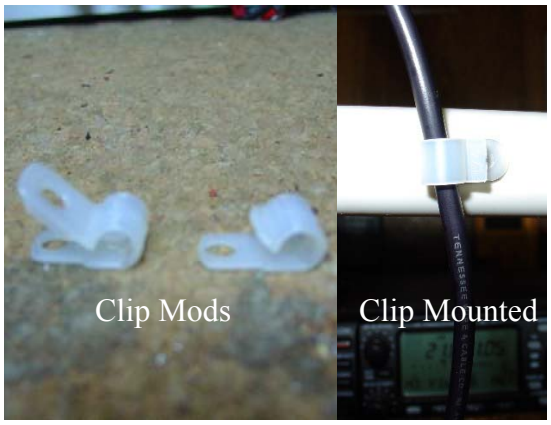


Figure 2: ½" CPVC Antenna Support Components

The nylon cable clips are cut down so that only the bottom mounting hole is used. Place the clips at the locations shown, mark the holes with a marker pen, and drill and tap holes for #6 screws. Then affix the clips in place with #6 nylon screws and some epoxy. Aluminum pop rivets are also acceptable. The photos below shows a close up of a mounted clip, the unassembled and assembled CPVC assembly, and the assembly with the 20-17 and 15-10 meter wires in place connected to the MFJ-932 loop tuner.

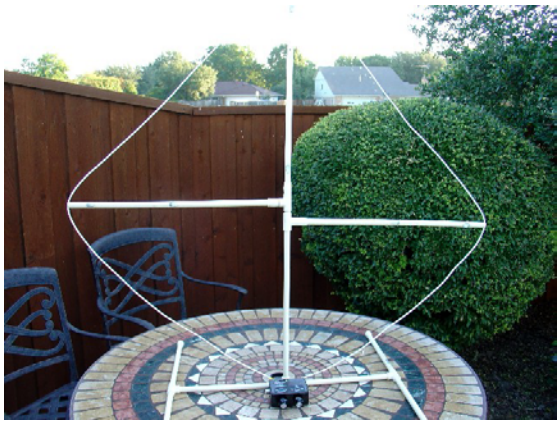


Nylon clip mounting details


Unassembled MFJ-932 CPVC support


Assembled MFJ-932 CPVC support


CPVC stand-alone (l) vs MFJ-58B (r)


10.5-ft 20-17m 10-gauge wire & MFJ-932


6-ft 15-10m 10-gauge wire & MFJ-932

Antenna Considerations – Copper Tubing Loops

As discussed earlier, ¼" diameter copper tubing has much less loss than 10-gauge wire. Larger diameter copper tubing is even better. However ¼" diameter copper refrigerator tubing is inexpensive, flexible, and self-supporting when used with the MFJ-933/935/936 series loop tuners. It can even be part of a portable set-up as the copper tubing can be tightly rolled for transport and then unrolled for installation. It is also easily shaped into

the more efficient circular shape. The following lengths of copper tubing have been found to work well with both the QRO and QRP loop tuners. As you can see, the 10-foot copper loop does give coverage from 20-10 meters with the MFJ-932, though this does violate the "small loop" definition as the length is greater than λ/4 on 12 and 10 meters.

Loop Length	MFJ-933/935/936	MFJ-932
10-feet	30-20 meters	20-10 meters*
6-feet	20-15 meters	15-10 meters
5-feet	17-10 meters	

* 20-15 meters for small loop definition, but does work 20-10 meters

For the tubing ends, use tubular copper ground lugs with ¼" mounting holes (ACE Hardware/Noble 924). These can be crimped on the end of the copper tubing with an RG-6 crimper, and then soldered in place using either a butane or propane torch, or a large soldering iron. The photos below show the details.

Tubing & lug before soldering

Tubing & lug after crimping & soldering

The photos below show the tubing mounted in place on the MFJ-935B.

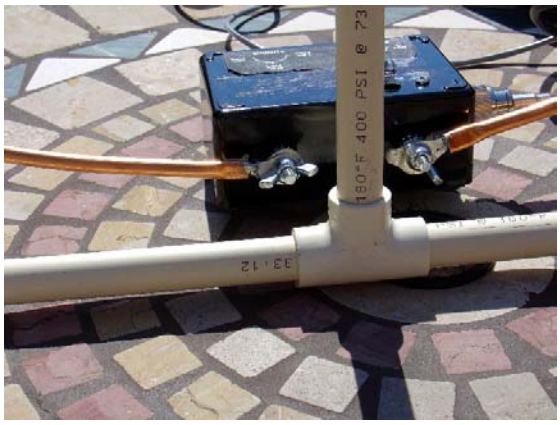
MFJ-935B copper loop mounting

10-ft 30-20m copper loop & MFJ-935B

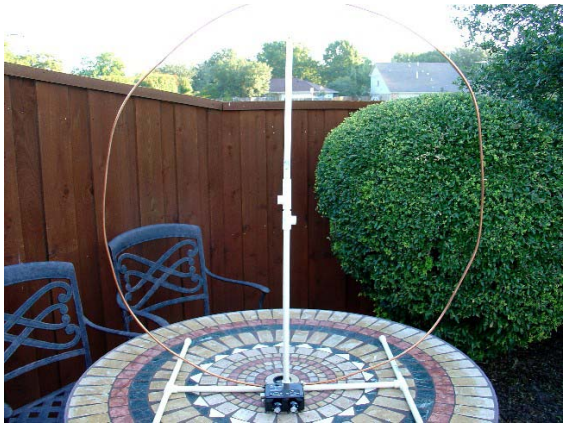
6-ft 20-15m copper loop and MFJ-935B

5-ft 17-10m copper loop and MFJ-935B

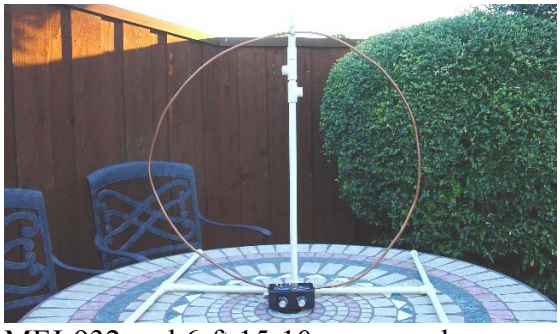
The small and light MFJ-932 QRP loop tuner needs an external support for the copper loops (part of the ½" CPVC assembly discussed earlier). The photos below show the MFJ-932 with the 10-foot 20-15 meter (actually 20-10 meter) and the 6-foot 15-10 meter copper loops in place.



MFJ-932 copper loop attachment



MFJ-932 and 10-ft 20-15m copper loop



MFJ-932 and 6-ft 15-10m copper loop

Conclusion

Small loop antennas can be very effective when care is taken in the design of the loop tuner and the loop antenna itself. This paper has attempted to provide the reader with information on building an effective small loop antenna system optimized for the MFJ series of manual loop tuners.