A Practical Approach to building and Evaluating a Broadband Active Loop Antenna, looking at the Mobius, Conventional Shielded and Wire Loops

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I have been experimenting with receiving loop antennas now for the last 3 years, building several Ferrite Sleeve Loop antennas, Air Loop antennas and Active Broadband wire loop antennas. Because of some local electrical noise issues here at my location I decided to start looking at some other options. My first experiments had looked at a conventional Coax Shielded Loop, which showed some improvement in the noise situation over that of an active wire loop. However, I wanted to see if I could find something even better, so I decided to also experiment with a Mobius configured shielded loop. It was suggested, in what little information I could find, that the Mobius loop antenna was a very low noise antenna.

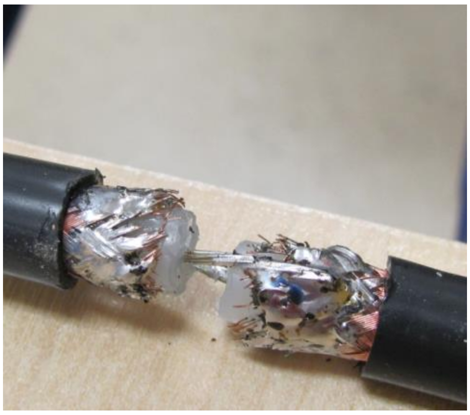


Figure 1


Figure 2

There is an article that can be found on the web "Sensor and Simulation Notes VII Characteristics of the Mobius Strip Loop" (http://ece-research.unm.edu/summa/notes/SSN/note7.pdf) written by Dr. Carl Baum, and it is the basis of the commercially available Pixel Loop Antenna. This article only covers the theory, but there is another article, posted in the files section of the Yahoo Loop Antenna site, by Chris Trask "Mastering the Art of Shielded Loop Aerials", which also covers the theoretical aspects of the Mobius loop as well as some construction information. Likewise, I could find only a little information about broadband active shielded loop antennas. There is, however, a lot of information about tuned shielded loops.

I purchased an 11' piece of RG11/U 75 ohm coax that had a 98 % braided shielded and stranded center conductor. The reason for choosing RG11 over RG8, or RG213, was that 75 ohm coax has a lower capacitance per foot than 50 ohm coax. The RG8, 50 ohm coax, runs around 30 pF per foot and 75 ohm coax runs about 20 pF per foot. Based on what information that I could find, having higher capacitance could limit or degrade the upper frequency range of a Mobius shielded loop antenna, and my goal was to end up with a antenna that would cover LW to 30 MHz.

The RG11/U coax was cut in the middle and I stripped off 1" of the sheath material from each of the two pieces of the coax that I just cut and then cut the braid back 3/4", leaving about a 1/4" to 3/8" of exposed shield. I then removed 3/4" of the center conductor insulation. The center conductors from each side were soldered to the shield on the opposite side, see Figure 1. This contrasts with the conventional shielded loop which has no connection between the shields at the cut in the center of the coax, and leaves the two center conductors connected. (See Figures 3 and 4)

I added two layers of shrink tubing over the joint to strengthen it. You need to measure very carefully from the center of the connection to each end to make sure each end of the coax is the same length, or you may not have equal nulls at 180 degrees. I soldered on some more flexible wires to the center conductors of the coax to make it easier to connect to the various matching transformers and preamplifiers that were being evaluated during my experiments (see Figure 2).

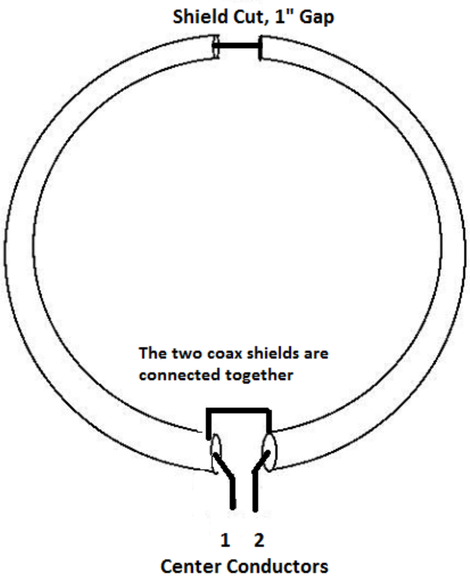


Figure 3 Conventional Shielded Loop

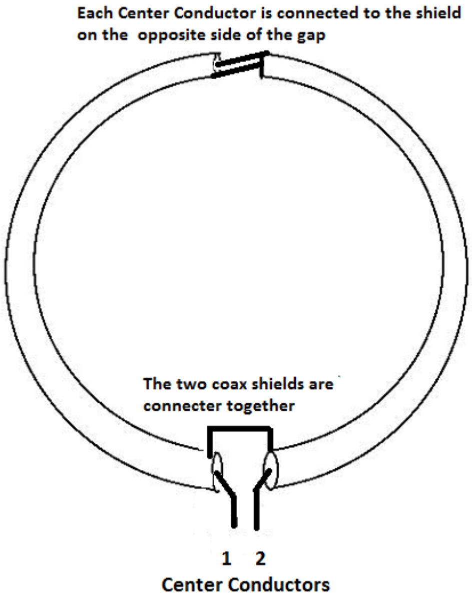


Figure 4 Mobius Shielded loop antennas

The loops were encased in 3/4" PEX water pipe, which is a polyethylene (PE) material with an OD of 7/8" and ID of 5/8". The pipe can be purchased at Lowe's or Home Depot for about $6. My piece was 10' long, which gave an ending diameter of 40" (~1 Meter). I used a 4" plastic electrical junction box at the bottom. The holes were too small in the junction box, so I reamed them out with a 7/8" Unibit in order to fit the PEX pipe inside of the holes in the junction box. The PEX pipe was held in place inside the junction box with set screws (similar to Figure 18).

The loop is pictured in Figure 5, which is mounted on a Lazy Susan. I made up two of these loops, so that I would have similar setups for comparison, using an A/B switch between the antennas and the Icom R75 radio that I was using as the receiver.

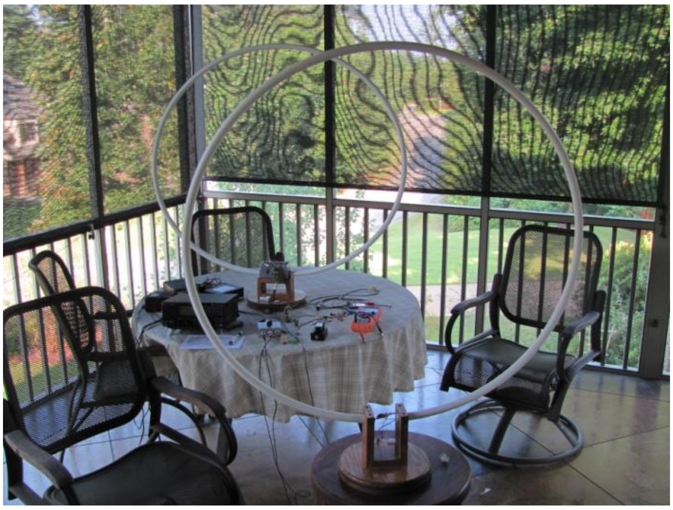


Figure 5 Loop on a Lazy Susan turntable

The amplifiers with which I was experimenting were a simplified M0AYF loop amplifier (original versions at http://www.pa1m.nl/pa1m/simple-active-receive-loop or http://www.qsl.net/m0ayf/active-loop-receiving-antenna.html), and a W7IUV (I modified one from Kits and Parts, http://kitsandparts.com/rfamp1.3.php). I eliminated a lot of the parts that were in the original M0AYF amplifier, which was designed for remote power, because I wanted to keep it simple; I was only going to power it with a battery. I also changed T1 in that amplifier from a toroid to a binocular core. The W7IUV amplifier was modified by changing C1, C2 and C4 from 47nF to 1 uF and replacing T1, which used a FT37-43 core, with a FT50-75 core. Figures 6 and 7 show the amplifier schematics. (NOTE: I built two of each of the two preamps, so I would be using the same type of preamp in doing the A/B comparisons)

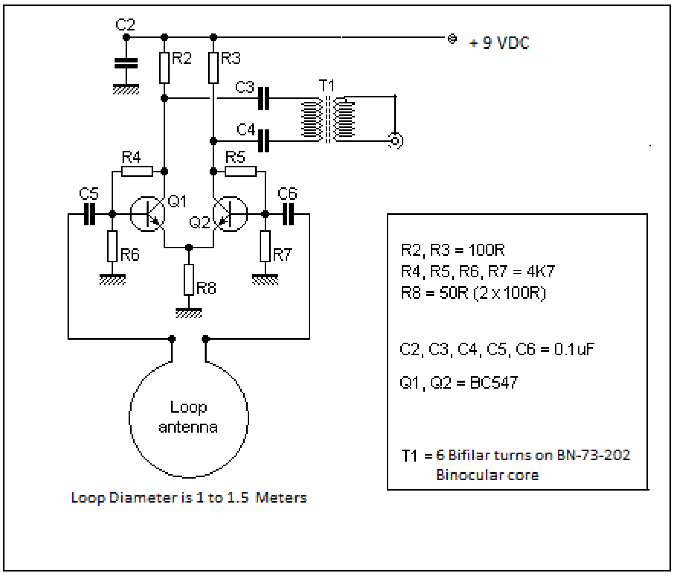


Figure 6: original M0AYF broadband amplifier

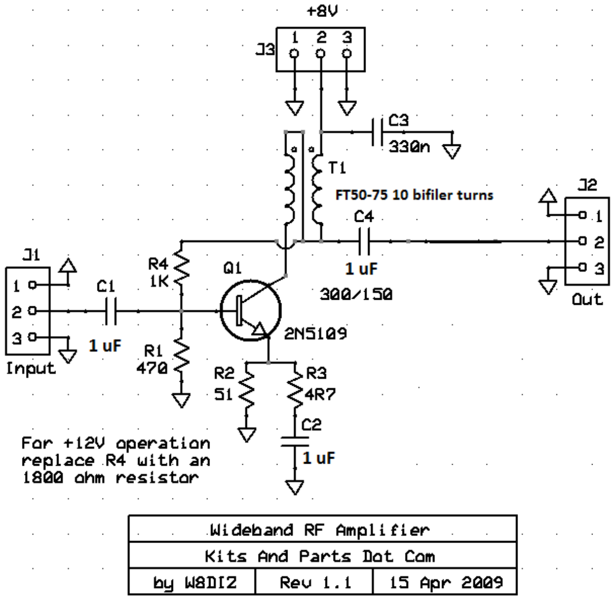
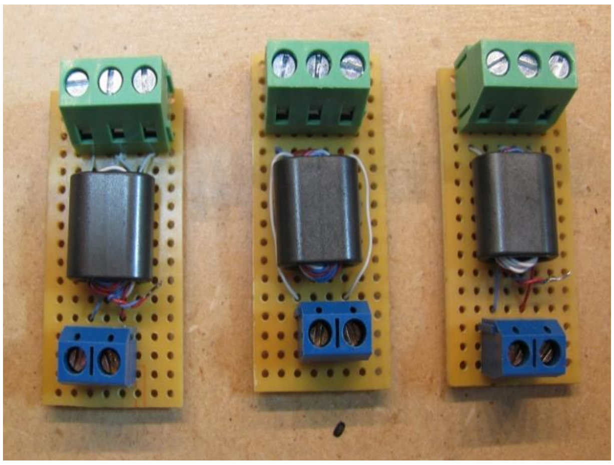


Figure 7 the modified Kits and Parts Preamp

I made up two sets of the matching transformers for this experiment, using BN73-202 binocular cores, with 1:1, 1:2 and a 1:3 turns ratio (Figure 8). The primary sides of the transformers were all center tapped and would be connected to the loop. Each side of the center tapped winding was to be connected to the coax center conductors from the loop (contacts 1 and 2 in Figures 3 and 4), with the center tap connected to the coax shield.



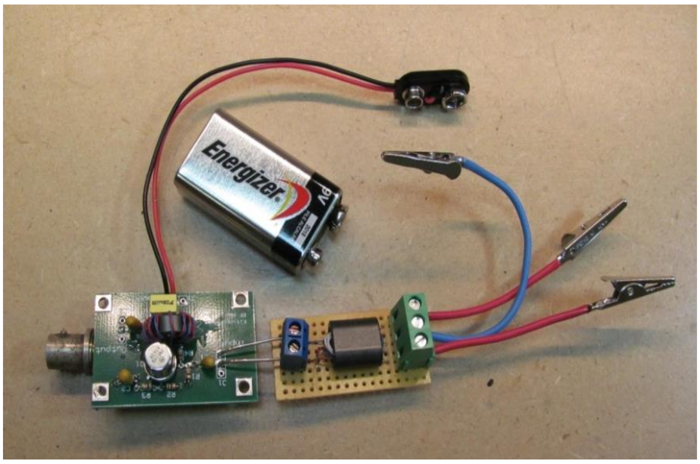


Figure 8: the matching transformers mounted on perfboard

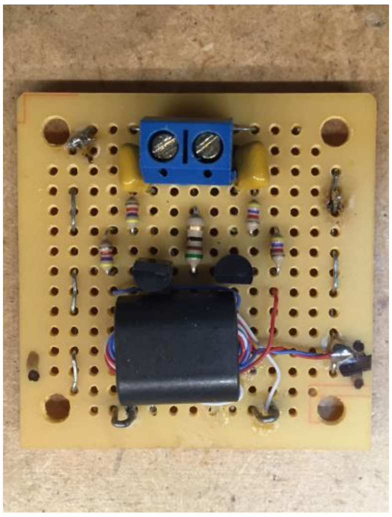
Figure 9 Kits and Parts preamp connected to a matching transformer

- The 1:1 transformer was wound with 6 turns on each side, with one side center tapped at 3 turns. *(1:1 impedance ratio, giving 50 ohms/50 ohms*)
- The 1:2 transformer was wound with 12 turns on one side and 6 turns on the other side, center tapped. *(1:2 turns ratio gives a 1:4 impedance ratio for 12.5 ohms/50 ohms)*
- The 1:3 transformer was wound 12 turns one side with 4 turns on the other side, center tapped. *(1:3 turns ratio gives a 1:9 impedance ratio for 5.5 ohms/50 ohms)*

On each transformer, the winding with the lower number of turns as well as a center tap, was connected to the loop, while the other winding was connected to the amplifier.

I used 9 volt batteries to power both the M0AYF and Kits and Parts preamps as each draws less than 40 mA. (see Figures 9 and 10)

The first experiments were comparing a conventional shielded loop to a wire loop. The shielded loop was made up of RG8X coax that had 1" of shield removed at the top, as pictured in Figure 3, with the two coax shields connected together at the bottom. The two center conductors were each connected to the amplifier. The wire loop antenna was using #14 wire and was the same length and diameter as the shielded loops, but there was no matching transformer used; the loop conductors were connected directly to the amplifier. Each loop had an M0AYF amp connected to it. I then started out on the LW band, moving up band, in steps, to 20 MHz, comparing both loops. I did see lower noise with the shielded loop, but I just did not see good rotational nulls with the shielded loop and I was quite disappointed with the results. From there I decided to look at the Mobius loop, again using the M0AYF amplifier, on both it and the wire loop. I again noticed that the Mobius loop was much quieter than the wire loop but still not performing correctly, as it too, did not seem to give good rotational nulls.



← Figure 10 -- the M0AYF amplifier

At this point I decided to start looking at the matching transformers that I had made up earlier, trying all 3 of them on both the Mobius and the conventional shielded loops, using the M0AYF amplifier, but they still did not seem to be performing correctly. So I decided to try one of the Kits and Parts preamps, using the matching transformers. After trying all of the matching transformers, I found that the 1:2 performed best on both antennas. This was with the 12 turn side connected to the preamplifier and the 6 turn side connected to contacts 1 and 2 on each of the two shielded loops in Figures 3 and 4, with the winding's center tap connected to the coax shield.

Preliminary Findings:

(1) The Mobius Loop was quieter on LW and MW than the conventional shielded loop, but not by a lot. The Mobius loop gave a little higher S meter readings then did the conventional shielded loop and had a lower noise floor on LW and MW.
(2) Both the shielded and Mobius loops using the Kits and Parts preamp, did a much better job of reducing most electrical noise, than did the active wire loop using the M0AYF amplifier. The Mobius loop had a very sharp null, much sharper and deeper than the conventional shielded loop. On several local AM radio stations, the Mobius loop gave a 20 to 22 dB nulls, whereas, the conventional shielded loop only gave about 14 to 16dB nulls**.** *Update: This was an interim observation. Several months later I modified the M0AYF amplifier further, and with appropriate connection to the matching transformer, was able to get both better nulls and better noise response than with the original amplifier See Part 4 of this article for details.*
(3) My first attempt at the M0AYF amplifier was a very poor performer on both the Mobius and conventional shielded loop, as it did not lower the loop's noise response nearly as well as did the Kits and Parts preamp. The nulls were also not very deep when using the original M0AYF amplifier on either loop. See the updated results using the modified MY0AYF amplifier in part 4 however.
(4) Both the Mobius and conventional shielded loops had a much lower output than did the wire loop, with the Mobius having the higher output of the two shielded loops, so if you are using a receiver with a poor front end, or do not have a built-in preamplifier, like the R75 has, then you may need to cascade 2 of the Kits and Parts preamps to get the desired signal levels. *Further pre-amplification is not required with the later version of the M0AYF amplifier, as it has plenty of output.*
(5) I replaced the M0AYF amp on the wire loop and tried a Kits and Parts preamp in its place, using a 1:2 matching transformer, and noticed a big improvement on LW with lower noise and stronger signals. I also saw less noise all the way up to 20 MHz. Connecting the loop shield to the amplifier ground as well as to the centre tap of the matching transformer made a world of difference in the noise levels, but did lower the signal output, necessitating the use of cascaded amplifiers to compensate for the low output. *Again, note that this was a preliminary conclusion, and that using the later version of the M0AYF amplifier instead of the Kits and Parts amplifier means that extra ground connections and preamplifiers became unnecessary.*

This was a very costly and time consuming project that went from excitement one moment to disappointment the next moment and then back again.
If you have a noise problem at your location and you want an active broadband loop antenna, then you might want to consider building a conventional shielded loop, or a Mobius configured loop antenna. If you are primarily interested in MW and LW bands, then I would lean more towards the Mobius loop, as it has a lower noise floor.

Parts suppliers

- Kits and Parts has a new SMD version of this amplifier which is $11. http://kitsandparts.com/rfamp1.3.php
- FT50-75 10 for $5 + shipping http://www.kitsandparts.com/
- BN73-202 toroids $5 for 10 of them + shipping http://www.kitsandparts.com
- Wire for winding Toroid and binocular cores, is Radio Shack #30 Wire Wrap wire, Red, Blue and White, about $6 each
- RG11/U 22' about $25 delivered from RF Connection http://www.therfc.com/ (he has the best wire and the best prices)

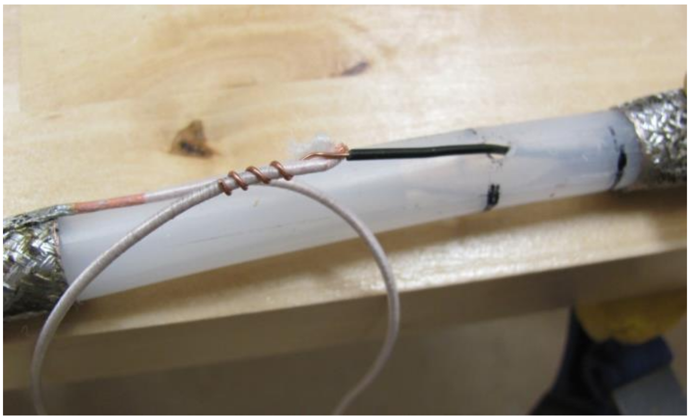
2: Improving the Mobius Loop

I have been in the process of trying to improve on the performance of the Mobius loop from my previous work. . One of the shortcomings of the Mobius design is it does not perform as well above 20 MHz as a conventional shielded loop, or as a solid single conductor loop. So, the two areas of interest were to increase the diameter of the loop to generate greater signal output and to try to reduce the overall capacitance of the loop in order to increase the upper frequency response of the loop. The first thing that I did was to review what was available in the way of low capacitance manufactured coax.

I could only find RG-63/QPL, which is 9.7 pF/ft, 0.41 diameter and RG-62A/V, which is 13 pF/ft 0.242 diameter. The RG-63/QPL looks to be difficult to come by unless you want to buy 1000'. The RG-62A/V can be found in small quantities but I was looking for a larger diameter coax, as my goal was to try to lower the capacitance as much as possible; the larger the inside diameter, the more space I would have between the center conductor and the shield, thus lower capacitance.

My only option appeared to be to try to make my own coax in order to reduce the capacitance. I made a trip to Home Depot and looked around the plumbing section to get some ideas, and what I found was some polyethylene (PE) hose. After looking through their inventory, I bought a roll of ½" OD X 3/8" ID X 25' and one roll of 5/16" OD X 3/16 ID X 25'. (NOTE: This is the same type material that is used to hook up an icemaker on your refrigerator, only that is 1/4").

I needed some kind of a shield to cover the ½" PE hose and I just happened to have some that measured ½" wide. I tried to see if I could get it to slip over the ½" PE hose and it did without any problem. I had 15' of it on hand, which was a good thing, as it took a lot more than 10' of it to cover 10' of PE hose.
I cut the 1/2" PE hose to 10' 3" and marked the center and measured back 1/2" on each side of the center mark and made a mark around the hose. I drilled a 1/8 hole at each mark, 180 degrees apart. I slipped the shield over the PE hose and pushed it up to the mark and cut off the excess from the other end and did the same on the other side. I removed the braided shield from both sides of the PE hose and soldered a piece of 660/46 Litz wire to the ends of both braids (you could use a #18 stranded wire in place of the Litz wire). The two wires needed to be cut 6' long.



← Figure 11

I used 660/46 Litz wire as the center conductor of my first attempt at manufactured coax (though ended up using magnet wire in later versions of my own coax). This is not stiff enough to feed through the hose unaided, so I put a fish wire inside of the 1/2" PE hose to pull the Litz wire through it (see Figure 11)

After the Litz wire had been fished through the 1/2" PE hose, then it needed to be fed into the 5/16" PE hose. (The 5/16" hose was being used to give uniform spacing between the Litz wire and the shield, and needed to be cut to two 5' pieces, one for each side.) You should start by feeding the 5/16" hose inside the 1/2" hose, while pulling on the fish wire, trying to move both at the same time. (see Figures 12 and 13 for details)

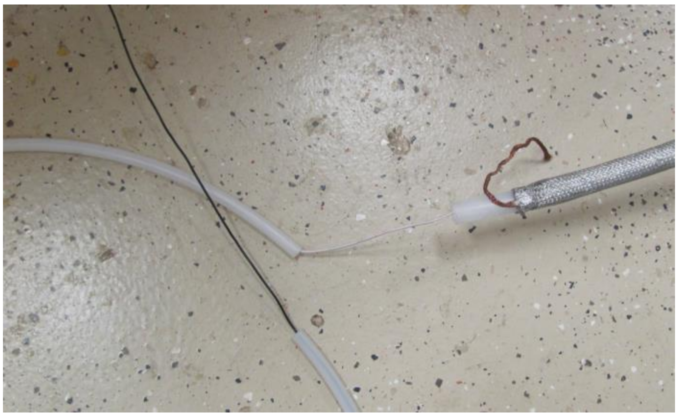


Figure 12 -- the 5/16" hose being fed into the 1/2" hose

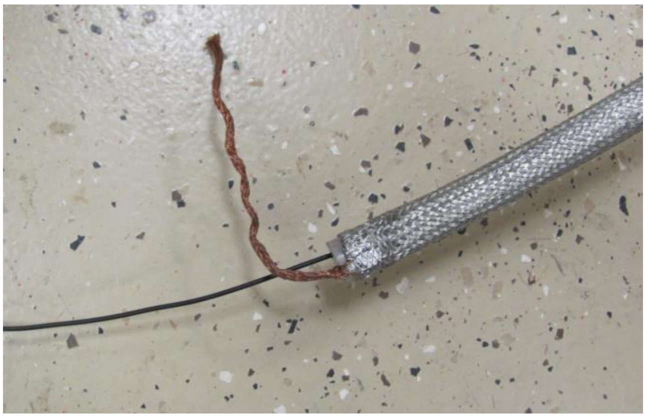


Figure 13 -- coax end with a braided wire soldered to the loop braid. Note the fish wire coming out the end.

← Figure 14 shows the finished "Roll Your Own" coax Mobius Loop. I checked the capacitance of the "Roll Your Own", while it was in place, it was **132 pF** and the inductance was **16.2 uH.** The RG-11 loop that was used on one of my previous loops was **247 pF** and **17.4 uH**.

In comparing the RG-11 Mobius loop to the RYO Mobius loop, side by side, I found that the RYO had much sharper nulls and the nulls were deeper by 5 dB. It was difficult to tell for sure, put I did detect a little less noise. Also I noticed that I was getting a little less output from the RYO loop. I traded the preamps back and forth just to make sure there were no differences in preamps, but the results were the same. I later discovered that a 1:1 turns ratio matching transformer, center tapped, worked better than the 1:2 turns ratio that I had previously been using on the RG-11 Mobius loop.

3: Further Loop improvement

Wanting to make further improvements and lower the capacitance of the Mobius loop, I did a web search looking for aluminum tubing and ran into an interesting product, called "PEX AL PEX". This product is a polyethylene pipe which has aluminum sandwiched between two layers of poly. The aluminum is 0.035" in thickness and is easy to form without any special tools or jigs. PEX AL PEX pipe has been used in Europe for several years and is used for water supply lines, heated floors, and is also used for natural gas feed lines to homes. In more recent years, it has been used here in the States for the same, but is not easy to find. I checked with local suppliers to try to find a source, but no one carried it. I made a web search and located a 100' roll of 1" PEX AL PEX and bought it. It was UPS shippable, so arrived in three days, which gave me time to come up with a plan for forming and making a Mobius loop.

I cut off an 11' piece of the PAP pipe and started binding it by hand, it was a little stiffer then I thought it would be, but still workable. I found the best way to form it was to hold the pipe in each hand, spreading your arms out, to the side as far as you can and lightly place your foot on the pipe, moving it back and forth, making small bends with your foot pressure as you move it back and forth.

After it was formed, I cut the pipe to 10' and then cut it again at the top center. The two cut pieces were checked to make sure that they were both the same size. (see Figure 15)

Figure 17 shows where the PAP pipe is joined together at the top using a 1" long piece of 1" PVC pipe as a spacer. Also you can see two screw heads 180 degrees apart, which is where the two center conductors are connected to the shield of the tube opposite. This join later had two pieces of shrink tubing placed over it to add some strength to the join.

Figure 18 shows the junction box for 1" PVC conduit. The holes in it are a little larger than the PAP pipe, which is 1.25" OD, however, there is a ridge on the inside part of the two holes in the junction box. I reamed them out using a small sanding drum, which allowed me to be able to slip the PAP pipe further into it. I drilled two small holes where each pipe end fits into the PVC box and put two small sheet metal screws into each to hold the PAP pipe in place. The two ground wires are connected together. Figure 20 shows the assembled loop.

Note the Dremel tool, with a small carbide bit, in Figure 16. This was used to cut away the poly to expose the aluminum at the top, in order to connect the two center conductors to the tubing. Also the poly was cut away at the bottom for ground connections.

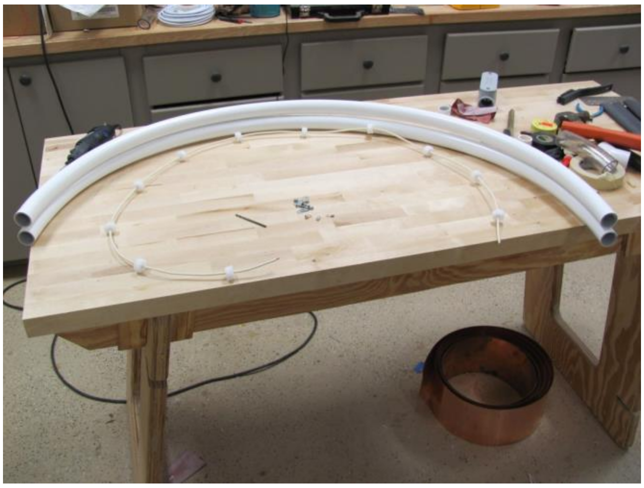


Figure 15

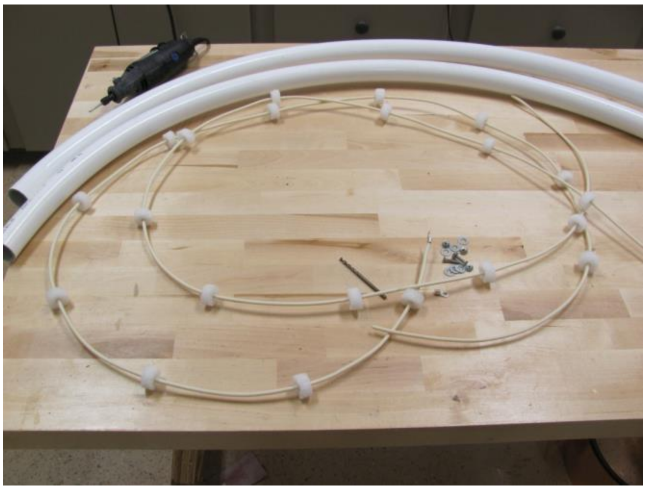


Figure 16

In Figure 16 you can also see the 7/8" diameter poly foam disks that act as spacers for the center conductor of the PAP coax. These disks were slipped over the conductor every 6” is to give uniform spacing between the center conductor and the tubing outer wall. The foam disks were cut out of 1/2" thick PE foam, using a piece of conduit with an ID of 7/8", the edges of which I had ground down to make it like a leather punch., Then I used an ice pick to make the holes in the center of each disk. This made a tight fit on the coax center conductor. (see Figure 19) Originally, this center conductor was the insulated center conductor of RG-58 coax, but I have since moved to using #22 magnet wire, and modified the spacers accordingly.


Figure 17

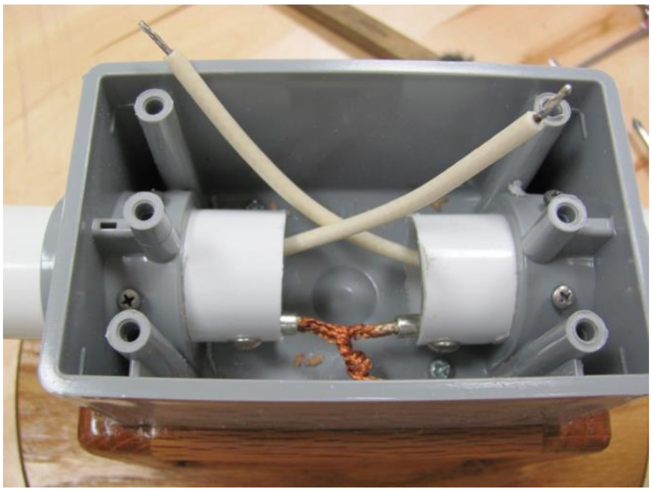


Figure 18

Figure 19

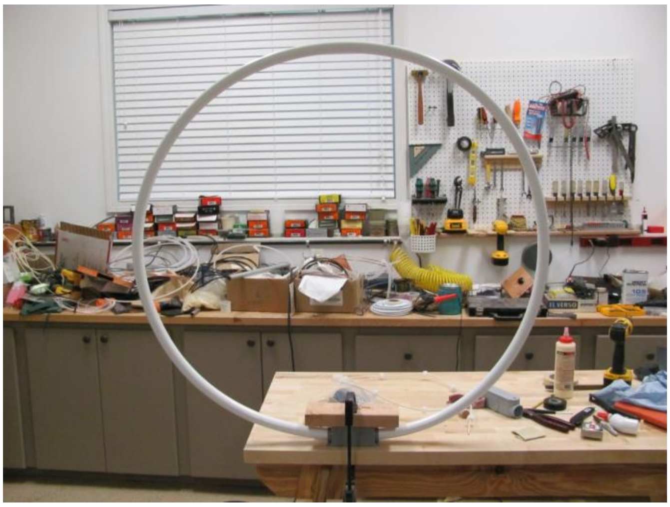


Figure 20

The loop to back right in Figure 21 is the new PAP Mobius loop; you can see the black shrink tubing at the top that is holding it together and water proofing the top joint.

← Figure 21

The finished loop ended up with a much lower capacitance than any of the previous loops that I built. It was 93 pF but when measured prior to building the loop it was 8 pF per foot, so 13 pF was added in the construction process. I think that PEX AL PEX pipe is a great material for making loop antennas and I plan on making a few more loops but with larger diameters.

4: Improving the Amplifier

I later found information on the web of a modification to the M0AYF amplifier that was posted by Steve Ratzlaff, where he changed the way T1 was connected in the circuit. I made the mod and also changed the transistors to MPSH10, to increase the higher frequency capabilities of the amplifier when used with a loop antenna. I found it difficult to get a good match with the transistors, so I added R9 to the circuit which allowed me to balance the voltage drop across R2 and R3 thus giving better balance to the two transistors. I also changed capacitors C5 and C6, which were 0.1 uF, to 1 uF, this seemed to improve the coupling between the antenna and the M0AYF amplifier. (the modified M0AYF amplifier is in Figure 22)

When first using the newly modified M0AYF amplifier I did not get the results I was looking for with the PAP Mobius loop design. The nulls were not any better than what I had seen from my earlier work. The problem, as it turned out, was that the 1:2 turns ratio matching transformer was no longer the proper match for the newly modified M0AYF amplifier. What turned out to work best was the 1:1 turns ratio, with the center tap connected to the loop shield and each side of that winding connected to the center conductors of the loop. Once this change was made, I saw a 10 dB improvement in signal strength on MW and I was now able to get 30 dB nulls from several of the local AM radio stations. I also noticed lower noise on LW.

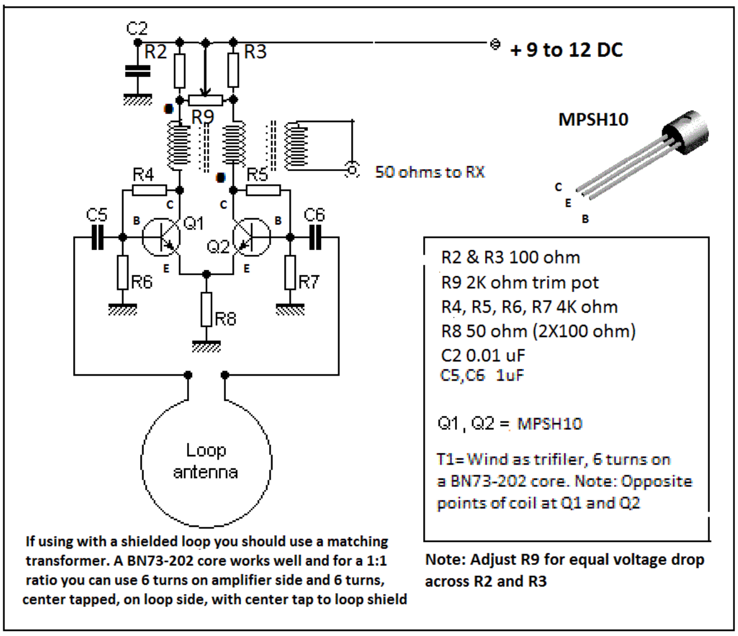


Figure 22

Figure 23: the finished portable Mobius Loop

5: The final configuration

Once I was satisfied with the performance of the Mobius configured loop with the modified amplifier and the 1:1 matching transformer I built a permanent model to use for portable operation (Figure 23). It is powered with a rechargeable 9VDC Lithium-ion battery that puts out 8.3 volts. With the amplifier drawing 65 mA, the battery lasts for several hours.

The modified M0AYF amplifier was built on a 2"X 2" perf- board and placed inside of the PVC electrical junction box to which I added a switch, LED and a BNC connector for the 50 ohm output (Figure 24). I use this portable Mobius loop to take out to places that have less noise and use it with my CommRadio CR1A radio. The batteries in both the loop and the CR1A last about the same length of time, 6 to 8 hours.

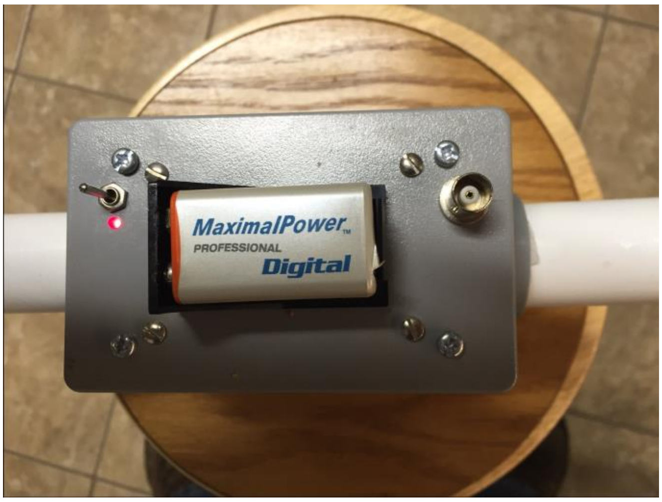


Figure 24

Figure 25

6: A larger outdoor variant

Several months later, I bought a RFSpace NetSDR receiver and wanted a larger antenna to put outside. I was so pleased with the prior work and experiments with the Mobius configured loop that I wanted to build a larger one to go with the Clifton Labs Z1501D Active Whip antenna that I had. After some thought I decided to build a Mobius loop that was 6' in diameter.

In order to do that I need to go back and add some additional circuitry to the M0AYF amplifier, so I could feed power to it through the coax. I went back to the original article that I started with (http://www.qsl.net/m0ayf/active-loop-receiving-antenna.html) and added what was needed to the circuit to enable it to be used with remote power. I wanted to use the Clifton Labs Power Coupler to power the loop, however, it uses 18 VDC, so I added a 12 volt regulator to the amplifier circuit. The amplifier, when using 12V with the MPSH10 transistors, pulls 105 mA, which is pushing the transistors, as they are rated at 50 mA collector current. However, the loop has been operating now for about 3 years without any problem.

I built a 6' diameter loop using the 1" PAP pipe and used 22 gauge magnet wire as the center conductor, which lowered the capacitance between the center conductor and the shield to 5.5 pF per foot. With the lower capacitance per foot, I was able to compensate for the larger size loop, which otherwise would have had a greater total capacitance. The lower capacitance allowed for better performance at the higher frequencies. I had to use a larger electrical box, 6" X 6" X 6" at the loop, in order to accommodate the extra amplifier circuitry. I found that the same 1:1 matching transformer was the best choice for this new loop.

Once the loop was installed I added a Dow-key relay outside so I could switch back and forth between the 6' Loop and the Active E Probe Whip.

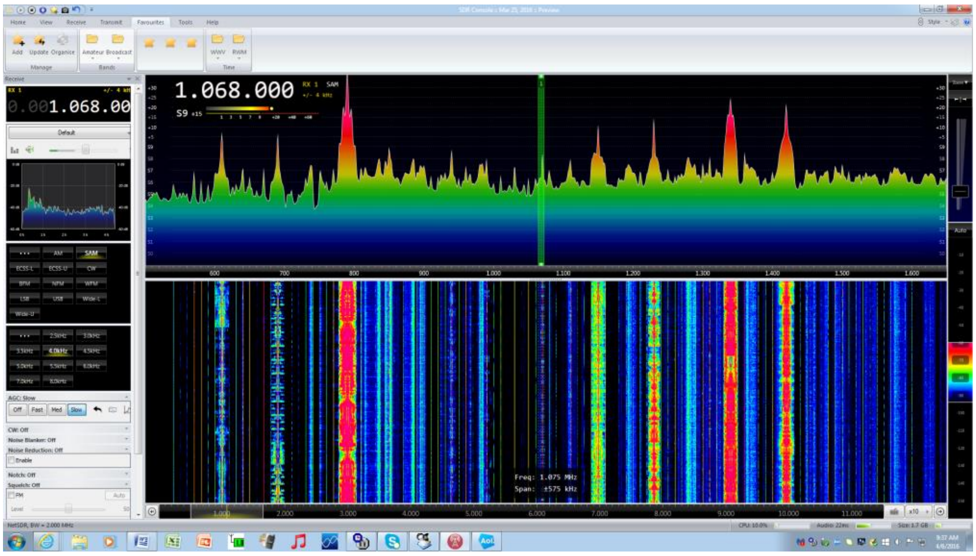
Pictured in Figure 25 is the Clifton Labs Power Coupler, with the added switch on its side to allow switching back and forth between the two antennas. I use the two antennas with my NetSDR receiver. Also from time to time I will use the antennas with my Elecraft K3S, as the receive antenna. The Clifton Labs Power Coupler has a disable feature, where I can connect it to the K3S Key Out and when I transmit it will shut down either of the two RX antennas.

I was able to hang the 6' Mobius in a tree and tie it off in a direction that gave me the least amount of noise (see Figure 26) The Z1501D Active Whip is 102” long and mounted on a pole six feet above ground level. (see Figure 27)

Figure 26

Figure 27

7: Performance



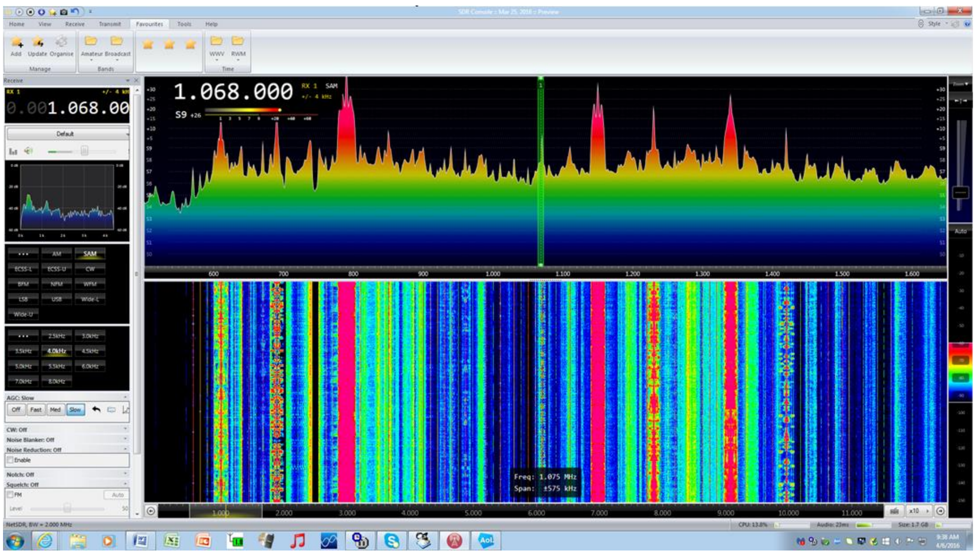
Figures 28 and 29 show screen shots of reception using the 6' Mobius loop and Clifton Labs Z1501D Active whip.

← Figure 28 6' Mobius Loop reception

The whip antenna picks up a lot more noise, but it has the advantage of producing better signal than the Mobius loop below about 300 KHz and is way better below 100 KHz. That is why most NDB DXers use E probe antennas. If there is no electrical noise, then the Clifton active whip is a very good antenna.

http://www.ircaonline.org/uploads/690kHzeprobe.mp3 exhibits the noise that I hear daytime here in Tuscaloosa, AL on 690 kHz using Clifton active whip; http://www.ircaonline.org/uploads/690kHzloop.mp3 apparently shows not too much of an improvement using the Mobius loop. However, quite a bit of work was required to bring the noise down to this level on the active whip: Its BNC connector is "floating" (not grounded), while the antenna base and amplifier are at earth ground to eliminate any possibility of a ground loop. Also I have common mode chokes located in several places along the feed line coming to my house. In contrast, there is no earth ground on the loop, nor are there any common mode chokes in the line coming to the house, so it is an easier antenna to deploy in a noisy environment.

A more striking contrast is found between http://www.ircaonline.org/uploads/960kHzeprobe.mp3 which is a fairly noisy daytime signal from a Birmingham station on 960 KHz that is about 70 or so air miles from here. The recording, http://www.ircaonline.org/uploads/960kHzloop.mp3, made using the loop, is considerably quieter. For whatever reason, I have a lot of noise during the daytime, with most of it gone during the night. So the loop is a big help for daytime listening, but also helps at night too.



← Figure 19 The Z1501D Active Whip reception

After seeing the results from this project, why would you ever want to use a tuned loop? I have compared this Active Mobius loop to all of my tuned loops and in most cases it works as well, if not better and picks up a lot less noise, especially when placed away from the house. With this Active Mobius loop you have one antenna that replaces several antennas and with no more tuning or band-switching every time you change frequencies. It gives coverage from LW through well above 30 MHz.

(the above article originally appeared in the Technical Column of IRCA's DX Monitor, and is used with the permission of IRCA and of the author)