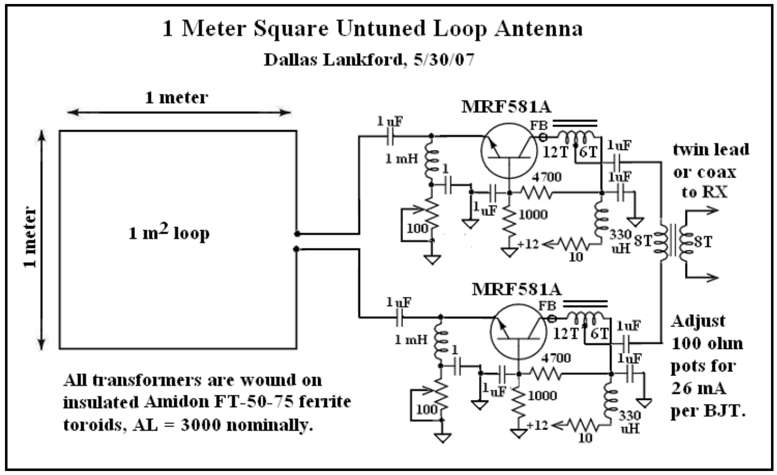
Amplified 1 And 4 Meter Square Untuned Loop Antennas

Dallas Lankford, 5/14/07, rev. 8/7/07

The 1 meter square untuned loop antenna described here was motivated by a posting from John KC0G to to a loop antenna group. One of my PC boards for push-pull Norton amps was reconfigured as a push-pull common base amplifier and populated with parts which I use for Norton amps. A wood frame slightly larger than 1 meter square was made, the amp was attached, and they were hung from a tree in my yard about 20 feet from my house. An amplified 15' relay tuned noise reducing antenna about 10 feet away from the loop was used for comparison with the loop.



Originally a 6 turn to 3 turn step down transformer was used at the input of the amplifier which was consistent with the posting recommendation. Later, after measurements of loop inductance, amp input resistance, and amp gain, the input transformer was deleted; more details of this change are found near the end of this article.

Overall the loop performance has been mostly good, although not any better than many other antennas which I have used, and not as good as some. Small loop antennas like this are not more immune to man made noise than other antennas, and less immune than some. For example, I compared the the loop and 15' vertical on the 120 meter band Australians at sunrise this morning and found no difference in signal to man made noise ratios. Many other comparisons have been made in the LW, MW, and SW bands. In the SW bands at some times the loop would have a temporarily better signal to man made (or other kinds of) noise ratio than the 15' vertical, but at other times the advantage went to the 15' vertical. Overall (for long term averages) the vertical usually had a better (typically 70% of the time) signal to man made noise ratio than the loop. Thermal noise originating in the loop element began to be audible above man made noise in the MW band at my location. It sounded like hiss. Loop element thermal noise slowly increased in intensity as frequency decreased, which is in agreement with theory for small untuned loop antennas. Towards the lower end of the NDB band the loop was clearly sensitivity limited by this hiss. For example, GV 201 in Greenville, TX, about 240 miles away was clearly audible on the 15' noise reducing vertical with moderate man made noise, but inaudible on the loop (only hiss was heard, and yes, the loop max was pointed at Greenville). Also, for example, as Turks & Caicos 530 became audible during sunset transition, it was audible first on the 15' vertical; at the same time only hiss was heard on the 1 square meter loop (yes, the loop max was pointed at T&C). Of course, later in the evening at full strength T&C was heard equally well on the vertical and loop. The insensitivity of small loops like this at lower

Untuned Loop Antenna Sensitivity
At 500 kHz

Dallas Lankford, 5/13/07

A (area)	L	Noise Floors		10 dB S/N	
		2 kHz BW	6 kHz BW	2 kHz BW	6 kHz BW
1 m^2	6 μH	2.4 μV	4.1 μV	7.6 μV	13.2 μV
4 m^2	12 μH	1.2 μV	2.1 μV	3.8 μV	6.6 μV
25 m^2	24 μH	0.26 μV	0.45 μV	0.82 μV	1.4 μV
225 m^2	100 μH	0.06 μV	0.10 μV	0.19 μV	0.60 μV

frequencies may have caused some people to believe that such loops are more immune to man made noise than some other kinds of antennas. The table above, taken from my article (in The Dallas Files) on loop antenna sensitivity, gives sensitivities for untuned loops of various sizes.

4 Square Meter Area Loop Head

To verify that the increasing hiss vs. decreasing frequency was indeed thermal noise due to the loop element, and not amplifier noise, a square loop element with 2 meter sides was built. For the 4 meter square loop element the amp input transformer was changed from 6:3 turns step down to 8:3 turns step down to slightly reduce signal levels at the input of the amp. The 4 meter square loop was connected to my modified 746 Pro tuned to 201 kHz listening for GV Greenville, TX with the loop max pointed at Greenville. To my utter amazement all I heard was loud man made noise and some static from thunderstorms further away in West Texas. I switched over to my 15' amplified noise reducing vertical antenna and there was GV together with some moderate static and weak man made noise, but easily ID-able. I changed the loop power supply to a 12 volt battery, thinking that the noise might be due to the AC-DC power supply, but the noise was still there, just as strong as before. So I went outside, rotated the loop 45 degrees, came back inside, and the man made noise from the loop was much lower, only slightly more than from the 15' noise reducing vertical. The loop null was necessary to reduce man made noise to the same level as the 15' noise reducing vertical! Loops are more immune to man made noise than other kinds of antennas? Of course not. I already knew this, but I have never before encountered such a dramatic example as this one. Anyway, with the man made noise nulled, I thought (wishful thinking?) I could hear GV on the 4 meter square loop antenna occasionally surfacing out of the man made noise in between static bursts. On the 15' noise reducing vertical GV was weak, but still clearly audible. Perhaps I could have heard GV 201 clearly on the 4 meter square loop if (1) the loop were mounted on a rotor (which might have enabled me to obtain a deeper null on the man made noise source), or if (2) the man made noise to which the loop is more susceptible than the 15' vertical were not there. As for the loop element thermal noise (the hiss), it was mostly, if not entirely, below man made noise at the low end of the NDB band, and completely below man made noise in the MW band. So for MW (and definitely for SW) listening, the 4 meter square loop sensitivity seems to be more than adequate unless, perhaps, you are at a really low man made noise location (miles away from power lines, etc.).

A thorough evaluation of the 4 meter square loop antenna cannot be done until next fall when atmospheric noise levels decline and nighttime MW propagation conditions begin to improve again. At that time I will determine if the 4 meter square loop antenna is satisfactory for me at my location as part of a compact phased array for MW DXing. For a number of years Mark Connelly has used a broadband loop of similar size, but with a different amplifier, and has been very satisfied with it from all reports. According to what I have read, he has mounted his loop and an active whip on top of his car and driven to low noise New England seaside locations for excellent MW DXing. I wish I has such a great place to go to listen. Additional information about Mark's 4 meter square broadband loop antenna can be found by searching the internet.

A late spring cold front passed through last night dumping about one half inch of slow rain, washing trash off the power lines hardware and sending bye-bye the man made noise which defeated the loop's man made noise immune system for the past two days. This morning it was pleasantly cool, in the 60's, overcast, and when I fired up my 746 Pro and 15' noise reducing vertical, man made noise was as low as it ever gets here... perfect for some more comparisons. I switched over to the loop and got (gasp!) 20 over S-9 loop amp noise. The loop amp had gone belly up. Confession time: Carelessly I had not put ferrite beads on the collector leads. Moreover, I had “cheated” and used 2N5943's (fancy 2N5109's) left over from a long defunct project, and had to keep the leads long so they could be bent to fit the PC board which was laid out for MRF581A's. It is likely that one or both 2N5943's had gone into VHF or UHF parasitic oscillation and self destructed. I replaced the 2N5943's with the specified MRF581A's, used ferrite beads on their collector leads, checked the amp for correct operation, and hung the loop back in the tree. Then I tuned to 201 kHz on the 15' noise reducing vertical and listened. Nothing. But after a few minutes there it was, GV surfacing out of the man made noise. I switched over to the loop and there GV was too, but not quite as clear as on the 15' noise reducing vertical. If you live in a location with low man made noise, and if you want a relatively small one turn untuned loop antenna with almost adequate sensitivity at the lower end of the NDB, then you should use a 4 square meter loop element. If you use a receiver which is insensitive in the NDB band, as some are, then you will need an additional amplifier, say a 10.8 dB nominal gain push-pull Norton amp. Unless you use a rotor, or phase the loop against another antenna (15' noise reducing vertical recommended), many daytime MW and LW signals will not be heard at the best possible signal to noise ratios, and some not at all. Similarly, nighttime MW and LW results with such a loop will be less than entirely satisfactory unless a rotor or phasing is used.

Originally the 1 meter square loop used a 6 turn to 3 turn step down transformer at the amp input which was based on theoretical calculations that the amplifier input resistance was about 2 ohms, and the posting recommendation that the loop termination resistance should be about 8 ohms for a -3 dB 550 kHz roll off frequency. According to the posting, theoretically the input resistance of a common base amp is R(input) = [(26 mV) / (transistor current)]. For a single MRF581A adjusted for 26 mA current the theoretical input resistance would thus be R(input) = 0.026/0.026 = 1 ohm, which is 2 ohms for push-pull. The 2:1 turns ratio of the original input transformer provided a 4:1 impedance transformation, which in theory presented 8 ohms termination resistance to the loop as proposed for a -3 dB 550 kHz roll off. However, the measured input resistance of of the MRF581A push-pull common base amp drawing 26 mA per amp turned out to be about 7 ohms. So much for theory in the case of MRF581A's. Consequently, in the case of 8 ohms loop termination no input matching transformer is needed for the 1 meter square loop antenna when MRF581A's are used. Measured amp gain was 18 dB at 1600 kHz, which in good agreement with the gain formula for common base amps, namely $G = 10 \log(R_{\mathbf{out}}/R_{\mathbf{in}}) = 10 \log(450/7) = 18.1$ dB when attached to a 50 ohm load. This is considerably less than the 26 dB gain proposed in the posting, but does not seem to have an adverse effect on signal to noise ratios of LW, MW, or SW signals. If your receiver is insensitive, or if you want to use the loop as part of a phased array, then an amplifier should be used at your receiver. With the input step down transformer deleted, sensitivity of the 1 meter square loop antenna at the low end of the NDB band seemed to be slightly better than the original. For example, GV 201 in Greenville, TX was heard sporadically on the loop without input transformer, while GV was never heard on the original 1 meter square loop. But, of course, that could be due to differences in propagation conditions or man made noise levels for the different times when observations were made. Nevertheless, the 15' noise reducing vertical outperformed the 1 meter square loop with and without an input transformer, producing GV audio more often than the loop. No listening tests have been conducted with the 4 meter square loop without input step down transformer or with a different turns ratio input step down transformer. The loop elements in both cases were made from #18 stranded copper wire. The measured inductance of the 1 meter square loop was 5.3 uH. According to the posting, the lower -3 dB frequency f of the roll off frequency response for a loop termination resistance R_{LT} is $f = R_{LT}/(2\pi L)$, which for this 1 meter square loop with 7 ohms output termination is $7/(2\pi \times 5.3 \times 10^{-6}) = 210$ kHz. For the 4 meter square variant, if direct input coupling is used, the lower -3 dB frequency roll off will be lowered to about 105 kHz.