# High Dynamic Range Balun Loops

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This article is a continuation of my previous article, "What's Wrong With Present Day Loop Antennas." In that article I pointed out that the main problems were excessive amplifier gain, usually accompanied by spurious responses, and amplifier noise. The improved version of Ralph Sanserino's balanced differential amp which I presented in that article is excellent for use with ferrite rod loop antennas, and very nearly solves those problems completely. For DXers in large urban areas with high ambient noise levels, one of the amplified ferrite rod loop antennas I described in my previous article is more than adequate for their needs, provided it is used with a top-of-the-line tube receiver such as an HQ-180(A) or R-390A in good operating condition. But for some of us who are fortunate to have occasional low levels of power line and other man-made noise, a well designed 2 foot air core loop antenna will sometimes produce audible signals where these kinds of amplified ferrite rod loop antennas will not. It may be that small feerite rod loops are inherently less sensitive than a 2 foot air core loop, or it may be that balanced differential amp noise limits their sensitivity. In any case, I have concluded that a 2 foot air core loop is the best starting point for a high performance MW loop antenna.

As I said in my previous article, no single loop antenna is ideal for use with all receivers. For example, a 2 foot unamplified air core loop is sensitive enough and provides adequate signal levels for an HQ-180(A). In fact, it is ideal for an HQ-180(A). An amplifier would not improve sensitivity; it would merely degrade the dynamic range of the receiving system. For other receivers, such as an R-390A, 51J-4, or HQ-150, the signal levels produced by an unamplified 2 foot air core loop antenna are not sufficient. Perhaps a larger air core loop, say 4 feet square, would provide adequate signal levels for these receivers. But as I said in my previous article, most DXers do not have adequate space for a 4 foot square air core loop, and mechanical stability becomes a problem for such large loops. A better solution is to use a low gain, high dynamic range amplifier with a 2 foot air core loop.

In this article I will describe a balanced 2 foot square air core loop in several versions for use with the receivers mentioned above. First, I will describe the loop with balanced feed lines for use with an HQ-180(A). Next, I will describe the loop with a balun (BALanced to UNbalanced transformer) so that the loop can be connected to an HQ-180(A) with a single unbalanced feed line. Finally, I will describe the loop with a low gain, high dynamic range amplifier which makes the 2 foot air core loop ideal for use with an R-390A, 51J-4, or HQ-150. Curiously, the amplified version has virtually no gain when used with an HQ-180(A), and so the amplified version can be used with all these fine receivers.

In my opinion, loop antennas should be balanced because balanced loops have deeper nulls than unbalanced loops, which makes them better for nulling local noise sources or strong interfering stations. The simplest way to connect a balanced air core loop to an HQ-180(A) is by direct coupling with balanced taps; see Fig. 1 below.

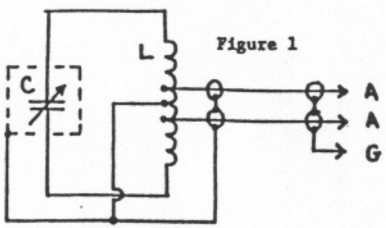



Figure 1

An HQ-180(A) has two A terminals and a G terminal on a rear chassis terminal strip. When the shorting link between the G terminal and the adjacent A terminal is opened, the antenna input terminals are configured for balanced input. With a 14 turn loop coil, which is typical for 2 foot air core loops, the coil taps should be one turn each side of center tap. In this case, the taps provide an impedance transformation of 49:1. Taking 240K ohms as the impedance of a tuned circuit at resonance, a source impedance of 4.9K ohms is presented to the HQ-180(A) antenna input terminals. Theoretically, this is not a good impedance match. According to the HQ-180(A) manual, the antenna trimmer can be used to match antenna impedances between 50 and 600 ohms. However, as I will explain below, a better match does not increase signal levels or improve sensitivity.

While enough details will be given for an experienced builder to duplicate my circuits, it is not my intention to make this a step-by-step construction article. If you are not an experienced loop builder, but would still like to try building one of these loops, get the NRC Antenna Reference Manuals and Ralph Sanserino's IRCA reprint A8, and study how loop antennas are built. It is unlikely that you will copy any of those designs exactly because your loop frame will be determined to some extent by locally available construction materials.

My loop coil L is 14 turns, center tapped, of #18 stranded bare copper wire, 7 strands of #22, which was obtained by stripping the insulation from some Radio Shack speaker wire. The 7x22 speaker wire does not seem to have a fixed Radio Shack catalog number, but my friendly Radio Shack salesman stripped about an inch off the end of a 50 foot spool and let me count strands. I do not recommend other kinds of wire because I have found that the 7x22 has the best balance of strength, rigidity, and flexibility. Currently I am using 11/16" spacing between turns with a 1-3/4" gap between the two 7 turn halves of the loop coil. The 1-3/4" gap is due to my use of 2 by 2 fir (actual dimensions 1-3/4" by 1-3/4") for the loop cross arms and a metal box containing the tuning capacitor C mounted on a cross arm below the bottom loop coil support; see Fig. 2 below.

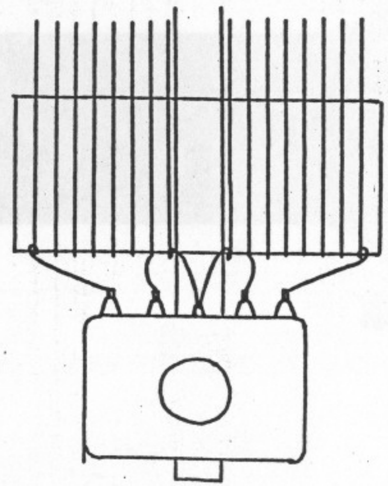
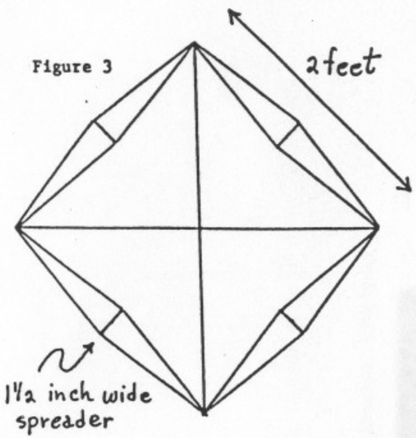


Figure 2

The upper and lower frequency limits of the tuning range are determined by the air variable capacitor capacitance range and by the spacing between turns. In my previous article I recommended a 660 pF air variable, and discussed several sources. In that article I neglected to mention that if the capacitor has trimmers, the trimmers should either be removed (the best approach) or at least set for minimum capacitance. Otherwise, the minimum capacitance of your air variable capacitor may be rather high, which would restrict the tuning range. With 11/16" spacing between turns, 1-3/4" gap between 7 turn halves, and a 600 pF air variable, the tuning range is from just below 540 KHz to beyond 2000 KHz for the circuit of Fig. 1. With the amplified version which I will describe below, the tuning range is about 510 KHz to 2050 KHz. I did not have a 660pF air variable capacitor when I built my original loop, so the tuning range is not quite as wide as I would like. My design target was at least 500 KHz - 2000 KHz. That is why I recommend a 660pF capacitor for the main tuning capacitor. With narrower spacing between turns, the high end frequency limit is lower — about 1925 KHz for 1/2" spacing, and about 1750 KHz for 1/4" spacing. The narrower spacings also lower the low end frequency limit (to well below 500 KHz for the amplified version). I don't recommend spacing between turns wider than 11/16" because that is about the widest spacing possible with 12" coil supports, and wider coil supports might present rigidity problems.

I used 12" wide by 4" high pieces of 3/16" thich plexiglass for my loop coil supports. A better choice would have been 1/4" thick plexiglass, at least for the bottom support, because when tension is applied to the coil with spreaders, the bottom loop coil support flexes slightly. Spreaders are desirable because they apply tension to the #18 stranded wire which helps maintain uniform spacing between turns and a rigid geometry for the turns. I used 12" long pieces of 2 by 1/2 fir (actual dimensions 1-1/2" by 3/8"), and threaded the spacers between alternate turns of the loop coil; see Fig. 3 below. The plans for "The N.R.C. Two-Foot Loop" specify 3/4" wide spreaders, but I found 1-1/2" wide spreaders a better choice.

Figure 3

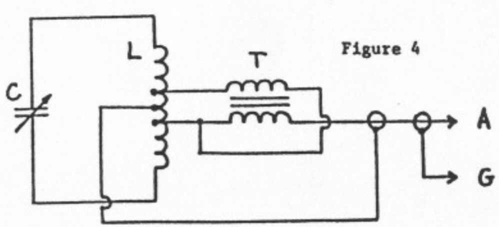



As shown in Fig. 1 the tuning capacitor C is mounted inside a metal box. This is not necessary for the unamplified version. In my experience nulls are about as good with a simple "open air" mounting arrangement as with a metal box. However, the box does protect the capacitor from dust and from damage by accidental contact. If the capacitor is mounted in a metal box, it must be insulated from ground, and the tuning knob should be isolated from the tuning knob with an insulated coupler such as a Millen #39002. Shortcuts like using a short length of 1/4" wood dowell are acceptable for prototyping loops, but they don't hold up well under heavy use. The coax for connecting the loop to the receiver may be RG-58 (my choice), RG-59, miniature coax, or even audio coax. Wires entering and exiting the box may be implemented with grommet lined holes, or with insulated feedthroughs (H. H. Smith #9550 or #9555) and connectors (RCA, BNC, or SO-239). I like Smith #9550 feedthroughs and BNC connectors.

To make tuning easier, I recommend a 6:1 planetary reduction drive. If you plan to use the loop as part of a phased array for generating cardioid patterns, you should use the amplified version below with a dual speed 6:1/30:1 Jackson Brothers planetary drive.

As I said above, the output impedance of the loop of Fig. 1 is not well matched to the input impedance of an HQ-180(A). A better impedance match is obtained by using a balun; see Fig. 4 below. The balun T of Fig. 4 is a 4:1 balanced to unbalanced broadband transformer. With the 4:1 balun, the 4.9K ohms source impedance of the taps is transformed into a 1.25K ohms source impedance. However, there is little, if any, difference between the S-meter readings for the two methods of feed. Apparently any loss due to mismatch in the balanced feed of Fig. 1 is offset by the higher voltage levels of Fig. 1. The only advantage of the unbalanced feed circuit of Fig. 4 is that it permits the use of a connector (PL-259, or BNC with a BNC to PL-259 adapter) for connecting the coax to the HQ-180(A).

Figure 4




The balun T of Fig. 4 is 70 bifilar turns of #30 enameled copper wire on an Amidon FT-82-61 ferrite toroid core. This is not an off-the-shelf item. You will have to wind the balun yourself. Take two 8 foot lengths of #30 enameled copper wire, twist the two lengths together, about 4 twists per inch, and start winding. It is somewhat like sewing. The 70 bifilar turns are close spaced, and will just barely fit, covering the entire toroid. The exact number of turns is not critical. With close spaced turns, which means the turns touch each other on the inside circumference of the toroid, you will be within a few turns of 70 turns when the toroid is completely covered.

As with Fig. 1, the circuit of Fig. 4 may be mounted "open air" or the capacitor and toroid may be mounted in a metal box. And as before, the nulls of the open air version of Fig. 4 are about as good as with the metal box mounting arrangement. In Fig. 4 I have shown the coax attached to the A and G terminals on the HQ-180(A) chassis rear. Alternately, you may use a PL-259 connector and attach to the SO-239 socket on the HQ-180(A) chassis rear. In both cases, be sure that the shorting link is connected to the adjacent A terminal.

The 2 foot, unamplified, air core loops I have described are ideal for use with an HQ-180(A). Unfortunately, the signal levels are not quite adequate for an R-390A, 51J-4, or HQ-150 if (and only if) you occasionally have very low levels of power line and other man-made noise. In that case, some (but not much) amplification is needed. After extensive testing over several years, I have arrived at the amplifier design shown in Fig. 5 below.

Before I discuss the amplifier, let me belabor the point I have made repeatedly in this article and the previous article. Excessive signal levels do nothing but degrade the dynamic range of a receiving system, which may make it more difficult to hear the DX you want to hear. At my location, for a foreign split to be audible with my amplified loop or 80 foot inverted L, the signal level must be at least 30 dB and usually more like 40 dB on the R-390A carrier meter. The signal levels with one of the unamplified loops I have described are typically about 15 dB lower than with the amplified version when used with an R-390A, so a split becomes audible when it reaches 15 to 30 dB on the R-390A carrier meter. That is plenty of signal. Virtually any foreign split I can hear on my R-390A with the amplified loop can be heard equally well with the unamplified version of Fig. 4. The only exception might be Senegal on 765 KHz at local sunset which tends to have lower signal levels, but I have never made a comparison to find out. For DXers in large urban areas with high power locals, one of the unamplified versions may be a better choice for the following reasons. Because they have no amplifier, the unamplified versions have theoretically infinite dynamic range and no spurious responses. Any spurious responses you hear with the unamplified versions originate in your receiver or elsewhere. If you are plagued by powerful locals, one of the unamplified versions may actually improve the performance of your receiver. Here is how. In theory the 3rd order IMD products of any amplifier increase or decrease 3 times as fast as the fundamental signals increase or decrease, and the 2nd order products increase or decrease 2 times as fast. Consequently, in theory the 3rd order IMD products should be about 45 dB lower and the 2nd order IMD products should be about 30 dB lower when using one of the unamplified loops I have described as compared to the amplified version below. The only cases where the amplified version is need with an R-390A are for sunrise DXing, daytime DXing, sunset DXing, and when using the loop as part of a phased antenna system.

The amplifier is based on designs discussed in A. Burwasser's November 1979 Ham Radio article, "How to design broadband JFET amplifiers to provide top performance from VLF to over 100 MHz," pages 12 - 18. The amplifiers discussed in that article are grounded gate amplifiers which have low input impedance, low gain, and high 2nd and 3rd order intercepts (typically 35 dBm and 25 dBm respectively). Their only disadvantage is that the source is usually biassed for rather high current drain, typically 18 mA, which eats up batteries quickly. The drain current is determined by resistor R of Fig. 5. The article above contained no information on how a lower drain current would effect the 2nd and 3rd order intercepts. So I spent a lot of time listening with different values of R. I observed no spurious responses with values of R as high as 470 ohms (which corresponds to 5 mA current drain). I recommend against lower drain currents (higher values of R) because a Siliconix data book shows that the noise figure for grounded gate U-310 amps begins to increase as drain currents fall below 5 mA. There is only one super local at my location, so it is possible that some spurious responses would be experienced in urban areas with several super-locals. I suggest that you start with R=470 ohms and use a lower value of R (higher drain current) only if spurious responses are observed.

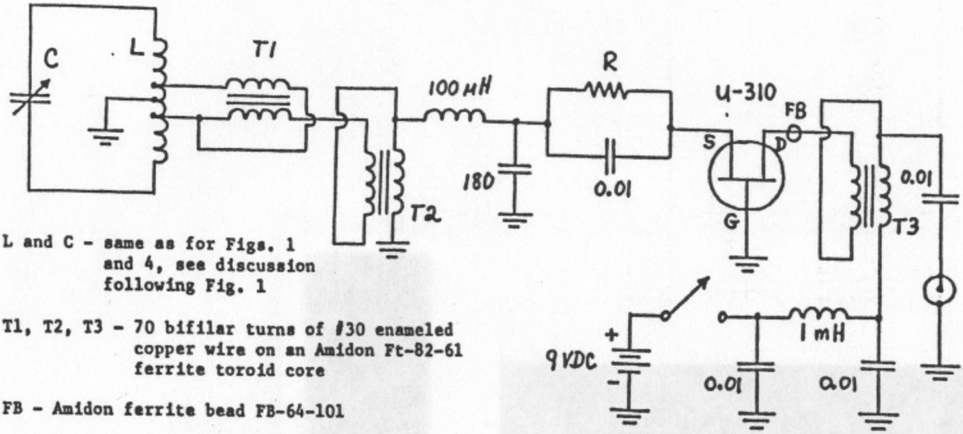
Transformer T1 is a 4:1 broadband balun which converts the balanced and rather high impedance of the loop coil taps to an unbalanced and lower impedance. Up to this point, the circuit is identical to the circuit of Fig. 4. Transformer T2 is a 4:1 broadband transformer which converts the impedance to a still lower value, about 312 ohms assuming 240K ohms for the

A101-3-3

**Figure 5**

**Amplified Loop For R-390A, 51J-4, HQ-150 And Other Receivers**

**TWO FOOT AIR CORE HIGH DYNAMIC RANGE BALUN LOOP**




L and C - same as for Figs. 1 and 4, see discussion following Fig. 1

T1, T2, T3 - 70 bifilar turns of #30 enameled copper wire on an Amidon Ft-82-61 ferrite toroid core

FB - Amidon ferrite bead FB-64-101

R - nominally 470 ohms, which gives a drain current of about 5 mA; if spurious responses are experienced, try a lower value for R which gives a higher drain current: 220 ohms gives about 9 mA, 100 ohms gives about 15 mA

impedance of a tuned circuit at resonance. The 100 μH choke and 180 pF capacitor following T2 are artifacts from a previous design of mine and are supposed to function as a 3 MHz cutoff low pass filter. The 180 pF capacitor seem to have little or no effect in the circuit of Fig. 5, and so could be omitted. The 100 μH choke should not be omitted because it seems to reduce amplifier noise. The ferrite bead on the U-310 drain lead is to suppress VHF parasitic oscillation which sometimes occurs in broadband JFET grounded gate amps. The output is coupled to the receiver through a 4:1 broadband transformer.

The gain of the amp depends on the load it sees. For example, a receiver with a 50 ohm antenna input impedance presents 200 ohms as a drain load for the U-310. In theory, the voltage gain equals the power gain for this amp, and both are equal to $R_L/R_{in}$ where $R_L$ is the load resistance and $R_{in}$ is the resistive component of the U-310 input impedance. Taking 10,000 micromhos as the nominal transconductance of a U-310, it can be shown that the input impedance is approximately 100 ohms. Thus when this amp is used with a receiver having a 50 ohm antenna input impedance, the voltage gain is 2, or 6 dB. For an R-390A the nominal antenna input impedance is 125 ohms, so we would expect about 14 dB gain. This is in good agreement with the observed gain when the amp is used with an R-390A.

Curiously, as I mentioned before, the amp has virtually no gain when used with an HQ-180(A) By this I mean that signal levels with the amplified version of the loop are at most maybe 3 dB greater than with the unamplified version when they are used with an HQ-180(A). I do not consider this to be a problem, but rather an advantage because the amplified version of my loop works equally well with all of the top MW tube receivers - HQ-180(A), R-390A, 51J-4, HQ-150.

For best performance, I recommend that the amplifier and tuning capacitor be enclosed in a metal box.