Low Cost Dual Crossed Small Loop Receive Antenna

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Abstract

This paper describes a small, low cost dual crossed-loop receive-only antenna used in active ionospheric sounder experiments in 2015[1]. The loop amplifier as used in those experiments is presented. That particular configuration favored very high amplifier dynamic range and low cost at the great expense of gain and low noise. That tradeoff is unlikely to be desirable in the majority of use cases, thus two other variants of the loop amplifier and described with different tradeoffs that may be more desirable in most cases.

Loop Construction

There are two loops, one for each axis. The loops are of conventional design, consisting of an 11-1/2 foot piece of RG-8X coaxial cable with a 1-inch section of braid removed at the center of the coax, then re-sealed with electrical tape. The length of the cable is trimmed afterwards to fit into the housing and extend to the amplifier, the length is not critical. Each loop and corresponding amplifier is completely electrically isolated from the other. Each loop is inserted into a 10-foot long piece of PEX tubing commonly available at the hardware store.

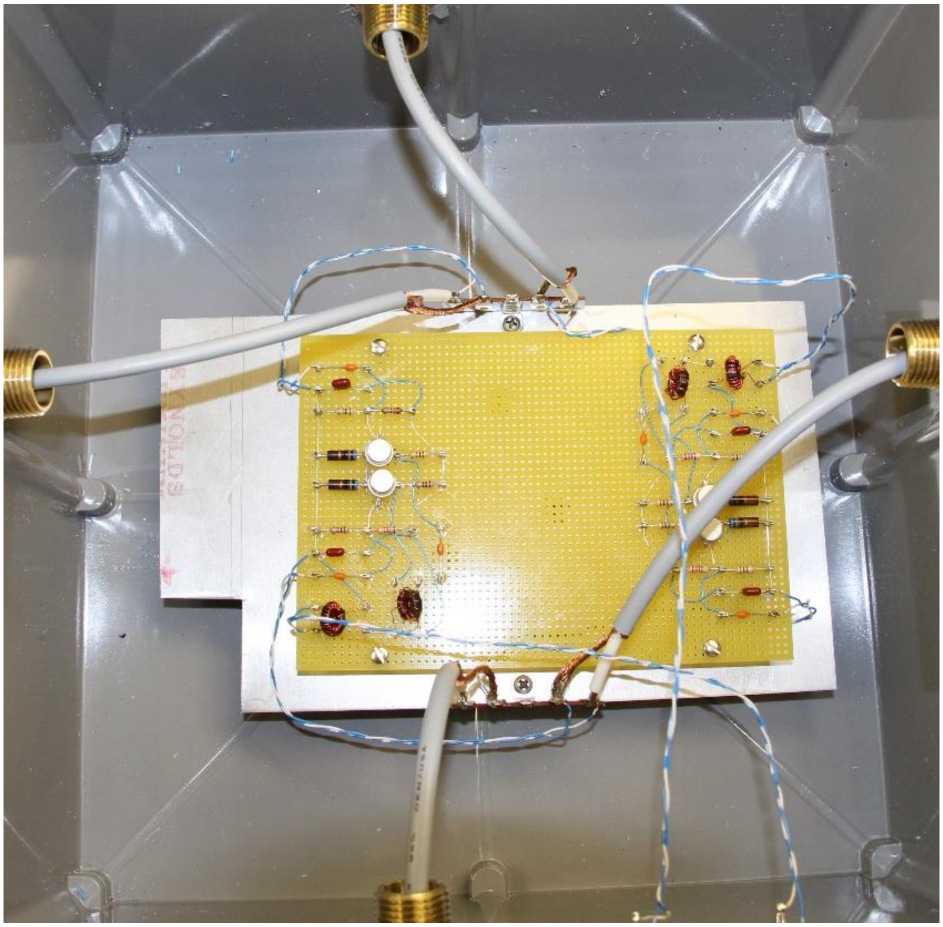
The housing is a 12 x 12 x 6 inch plastic electrical box, also commonly available at the hardware store. The PEX tubing is anchored by barbed brass fittings and hose clamps. The barbed fitting is inserted into a hole drilled in the box, and secured with a nut. The barbs protrude out from the box. The PEX tubing is pushed over the barbs and secured with hose clamps. The two loops are supported with a closet flange attached to the box and some PVC fittings glued to provide a crossed-Tee arrangement with the PEX pushed through the PVC fittings. The PEX could be secured to the PVC for a sturdier mounting. See Photograph 1. The inside of the housing where the fitting passes through is sealed with RTV after construction.

The amplifier is constructed inside the amplifier using flea-clips and perforated fiberglass board. Two F-type receptacles are inserted into holes drilled in the plastic enclosure. Complete electrical isolation is maintained between the two loops and amplifiers.

[1] Measuring the Ionosphere at vertical incidence using Hermes, Alex, and Munin Open HPSDR and Gnuradio, Tom McDermott, N5EG. ARRL/TAPR Digital Communications Conference 2015 proceedings.

DC power is provided independently to each amplifier on the center conductor of the receive F connector using a bias-T at the receiver. Nominally +13.6 VDC is used, but the exact voltage is not critical.

See the photographs for exterior and interior views of the antenna.



Receive Amplifier

For the active ionosphere experiments, the transmit antenna was located 20 meters away, and the testes were conductive full-duplex. This means that the dynamic range of the receive path was of utmost concern. The amplifier used actually had -5 dB of gain in the HF range. The amplifier was designed using very common parts already available in the junkbox, and of very low cost. This will be called Amplifier ‘A’.

Such a design is unlikely to be useful in almost any case where full duplex operation is not needed, and a different amplifier configuration is recommended instead. Two alternative designs are presented, one using older parts that might be available in the junkbox, (Amplifier ‘B’) and another that has superior noise and gain using low-noise amplifier integrated circuits (Amplifier ‘C’).

Amplifier A

One (of the two) loop amplifier A schematics is shown in Figure 1. It consists of a bipolar differential pair driving a transformer to convert the output signal to single ended.

It is fed by a common mode choke. The cores are both ferrite FT37-43 wound with #30 magnet wire arranged as bifilar, relatively tightly twisted together, and then wound over the core. The transformer uses 10 bifilar turns, while the common mode choke uses 20 bifilar turns. The loop was modeled using the Trask[2] small loop model. The components inside the dashed line in the schematic is the RG-8X coaxial cable loop. The variable inductor is in series with a capacitor and is tuned to provide a single rejection notch adjustable within the AM Broadcast band. It can be tuned to reduce the strength of one offending AM BCB station if desired. The value of C3 may need to be changed if the frequency notch is out of range of the inductance adjustment range. Additionally, the value of R9 or R6 may need to be tweaked slightly to balance the amplifier due to differences in the beta of Q1 and Q2, and the tolerance of the other resistors.

The amplifier is powered by +12 VDC on the center conductor of the feedline.

L3/L4 is one transformer core with bifilar turns, while L1/L2 is the other transformer core with bifilar turns.

This version of the antenna amplifier was successfully used in a very-high-dynamic range requirement full-duplex HF ionospheric experiment with transmit and receive antennas located about 20 meters apart.

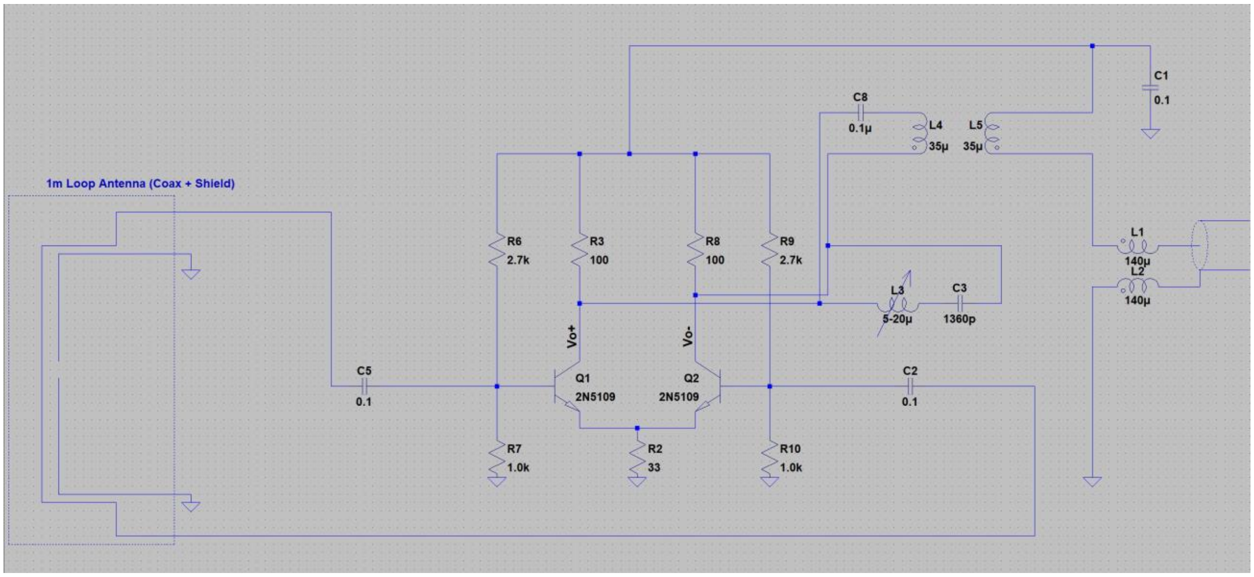


Figure 1 - Amplifier type A

[2] "A Varactor-Tuned Indoor Loop Antenna", Chris Trask / N7ZWY, Feb 13, 2009.

Amplifier B

The collector impedance of the bipolar pair in Amplifier A is swamped by the load impedance of the transformer that drives the coaxial cable. As a result the gain of the pair is actually negative 5 dB or so. In order to increase the gain, the collectors are isolated by emitter follower transistors, using 2N2222 or similar NPN transistors. These followers raise the impedance seen at the collectors. This increases the RF voltage at the collectors which reduces the dynamic range of the amplifier.

Anecdotally, three extremely strong very close local AM Broadcast stations overload this version of the amplifier. The output of the amplifier was measured at 5 volts peak-peak, with extensive intermodulation distortion from the vector summation of the three AM station carriers.

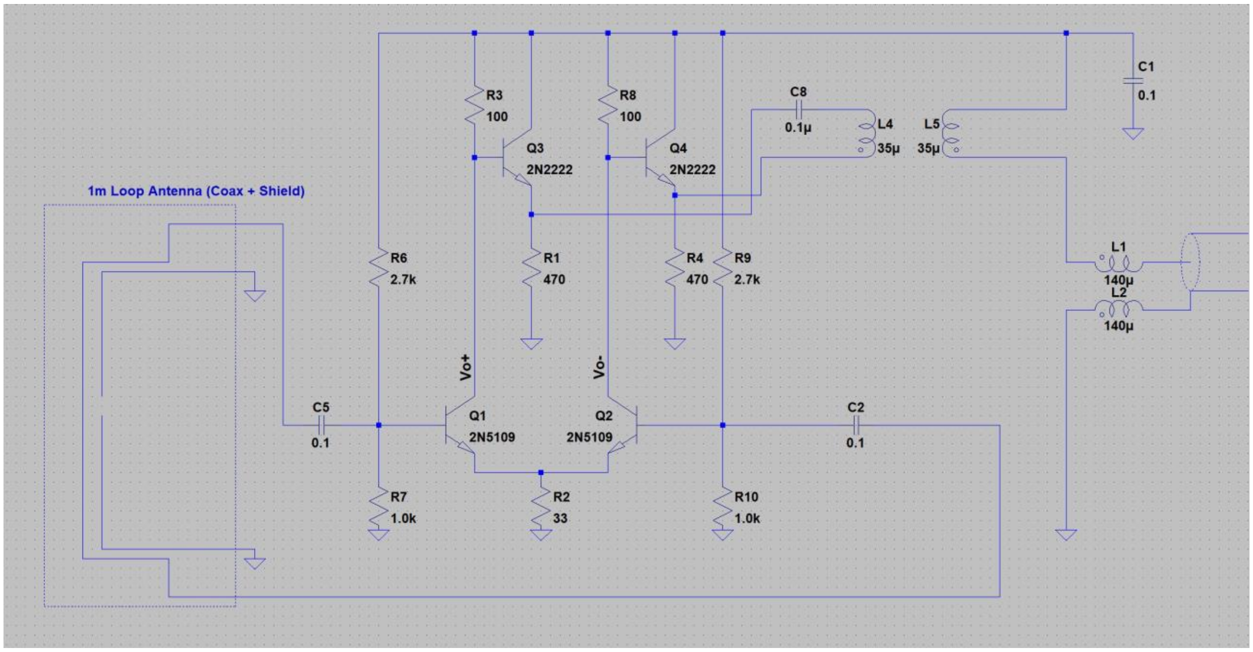


Figure 2 - Amplifier type B

Requested Features

During the discussion of the low-cost antenna numerous requests were raised. Many of these requests are mutually-exclusive. A condensed list of requested features includes:

1. Best possible sensitivity / lowest possible noise.
2. Highest possible overload IP2 and IP3 intercept points.
3. Deepest possible null in the side pattern.
4. Minimum coupling between the loops.
5. Maximal orthogonality between the loop responses (perhaps to achieve good X-wave and O-wave discrimination?).
6. Extensively protected against damage from lightning and strong nearby transmitters. This may degrade the intercept point conflicting with # 2.
7. Lowest possible frequency response.
8. Highest possible frequency response with cleanest pattern. This may require eliminating loop shielding to reduce stray capacitance (which lowers the resonant frequency of the loops).
9. Maximal common-mode rejection. This is usually helped by adding loop shielding.
10. Lowest possible cost, ability to build in the home workshop without specialized tools.

No single design is likely able to achieve all the above objectives.

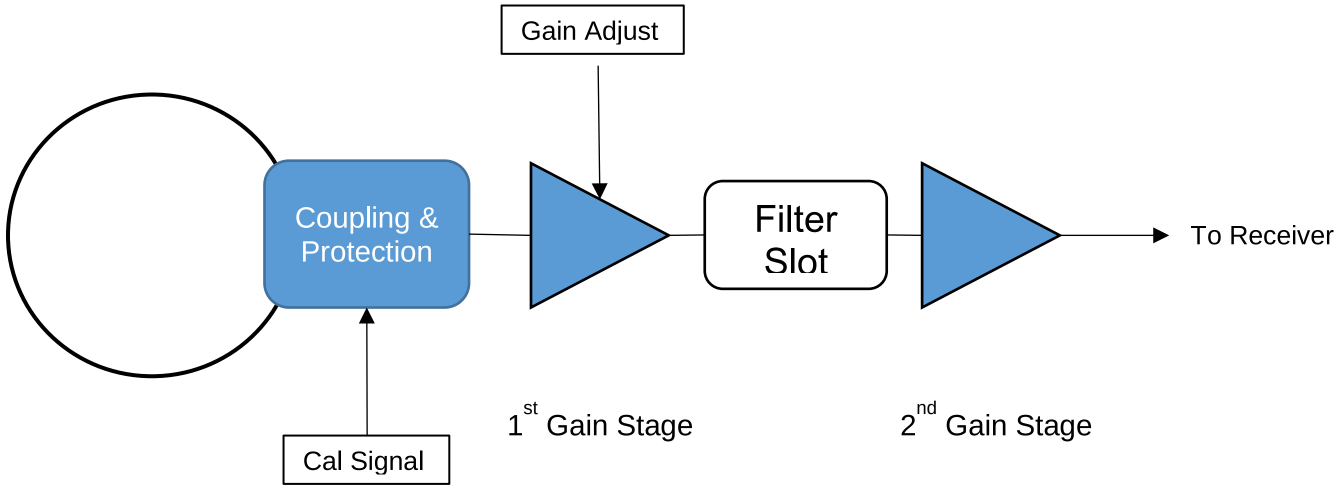
The HAMSCI team probably needs to decide what the initial science objectives are, and what antenna parameters are necessary to successfully achieve those objectives. That list hopefully results in a physically realizable antenna and preamplifier design.

In the TangerineSDR receiver a filter slot is provided in the receiver front end. That slot may be bypassed with a jumper, or it may be equipped with one of:

- Attenuator
- AM Broadcast band-stop filter
- Active amplifier

The receiver presents approximately 50 ohms input and output impedance to that slot.

A similar approach may be useful in a practical crossed-loop antenna design, with perhaps a mid-stage amplifier slot being used. In such a design the first amplifier could be a low noise, low gain amplifier providing 50 ohms output impedance. That would feed a (bypassable) filter slot. That filter slot would then feed an output stage that provides 50 ohms input impedance, additional gain, and drives coaxial cable to the receiver. That gain might be jumper selectable. See the block diagram.



Such a design might provide an antenna / preamplifier combination that could be tailored to several different science needs, or might be able to adapt to different site-related RFI problems.

Discussion

In cases where much lower noise and higher gain is useful, and specialized components are available, the benefits of using integrated circuits with low noise and higher gain are very worthwhile. Several designs are available, for example from Dr. Mike Trimpi discussed briefly in Appendix C.1 from[3].

Other similar designs are available. One issue with the mid-stage filter is that the phase delay of the filter will prevent feedback from being applied around the two gain stages (it would likely oscillate).

[3] "Receiving Antennas for the Radio Amateur, Eric P. Nichols, KL7AJ, ARRL 2018