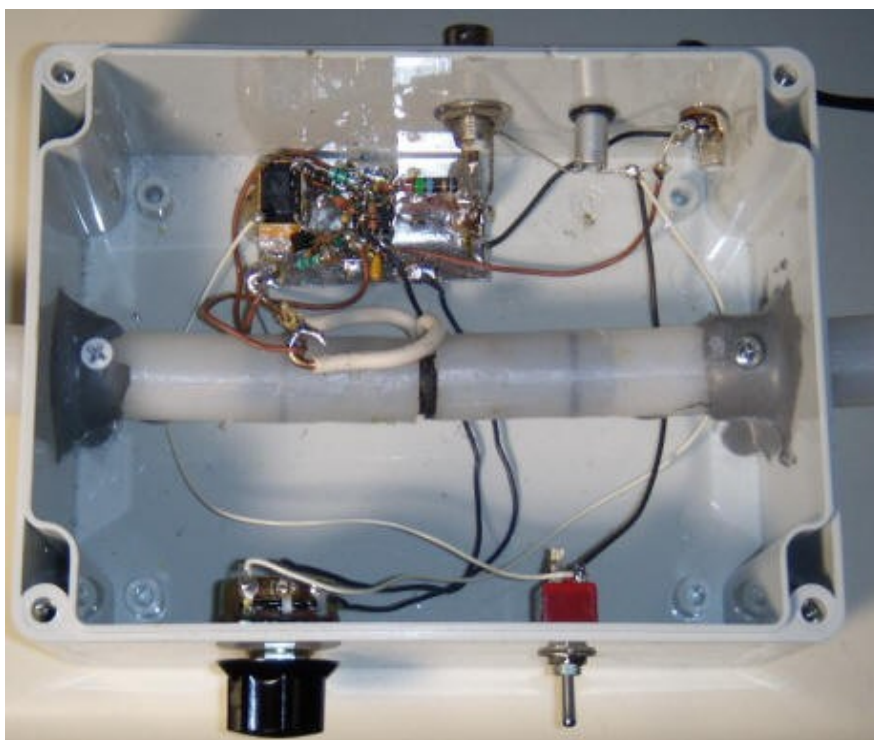


Antennas

Home-made antennas can greatly improve the performance of AM and FM radios, short-wave receivers, and scanners. If you are a talk-radio fan then experiment with the AM band antennas and you will be able to hear shows from all over the country with surprising clarity. Short-wave receivers are always coping with weak signals and they must have a good antenna to perform adequately. Scanners can pick up local police and two-way radio with the little telescoping antenna provided but with good antennas a scanner becomes an amazing ear on the world nearby. No pre-amp, filter or other receiver refinement offers anywhere near the level of performance improvement that a well-designed antenna offers. The results can be quite satisfying, leaving no doubt that the project was well worth the effort.

Active 3-30 MHz Hula-Loop Antenna for Shortwave

In the past, designs that incorporated an amplifier in the antenna were called "antennafiers" so perhaps this is a "loopifier". The differential amplifier solves matching issues and the varactor tuning gives excellent out-of-band rejection for even cheap receivers. I think the good common-mode rejection from the differential amplifier eliminates the need for a shield, too.

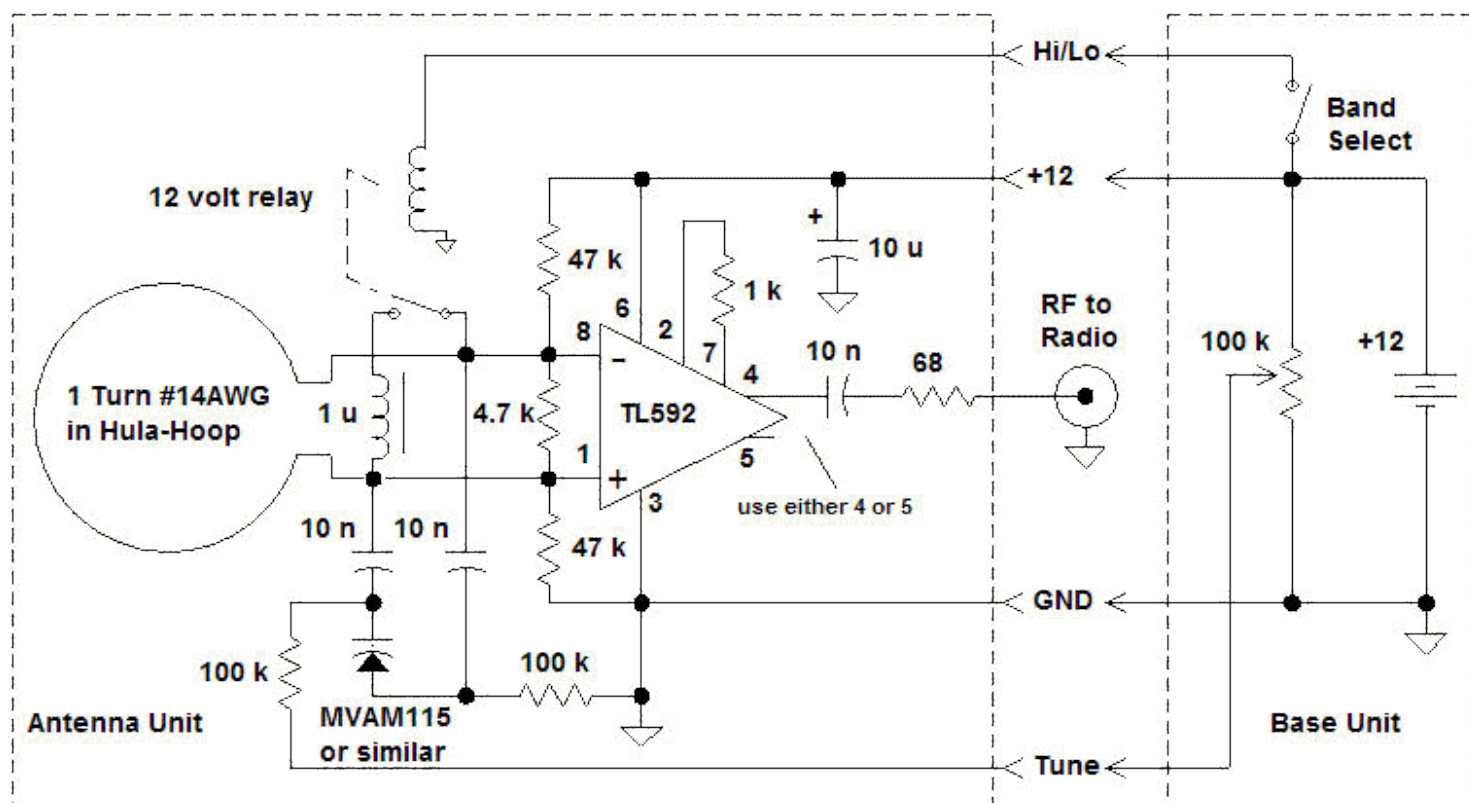


This active antenna for the shortwave band provides surprising performance, even indoors. As the name implies, the main loop is made from a Hula-Hoop with the metallic paint stripped off and a single turn of 14AWG copper wire inserted inside the hoop. (There isn't any need to remove the paint; mine was flaking and I didn't like the looks. Half-way through I regretted my decision!) These hoops are basically thin-walled plumbing tubing with a water-tight connector holding the ends together.

(Mine was actually filled with water to make a "swish-swish" sound, supposedly.) The ends of the hoop pass through two holes in a plastic project box and are then joined together. A hole was drilled in the middle of the original black tubing connector to bring out the ends of the insulated house wiring (heavy white wires). This single turn of wire has about 4 μH inductance. A couple of screws and some epoxy holds the loop in position. The screws were added as an afterthought, cracking the epoxy a bit, because the epoxy doesn't really adhere to the tubing very well. The solid copper house wire is too stiff to connect directly to the circuit so a couple of lengths of hookup wire were added. A little piece of tinned copper circuit board material holds the circuitry. The power is supplied by a molded power supply not shown.

The circuit avoids matching issues by employing a high impedance differential amplifier (TL592) connected directly across the loop. Even with the Q-killing 4.7k resistor, the impedance transformation is on the order of 100:1, an impractically high value for a broadband balun of reasonable cost! Even though the TL592 isn't the lowest noise amplifier ever designed and the resistor kills some of the signal, this configuration picks up so much signal that the circuit noise contribution is negligible! In fact, the amplifier is operating at a very low gain simply to avoid clipping and most signals push the signal meter well over S-9. I've never heard so many stations! The picture to the right shows the signal strength with the antenna tuned to WWV at 10 MHz with the antenna and receiver sitting on the kitchen table. That beats the nice vertical on my roof. Don't be misled, however; the antenna doesn't perform miracles. The atmospheric noise is also amplified so the signal-to-noise does depend on the location of the antenna and other conditions. Nevertheless, this indoor antenna has consistently outperformed my rooftop whip and when moved outside, it "blows away" the rooftop antenna, in some cases giving a strong signal when the whip gave no discernable signal at all. (Without the Q-killing 4.7k resistor across the coil, the bandwidth was only 10 kHz at 5 Mhz. That's a Q of 500! There might be some future projects that take advantage of that.)



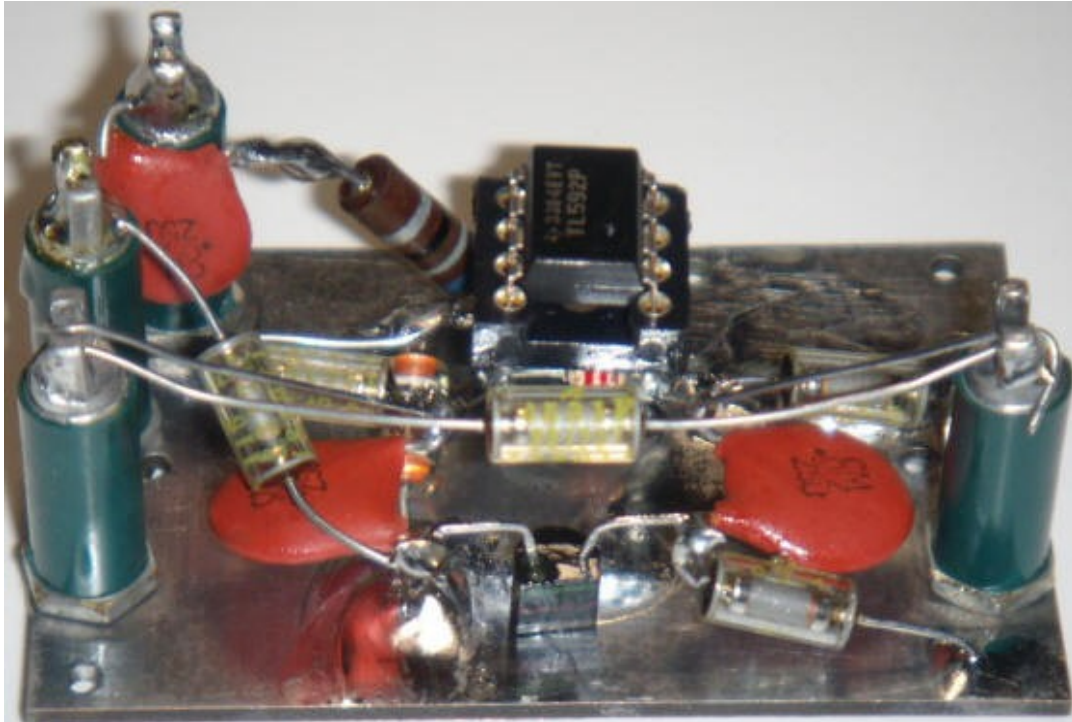


The indoor unit in the first photo combines both the "Antenna Unit" and "Base Unit" in one box .

Tuning is accomplished by an AM-band varactor like the MVAM115 or MVAM125. Suitable substitutes include the KV1560 or KV1520 but the potentiometer voltage must be reduced to avoid exceeding those diode's ratings. A 100k in series with the top pot connection should do the trick. Varactor tuning is recommended because longer leads for a mechanical capacitor may add resonances at FM frequencies, causing overload of the amplifier and nasty intermodulation at the output. The varactor should be kept close to the amplifier input leads to minimize the impedance at high frequency. A band switch activates a relay that connects a choke across the main coil for tuning above about 12 MHz. The schematic shows a 1 uH value but the best value will be determined by the choice of varactor and the tuning voltage range. My Hula-Hoop prototype above has two, 1 uH chokes in parallel to just reach 28 MHz but the square loop required 1 uH to tune to 30 MHz. It is pretty easy to tell where the antenna is tuned by observing the noise peaking on the receiver's S-meter. The original experiments were done at 15 volts and the extra voltage pushed the frequency to well over 30 MHz but I dropped down to 12 volts since 12 volt relays and power supplies are more common. The low end of the range is about 3 MHz and there is plenty of band overlap.

An outdoor version was built with ordinary PVC tubing in a square shape similar in dimensions to the Hula-Hoop (not critical). The stiff 14AWG copper wire was replaced with a heavy braid to make it easy to thread the wire through the square shape. The circuit is identical except that the potentiometer and band switch are in a separate box near the receiver (little white box) and a 4-conductor wire carries the DC signals to the remote antenna box (a PVC electrical junction box).





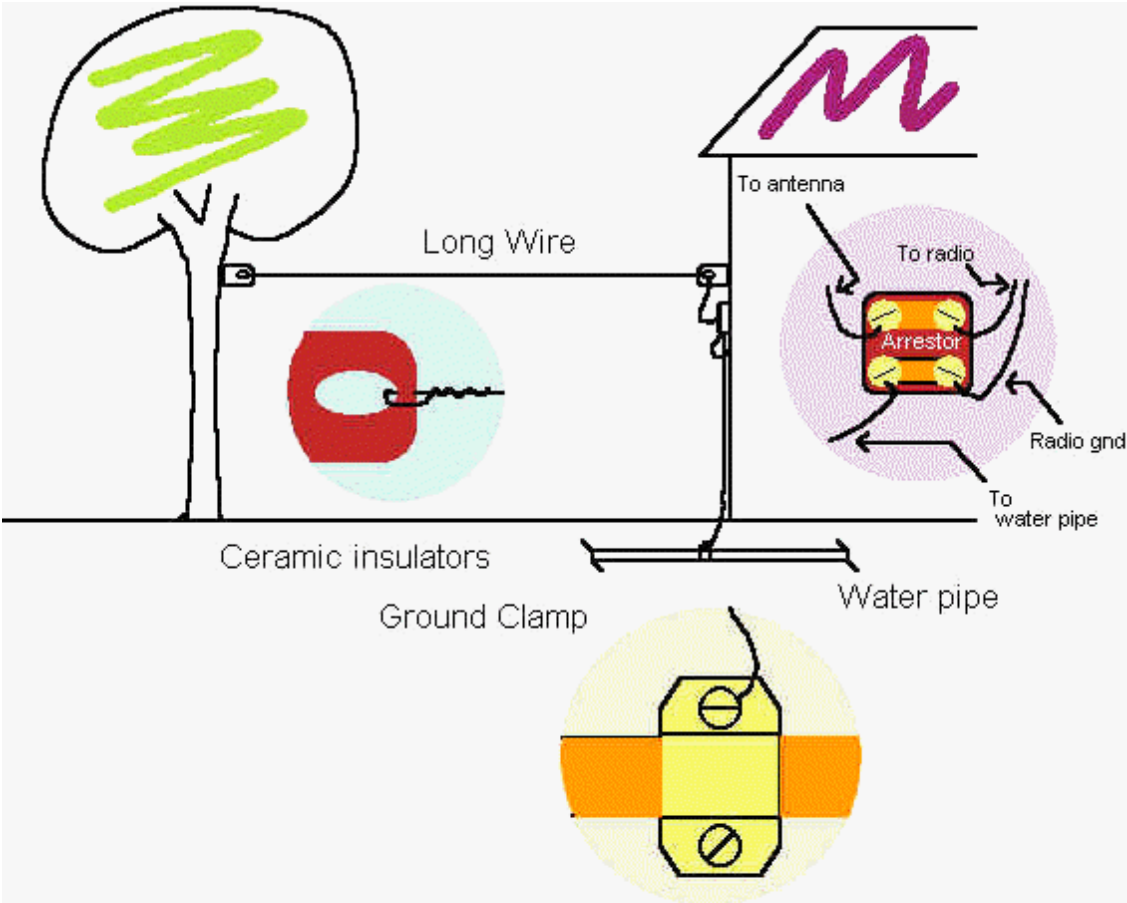
The relay was added after the photos of the outdoor box and board above. The wires coming down from the antenna include a cable with four-conductors to control the amplifier, a coax cable for the RF to the receiver, and a three-conductor cable for the antenna rotator.

The performance of the indoor antenna is good, moved outside on a flipped-over garbage can it is great, but the performance of this rooftop loop is spectacular! Simply tune the radio to the desired frequency then tune the antenna for maximum noise, switching the band somewhere around 12 to 15 MHz. (there is plenty of overlap). The Q is low enough that retuning is only necessary when moving from one band to another. In some areas lower Q may be desired to prevent amplifier overload. In only a couple of days I've heard stations all over the world including some "numbers" stations with S9 clarity!

If you would like a couple of the TL592s, send me an email. I recently bought 500 on eBay so there is a good supply.

Reader Minoe from The Netherlands has graciously provided a [board layout](#) designed by www.circuitz4u.com! Minoe says, "the zip contains both the Eagle files and the Gerber files. You can load the files in Eagle for editing (<http://www.cadsoft.de/freeware.htm>)."

Thanks Minoe!



AM Band

Figure 1: Long wire antenna for AM and shortwave radios.

Antennas

A good AM Band antenna can be a simple long-wire strung between two trees or across the top of the roof. Even a modest length wire will give your receiver greatly improved reception with less static because the signal pickup is occurring some distance from the interference generating appliances in the house. An insulator mounted high in a tree so that the wire has a large vertical rise will give great results. Mount the antenna as high and as far from the house as practical. Use a good quality ceramic insulator for holding the wire and add a commercial lightning arrestor where the antenna meets the house (Fig.1). Ceramic insulators are available with built-in wood screws and can be screwed into a tree or the wood parts of the house by hand. The wire may be tied to the far insulator as shown but the wire will stretch with time and require adjustment. A "trick" is to pass the wire through the insulator and fasten a fishing weight to the end so that the weight hangs a few inches below the insulator. As the tree sways in the breeze, the weight will move up and down and the wire will remain straight! (I must confess that my long wire antenna is made with insulated wire thrown over a branch with a rock tied to the end... Who has time to do it right? I do have an arrestor, however!) A good place for the arrestor is directly above the point where the water line enters the house. Run a heavy gauge ground wire straight down to the water pipe and attach it with a brass grounding clamp (assuming a copper water pipe - always use compatible materials or corrosion will result.). This connection also makes an excellent ground for the receiver. A shielded cable lead-in wire can give

improved results when the residence has unusually noisy appliances. If you do not have an AM radio with a coaxial antenna jack then consider using an auto radio. Auto radios are well shielded to prevent ignition noise from interfering with reception and all that is needed to make a superior receiver for the home is a 12 volt power supply and a speaker. Inexpensive AM car radios are quite common, being discarded for fancy stereo upgrades and even the cheapest car receiver will outperform most home radios.

Fig. 2 shows how to add a loading inductor to the antenna in the event that a little more signal strength is desired. Most long wire antennas will be considerably less than $1/4$ wavelength at AM band frequencies and behave as though a small capacitor is connected in series. The inductor resonates with this capacity and will increase the signal strength significantly. The required inductance range is from about 200 microhenry at the high end of the band to about 2 millihenry at the bottom end of the band for a 20 foot antenna.

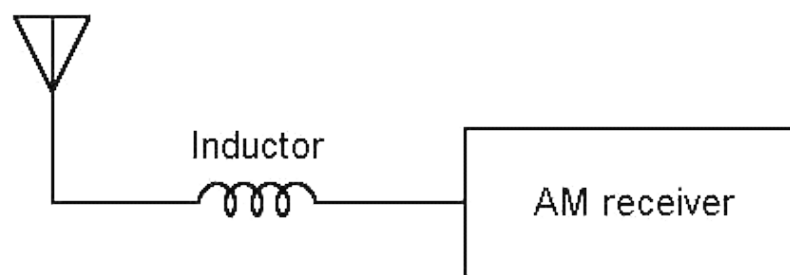


Figure 2: Adding a loading coil to the antenna.

Fig. 3 shows how to build a programmable loading coil using a 4.5 inch PVC coupling (found in the plumbing supply area of the local home improvement store) and 22 gauge insulated wire. The coil is wound with 100 turns with taps brought out every 10 turns by twisting a little loop in the wire. The total inductance of this inductor is about 1 millihenry so short antennas may need more turns for the lower frequencies.

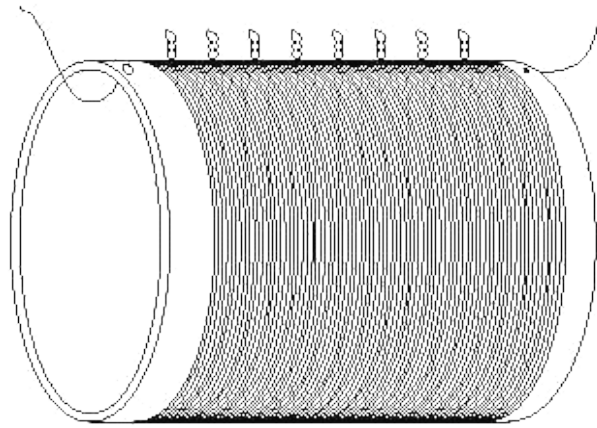


Figure 3: Multi-tapped loading coil wound on 4.5 inch PVC coupling.

Fixed inductors and a multi-position switch can be used to build a more compact and convenient unit shown schematically in fig.4. 220 microhenry chokes are shown to give enough inductance to handle shorter antennas but other values may be used depending on the application.

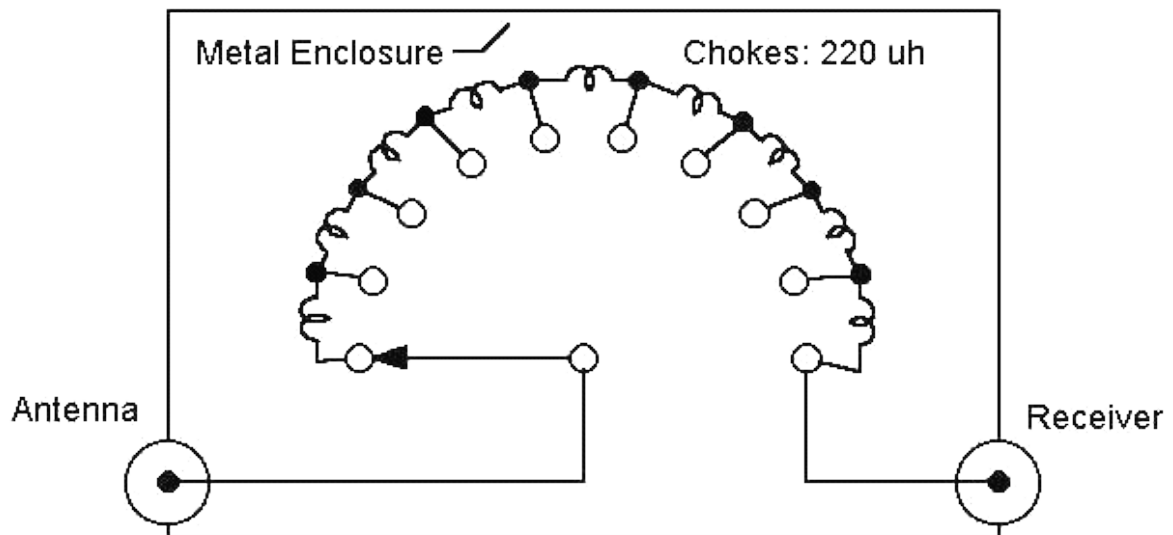


Figure 4: Adjustable loading coil built with a 10-position switch.

A directional antenna may be constructed with a ferrite rod and amplifier as shown in fig.5. A ferrite rod 5/16 inches in diameter and 7 inches long was wound with 90 turns which gave sufficient inductance (about 300 uh) to cover the AM band without tuning and gave good

reception well into the short-wave band. Experiment with whatever loopstick is available but larger is better.

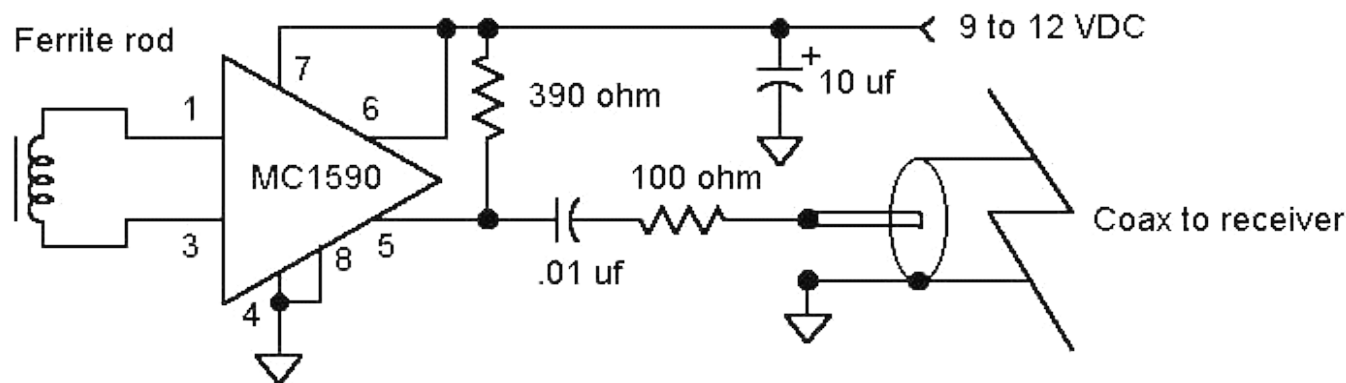


Figure 5: Ferrite antenna with built-in amplifier.

The MC1590 differential amplifier may be constructed on a small piece of copper-clad circuit board material using the copper board for ground connections. The amplifier should be mounted near the ferrite loopstick with the coax and power wire leading to the radio. No separate ground wire is shown since the coax shield will serve both purposes. The loopstick and amplifier may be slipped into a piece of 13/8 inch PVC with a cap on one end and a right angle coupling and pipe on the other (Fig. 6).

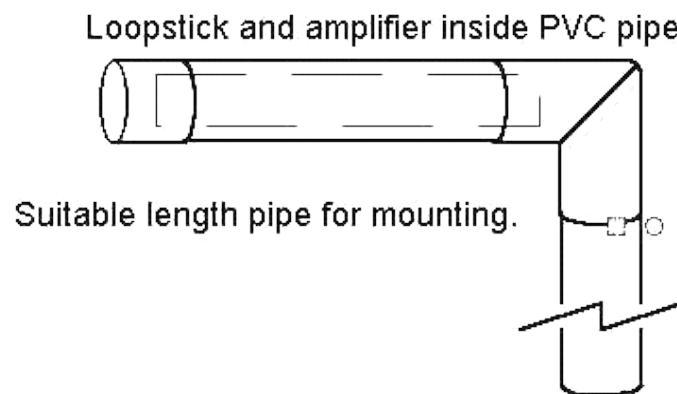


Figure 6: PVC enclosure for loopstick antenna.

The vertical pipe may be secured to the outside wall of the house with clamps loose enough to allow the antenna to be aimed. The wires can simply hang out of the bottom of the tube without any seal or a little squirt of foaming urethane caulking could be used to keep out insects. Ground the coax to the cold water pipe for lightning protection if the loop is outside and high.

A totally different approach to low frequency antennas is shown in fig.7. A very short antenna can give amazing results, often performing as well as a long wire antenna if the proper buffer amplifier is added between the radio and the antenna. The electrical model of a short antenna includes a very small series capacitor - so small that little signal gets through and the required resonating loading coil is impracticably large. However, if the antenna is connected to a high impedance buffer with a very low input capacity, the antenna capacity will not attenuate the signal significantly. The amplifier must have good intermodulation characteristics so that phantom stations don't appear all over the dial and the antenna must be kept short to prevent amplifier overload. Don't connect this circuit to a long wire antenna unless you are curious to hear what radio chaos sounds like. Keep the antenna under a few feet in length, especially if strong stations are nearby.

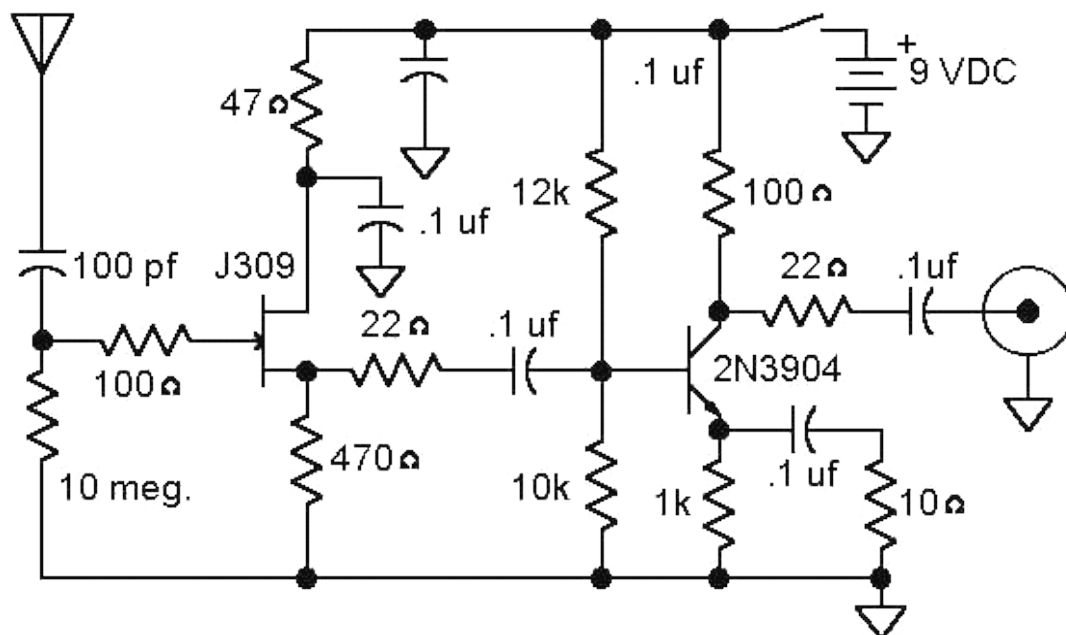


Figure 7: Short antenna buffer/amplifier.

The N-channel JFET shown is a J309 but most other numbers may be substituted. (Possible subs include: J308-310, U310, 2N4857-4860.) The source voltage (on the 470 ohm resistor) should be about 1.5 to 5 volts. This source resistor could be changed to get about 4 mA of FET current using the formula: $\text{New } R = V / .004$ where V is the voltage on the initial 470 ohm resistor. This source voltage will change when the new resistor is installed to replace the original 470 ohm but the final current value is not particularly critical. Even lower current could be used (bigger R) to prolong battery life but the performance will begin to suffer somewhere below a couple of mA. The antenna may be a few inches to about 6 feet but avoid using longer antennas. With the values shown the buffer will work well from below 100 kHz to about 15 MHz which covers the frequency range where an antenna buffer is useful.

Here is how it works: The 10 megohm resistor sets the DC gate voltage to zero volts and the voltage on the source will rise to about 2 volts as the negative gate to source voltage reaches equilibrium with the source current. The FET is a very high impedance voltage follower which converts the high impedance antenna voltage into a much lower impedance voltage suitable for driving the 2N3904 amplifier. The base of the 2N3904 is biased to about 4 volts by the two base resistors and the 1k emitter resistor sets the collector current to about 3 mA. The amplifier has an RF voltage gain of about 10 which is set by the ratio of the 100 ohm collector resistor and 10 ohm emitter resistor. Lower gain may be achieved by increasing the 10 ohm resistor if the circuit is being overloaded by large signals but a shorter antenna is usually the best approach.

Notes:

- If the signal sounds distorted or is modulated by the line frequency then reduce the 10 megohm resistor to 1 meg. or even 100k to reduce the low frequency gain. Also try a shorter antenna.
- If more gain is desired, lower the 10 ohm resistor - even a short should work well. Even more gain may be had by increasing the 100 ohm in the collector of the 2N3904 to 1k. These changes are especially useful for driving crystal radios.
- Couple to a crystal radio at a very low impedance tap or wind a few turns of wire around the coil for coupling. (Connect the two ends to the amp. output and ground.)
- Most small-signal NPN transistors will work in place of the 2N3904.

For higher frequencies, a resonant antenna becomes feasible. For example, Fig. 8 shows a simple vertical ground-plane antenna which connects directly to 50 ohm coaxial cable without a loading coil or matching network.

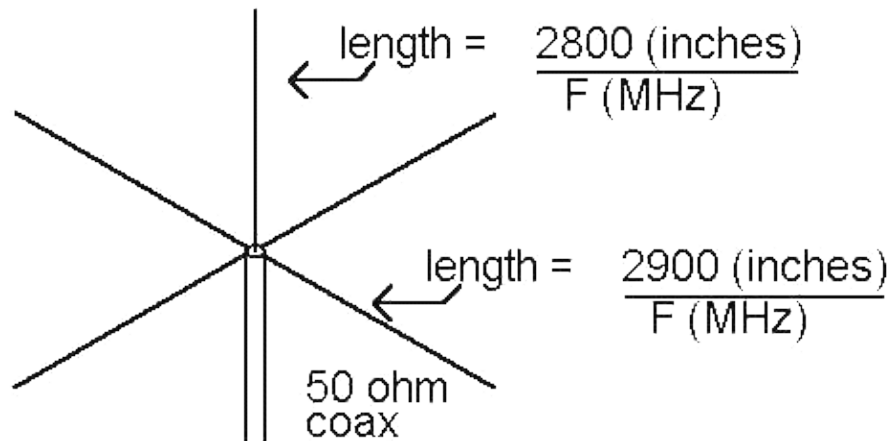


Figure 8: Vertical ground-plane schematic.

Using the equations shown, a 49 MHz antenna would have a vertical element 57 inches long and ground elements 59 inches long. The vertical element simply connects to the center conductor of the coax and the ground elements connect to the coax braid. The elements may be mounted on a small square of phenolic, fiberglass, or other weatherproof board material. Try not to let dissimilar metals come in contact or, if they must, coat the contact area with silicone rubber. One simple approach is to make the whole affair from PVC pipe with copper wire or tubing on the inside. It is often desirable to have a fixed-frequency antenna with directionality for monitoring a particular station or for installing on an antenna rotator. For example, if you live within a mile or two of a fast food restaurant you can probably pick up the little wireless microphones they use to take orders. You are probably wondering why anyone would want to pick up those signals (which are around 33 MHz). Hmmm. Well, it would be a challenge. Or, how about building a dedicated antenna to receive a distant weather transmitter instead. Or the police in a neighboring town, or a remote airport. Those sound a little better. (When my kids were small I thought of making a tricycle "drive-up" window with real audio from the local fast-food restaurant - never got around to it...) The point is that a directional antenna will give greatly improved performance for any of the signals on your scanner. Multi-element yagi antennas are a good choice for single frequency reception and log-periodic antennas give excellent multi-band reception. The construction of these antennas can prove difficult and purchasing a factory assembled unit is usually a preferable approach. A three-element yagi is not overly difficult for the more experienced hobbyist and several design references are easily found on the internet. A search using "3-element yagi" turned up nearly 600 hits including excellent design articles and commercial sources.