Construction of a Vertical Antenna for Part 15 AM Broadcast use

At present, FCC restrictions require the use of an antenna with Part 15 transmitters to be either 10 feet or less, or limit field strength to 2400 / f in kHz. This applies in the the top of the AM broadcast band and certain other frequencies. Consult current FCC rules. However, as long as you are using 100 milliwatts and a 10 foot antenna, there is no specific limit on range. Typical antenna efficiencies at 1.6 MHz are about 0.5 to 1 percent. This limits effective radiated power to 1 milliwatt or less. This sounds discouraging, but it is not really bad. If an antenna radiating 1 milliwatt is placed at the center of a sphere of 1 mile in diameter, all this power is still present at the surface, less any losses inside the sphere (very small in most cases can be considered zero as in free space). The following is a mathematical demonstration of this but you can skip it and take our word for it should you not care for the details.

The surface area of a 1 km (1000 meters) radius sphere is 4 x pi x r squared, where pi = 3.14159 and r squared = 1,000,000

Surface Area = 12.56 x 10 exp 6 (12.56 million square meters)

Dividing 1 milliwatt (1/1000 of a watt) by this figure, we get the power per square meter as (79 x 10 exp -12 watts)

The signal in volts per meter can be calculated by realizing that free space has an impedance of 377 ohms

The signal strength in volts/meter is equal to the square root of the power/sq meter x the impedance in ohms

multiplying power/sq meter by 377 ohms and taking the square root we get 172.5 microvolts/meter at 1 kM (1000 meters or 0.62 miles)

At 1 mile this would be 107.15 microvolts/meter (uv/meter or uv/m)

Now, 107 uV/meter is a fairly good signal level. As signal levels of 50 uV/m are still useable a range of over 2 miles should be obtained with a properly tuned antenna and 100 milliwatts. A decent AM receiver with a ferrite loop antenna can easily pick this up. A good AM receiver with a sensitivity of 10 uV per meter might hear this signal at several miles. However, ambient noise and interference will be the limiting factor. Using similar antennas (8

foot whip with loading coil), Amateur radio operators have operated transmitters from automobiles on the nearby (in frequency) 160 meter ham band (1800-2000 kHz) and with 10 watts, two way contacts of 25 to 50 miles are possible. This would correspond to 2.5 to 5 miles range with 100 milliwatts. Typical AM receivers equipped with the usual ferrite rod or loop antennas have sensitivities ranging from 5 uV/meter for excellent receivers with large loop antennas, to as poor as 2000 uV/meter for cheap small AM portable sets. 50 to 300uV / meter is typical for average AM BC receivers. This depends on antenna size, receiver gain, and bandwidth. Note that this figure includes the loop antenna and is not the same as that would be measured at the 50 to 600 ohm input terminals of the receiver (if so equipped). In this case, in order to get usable radiation, the antenna must take as much power from the transmitter as possible and radiate it with maximum efficiency. This requires a reasonable ground system and an antenna that is properly matched to the transmitter. A 10 foot vertical or whip antenna has an impedance of about 3000 ohms capacitive reactance in series with about 0.1 ohm radiation resistance. The trick is to get as much current flowing in this 0.1 ohm resistance as possible. For 1 milliwatt radiated power this would be 100 milliamperes (0.1 ampere). To force this much current through the impedance of the antenna, an RF level of 300 volts is needed. This can be done by using a series inductance to cancel out the capacitive reactance of the antenna. A simple indoor 3 foot whip plugged into the transmitter, with no matching network, would look like about 0.007 ohm in series with 8000 ohms capacitive reactance. About 3000 volts of RF signal would be needed to have this antenna radiate 1 milliwatt. Since 100 milliwatts. A 100 milliwatt transmitter would supply about 2.3 volts of RF into 50 ohms. Open circuit or the level delivered into this antenna would be around 4.5 volts. The radiated power would be around 2 nanowatts. This would produce a very weak signal barely detectable at more than a few feet from the transmitter.

These high RF voltages appear on the antenna as a result of using a loading coil to get a series resonant circuit together with the self capacitance of the antenna. This capacitance depends on the antenna dimensions and will be around 30 pf for a 10 foot vertical, depending on its configuration and diameter. This capacitance can be calculated from electromagnetic theory or inferred from an antenna analysis program such as ELNEC. For frequencies in the 1.6 MHz region, around 350 to 400 uHy will be needed. At 530 kHz around 3000 uHy will be needed.

This inductance can be reduced by using a "capacity hat" on the top of the antenna. This is made up of 4 or 6 lengths of wire (12 inches) arranged horizontally like the spokes of a wheel, with one end connected to the top of the antenna (see fig). The calculated capacitance of this short vertical antenna is 36.3 pF and is fairly constant over the entire AM broadcast band. This allows a coil of 220 to 2400 microhenries to make this antenna resonant from 1700 to 530 kHz. The exact inductance will be affected by antenna location, height above ground, length of ground lead and size of ground plane, proximity to other objects, and other environmental factors. Therefore it is best to start off with a coil of somewhat higher inductance than actually needed, and adjust the number of turns experimentally. Best radiation efficiency is at the higher frequencies.

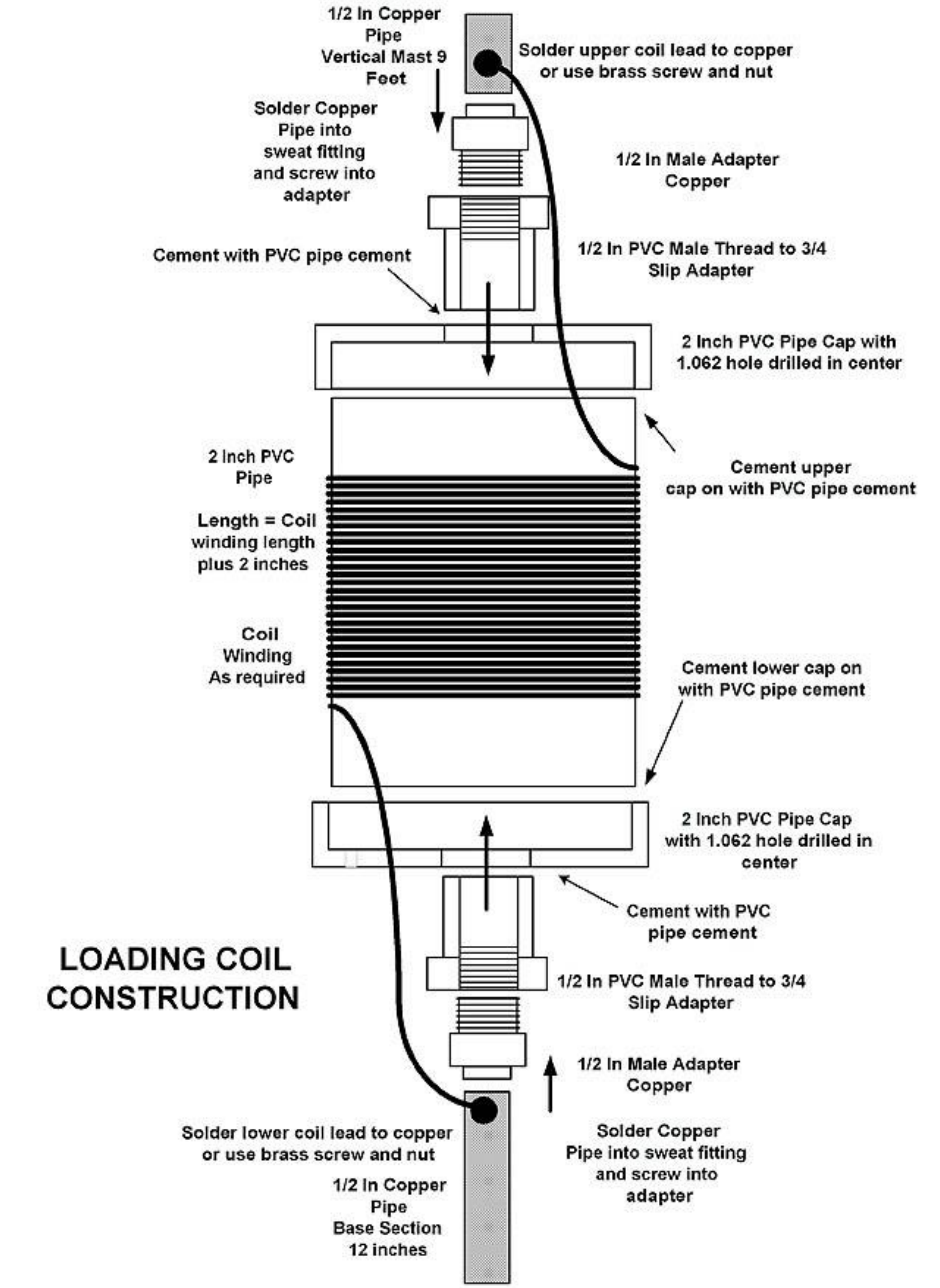
The table below is a guide to what is typical of a loading coil for various AM frequencies. Figures are for a coil wound on a 2" PVC pipe form (2.375 Diameter) used in the construction example to follow. All windings are close wound with no spacing between turns. A 9 foot 1/2 in dia. verticalradiator with a 12 inch radius top hat is assumed.

Loading Coil Dimensions AM Band frequencies

Frequency kHz	Approx Inductance uHy	Coil Winding # Turns & Gauge @ 2.375 In Dia.
530	2550	410 Turns #26 B&S Gauge Enamelled
600	1990	328 Turns #26 B&S Gauge Enamelled
1000	700	135 Turns #26 B&S Gauge Enamelled
1400	350	100 Turns #22 B&S Gauge Enamelled
1500	315	92 Turns # 22 B&S Gauge Enamelled
1600	270	81 Turns # 22 B&S Gauge Enamelled
1700	240	74 Turns #22 B&S Gauge Enamelled

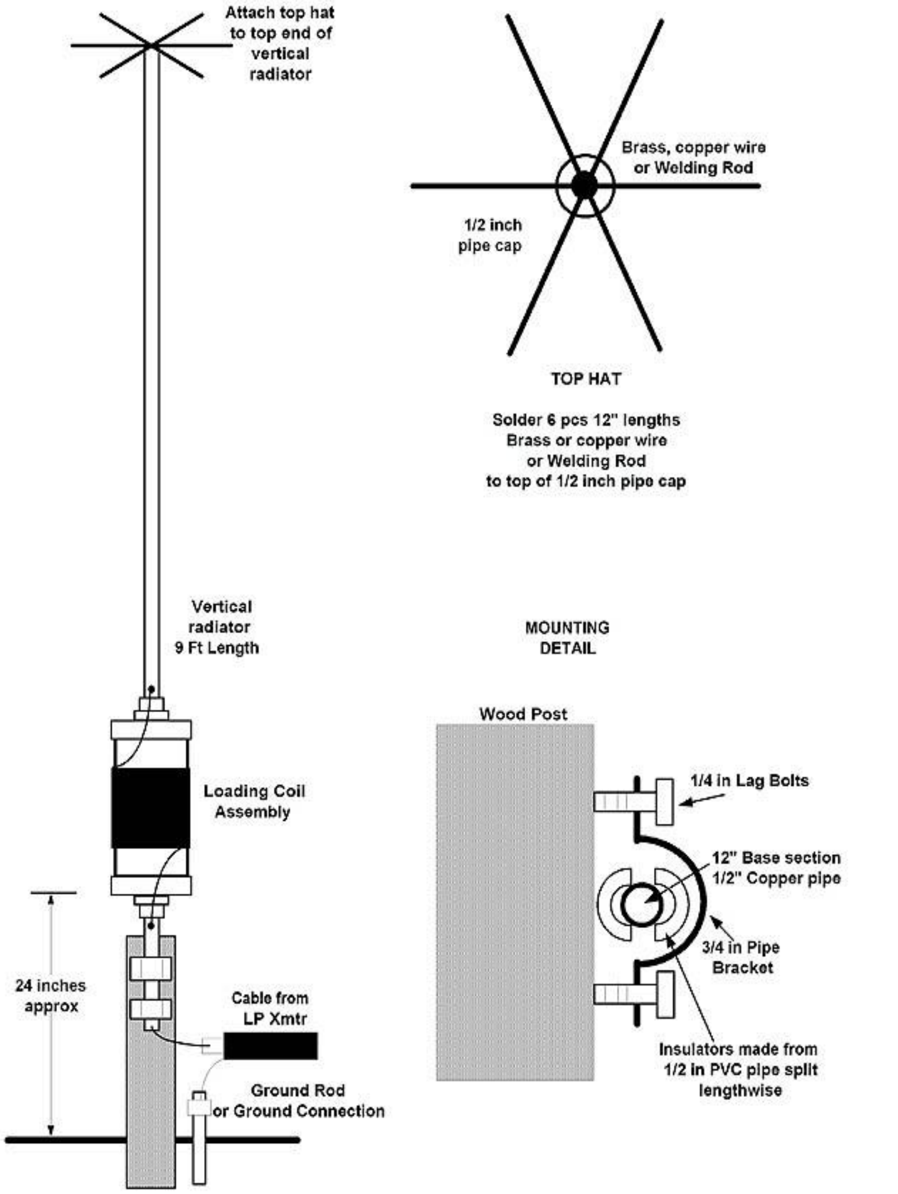
In practice several extra turns should be added to allow for unavoidable variations in antenna parameters and winding technique. Enamelled copper magnet wire is specified. This can usually be obtained from a parts distributor or a local Electric motor repair shop. The winding should be coated with clear lacquer or shellac to hold the turns in place

A good vertical antenna can be made up from a 10 foot length of 1/2 inch copper pipe and some plastic pipe, together with a few pipe fittings and a 4-5 feet of #12 copper wire. This wire can be salvaged from scrap lengths of house wire. Note that a ground is required if reasonable performance is expected. Below is a diagram of a typical loading coil made with PVC pipe fittings


1/2 In Copper Pipe Vertical Mast 9 Feet
Solder upper coil lead to copper or use brass screw and nut
Solder Copper Pipe into sweat fitting and screw into adapter
1/2 In Male Adapter Copper
Cement with PVC pipe cement
1/2 In PVC Male Thread to 3/4 Slip Adapter
2 Inch PVC Pipe Cap with 1.062 hole drilled in center
2 Inch PVC Pipe
Cement upper cap on with PVC pipe cement
Length = Coil winding length plus 2 inches
Coil Winding As required
Cement lower cap on with PVC pipe cement
2 Inch PVC Pipe Cap with 1.062 hole drilled in center
Cement with PVC pipe cement
LOADING COIL CONSTRUCTION
1/2 In PVC Male Thread to 3/4 Slip Adapter
1/2 In Male Adapter Copper
Solder lower coil lead to copper or use brass screw and nut
Solder Copper Pipe into sweat fitting and screw into adapter
1/2 In Copper Pipe Base Section 12 inches

The loading coil is assembled as shown. The pipe caps for the 2 inch pipe must be drilled to accept the Male thread adapters. Alternatively a 1/2 inch to 2 inch adapter can be used, but the ones available had several ridges that could collect rainwater. The pipe caps were slightly rounded, amd water would roll off and not accumulate. A small hole or two (1/8 inch) should be drilled in the bottom cap to allow any condensation or water to drain out of the 2 inch coil form. Tape can be used to hold the winding in place until it can be glued in place. Hot melt glue can be used to temporarily hold the wire in place until the coil adjustment is completed.

The completed vertical antenna should look like the figure below. The antenna is mounted with the bottom of the loading coil about 24 inches above ground, on a wooden post , with two pipe clamps. Insulators should be made from some scrap PVC pipe lengths split lengthwise to prevent electrical contact with the pipe clamps and post . A ground system must be provided (rod and/or radials) for proper operation. A low resistance ground (<10 ohms) is desirable for best results. Use as many ground rods as possible and as many radials as long as possible. Agricultural soil, pastures, or damp soils are usually best, rocky and sandy soils the poorest. Locations with a high water table or near the sea or a lake are good. The ground system is the largest factor in determining the efficiency of the antenna system. A length of cable is used to connect the transmitter, or the transmitter may be installed directly at the base, in some kind of weatherproof box.



LP AM VERTICAL ANTENNA

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The antenna must be tuned to resonance. This involves adjusting the coil turns (Number and/or spacing of turns) for maximum radiated signal. Make sure you are well away from antenna when evaluating adjustments as your body may detune the antenna. This is not a plug and play affair....every situation is different. Expect to do some experimentation and to spend some time on this adjustment if you want the best results. If you change the transmitter frequency you will have to re-tune the antenna, so if possible decide on final frequency you will use before tuning the antenna.