Constructing a Base-Loaded Vertical Antenna

Safety and Legal Warnings

Construction, installation, and use of this antenna is solely at your own risk. We can not be held liable for any personal injury, property damage, or any other legal liabilities that you may incur at any time during the construction, installation, or use of this antenna.

PERSONAL SAFETY

1. As with any DIY project using hand tools, power tools and chemical products, there is always a risk of *personal injury*. Read and understand the safety notices that are included with all tools and chemical products that you use.
2. Installation of this antenna may present a risk of *electric shock injury* or *electrocution*. You must take all precautions to ensure that the antenna and any connecting wires will not come in contact with a live electric wire while erecting the antenna into position during installation. You must also ensure that no part of the antenna will contact a live electric wire in the event that the antenna becomes dislodged from its mounting position for any reason at any time.
3. As with any outdoor antenna, there is always the risk of lightning damage. For your safety, and to reduce the risk of damage to your home or property, ensure the transmitter is properly grounded.

LEGAL ISSUES

1. Check your local ordinances and covenants to ensure that your antenna installation complies with any rules that may be in effect that restrict the size, height, and location of outdoor antennas.
2. When constructed according to the plans, this antenna will comply with the generally accepted interpretation of FCC Part 15 section 15.209 governing antenna dimension restrictions . Be aware that the FCC can order you to cease operations if you cause interference to any commercially licensed station. You will reduce your likelihood of receiving an FCC order if you build the antenna as described, choose an unused frequency in your area, and operate your station in a civil manner.

Important Transmitter Information

The transmitter must be set for use with an EXTERNAL ATU according to the instructions.

A well loaded-vertical antenna will allow you to get the maximum range from your Part 15 AM transmitter. The FCC restricts the total length of the antenna, feed line, and ground lead to 3 meters (118 inches). This is very short at AM broadcast band frequencies. Because of this restriction, even the best Part 15 compliant antenna will not be very efficient compared to those big commercial broadcast station towers. Because the feed line length is included in the total length, the transmitter must be mounted at the base of the antenna in a weatherproof enclosure.

The antenna described here is designed to be rugged and stable in an outdoor environment. All materials are readily available from your local home improvement store and from electronics mail order suppliers. You should be reasonably handy with hand tools and an electric drill. You also will need to do a couple of copper pipe "sweat" solder joints using a small propane torch and a few PVC solvent weld joints.

The antenna tuning range is restricted to 1500 kHz - 1700 kHz to make it simpler to construct.

For best results your antenna should be elevated by 20-25 feet, but you can still get good performance by mounting it on a pipe near ground level. Be sure to consider that you will

need to access to the bottom portion of the antenna and the transmitter for tuning after installation.

Familiarize yourself with the antenna drawing and parts list, next purchase any parts that you need. If you have ever done any plumbing around the house, you may already have some of these parts.

Power and Audio Cables

The power and audio cables will need to be long enough to reach the transmitter at its final installation location.

You can extend the DC power cable wire by fabricating an extension from readily available parts. Obtain one 2.1 mm power plug (female) and one 2.1 mm power socket (male). Make sure to connect the wire the same way around in both the plug and the socket. Correct polarity is very important, if you do not want to cause damage to your transmitter.

Obtain audio cables that is long enough to reach the transmitter in its final installation location. Long audio cables will attenuate higher audio frequencies. You can compensate by driving the audio from a low impedance source such as the 8 ohm speaker output terminals of a stereo amplifier.

Fabricating The Loading Coil

The coil is made by wrapping #16 insulated wire in a tight spiral around a section of 3" white schedule PVC pipe. However, tapping points must be formed at every other turn near one end of the coil, making the winding process a little more complicated. Note that the outside diameter of the 3" PVC pipe is actually 3 1/2". The 3" nominal size refers to the inside diameter.

Preparing The PVC Pipe Before Winding The Coil

PVC can be easily cut with a hacksaw. A 24-tooth blade will make a nice cut. Use a mitre box or other suitable method for guiding the blade to get a square cut. Or, you can mark the cut line with a pencil around the circumference, and make partial cuts incrementally around the circumference to avoid drifting off the line. Use sandpaper to remove outside burrs.

1. Begin by cutting an 11" section of 3" white PVC pipe (ref. 16).

2. Use medium-grit sandpaper to sand the entire outside surface until all lettering is removed and the surface is no longer shiny.

3. Mark the pipe 2 inches in from each end and wrap masking tape around the pipe at the marks so that the pipe is exposed between the marks. Coat the entire 7 inch long exposed area with exterior grade varnish to seal the pipe and keep it from absorbing moisture (PVC tends to absorb moisture over time which can lead to higher coil losses).

4. After the varnish dries, use a fine-tipped felt marker and a straight-edge to draw a single straight reference line from one end of the pipe to the other, parallel to the sides of the pipe.

5. On the reference line, mark and drill a 3/32" diameter hole 3" from one end. Now mark and drill a second 3/32" diameter hole 1/2" to either side of the first and at the same 3" distance from the end of the pipe. These two holes will secure the wire while you wind the coil.

Winding The Coil

You will now begin winding the coil, but first some important points. The coil must be wound tightly. There must be no space between turns. Be careful to avoid kinking the wire. Carefully straighten any kinks as you go along.

This is fairly stiff wire and will spring outward if you don't maintain constant tension on the wire while winding. Cut a bunch of 2" long strips of plastic electrical tape before you start. Keep them handy to put on the coil at various places as you wind to hold the wire in place. There will be a total of 87 turns in the coil. You should apply a strip of tape to the coil about every 5 turns or so to prevent the coil from springing out if you relieve the tension at any time. After winding is complete, you will be drilling two more holes to secure the wire at the far end. Once the wire is secured tightly through these holes, you can safely remove all the tape strips.

To avoid kinking the wire, it must be unrolled from the spool as you roll it onto the pipe. Place the spool of wire on a dowel or metal rod that is secured in a vice, or C clamp, in a vertical position. Devise a method for putting some drag on the spool to keep the wire in tension as you wind. One way to do this is to clamp the dowel somewhat off-vertical so the spool tends to bind slightly against the top of the vice as you unwind the wire.

1. Unwind some wire from the end of the spool and insert the end about 2" into the hole that is on the reference line. Using pliers, form the wire protruding inside the pipe into a U shape and feed it back out through the second hole. Keep forming and pulling the wire out until the wire is snug against the inside of the pipe between the holes. Bend the short end of the wire that now protrudes outside the pipe toward the closest end of the pipe to keep it out of the way while you wind the coil.

2. Electrically, it doesn't matter which direction you wind the coil. Choose a direction that is comfortable for you.

3. Wind 63 full turns of wire, tight and closely spaced around the PVC pipe. Secure this part of the coil well with tape before continuing to wind the rest of the coil.

Beginning at turn 63, you will be forming a tap point every other turn for the remainder of the winding process. A tap is formed by bending the wire with pliers to form a small "U" or hump in the wire. The hump should be about a quarter inch wide and about a quarter inch high. These measurements aren't critical. The objective is to form the wire out away from the pipe sufficiently to allow clearance for soldering a wire to the tap.

Before forming each tap, the wire needs to be tinned with solder for a total length of about 1" (1/2" on either side of the centre of the tap). The wire has an insulating coating. If you purchased the recommended insulated wire, you may be able to solder directly to the wire with a high wattage iron without first stripping the insulated coating. Test this by attempting to apply solder to the end of the short piece of wire protruding from the pipe at the start of the winding. It helps to scrape away a small area of the coating down to bare copper to aid heat flow to the wire. Start heating at the bare copper and flow a blob of solder onto the wire. Move the iron and solder blob slowly along the wire until the coating begins to bubble and the solder adheres evenly to the wire. If you are not satisfied with the results, you will need to thoroughly scrape away the coating all around the wire with a sharp knife before applying solder.

Taps should be staggered about a half inch each side of the reference line to make it easier to make a connection without shorting to adjacent taps. Begin with the peak of the first tap

hump positioned 1/2" before the reference line, then position the next tap hump peak 1/2" after the reference line, and so on.

4. Form the first tap at turn 63 (reference line minus 1/2").

5. Wind two full turns and form a tap that is staggered from the previous tap (reference line plus 1/2").

6. Repeat step 5 until you have a total of 12 taps staggered alternately before and after the reference line. The last tap should be at the 85 turn point.

7. After the last tap, continue to wind 2 more turns to the reference line.

8. Cut the wire with about 12" excess after the reference line. Secure the wire well with tape while you drill two more holes. This wire will be connected to the antenna pipe clamp in a later step.

9. As you did at the beginning of the coil, drill two 3/32" holes at the end of the coil, one on the reference line and one 1/2" beyond the reference line. Insert the wire end into the hole on the reference line and back out the other hole. This end wire is at turn 87 and will serve as the final "tap" point.

10. Now that the wire is secured at both ends of the coil, you can remove all the tape strips.

11. Coat the outside of the coil with a second coat of exterior grade varnish taking care not to get varnish on the wire ends or on the taps Coat just the coil, not the unvarnished ends of the plastic pipe.

12. After the second coat of varnish dries, remove the masking tape and cement the 3" PVC pipe caps (ref. 15) onto the ends of the coil pipe.

Antenna Construction Steps

First, some notes on cutting copper pipe. The best way to cut copper pipe is with a wheel-type tubing cutter. A cutter that can handle up to 3/4 in. pipe is inexpensive and worth purchasing at a home improvement store Copper pipe can also be cut with a fine-tooth hack saw.

1. Cut a 98" length of 1/2" copper pipe (ref. 2).

2. Solder the cap to one end (ref. 1).

3. Cut a 10" length of 3/4" copper pipe (ref. 4).

4. Solder the 3/4" sweat to 3/4" male threaded copper adapter (ref. 6) to one end of the 3/4" pipe (ref. 4). Soldering the adapter in this step before cutting slots in the pipe in the next step will alleviate possible problems caused by pipe deformation while clamping for the cuts.

5. Lengthwise slots must be cut in the top end of the 3/4" copper pipe (ref. 4). Clamp the pipe in a vice or clamp it to a work surface with C clamps. Use some small scrap boards to distribute the clamping force to prevent deforming the pipe. Using a hacksaw, make two 3 in. long cuts in the form of a cross as illustrated.

6. Bend two of the opposing tabs created in step 5 inward a little more than the thickness of the pipe wall to allow the tabs to overlap each other when the hose clamps are tightened.

7. With a fine tipped felt pen, mark the non-capped end of the 1/2" antenna pipe at three points 3", 7", and 11" from the end. Extend the marks at each point all the way around the circumference of the pipe. Label each line: "top" (at 3"), "mid" at (7"), and "bottom" at (11"). This will help during the tuning procedure to indicate the limits of adjustment.

8. Loosely position the two hose clamps (ref. 3) over the 3/4" copper pipe (ref. 4). Temporarily insert the non-capped end of the 1/2" copper pipe (ref. 2) into the 3/4" copper pipe for a distance of at least 4" or more. Tighten the top hose clamp while watching for the tabs in the 3/4" pipe to begin overlapping each other. If the tabs jam together and don't overlap, try loosening the clamp and re-bending two opposing tabs a little farther inward (repeat of step 6). Once the overlap allows you to clamp the 1/2" pipe firmly, tighten the bottom clamp firmly. Now that the clamps have formed the tabs in the proper position, you may loosen the clamps and remove the 1/2" pipe to make it easier to finish assembling the antenna.

9. Cut a 10" length of 1 1/2 " PVC pipe (ref. 9).

10. Cement a 1 1/2" slip to 1 1/2" female threaded PVC adapter (ref. 14) on each end of the 10" PVC pipe (ref. 9).

11. Screw the 1 1/2" male threaded to 3/4" female threaded galvanized iron reducing bushing (ref. 7) into the PVC adapter at either end of the 10" PVC pipe. The threads are tapered so the fittings will get tight when they are threaded together about half way. Tighten firmly with a wrench or large channel-lock pliers.

12. Screw the threaded end of the adapter (ref. 6) previously installed on the 3/4" copper pipe (ref. 4) into the 3/4" threaded centre hole in the reducing bushing (ref. 7). The threads are tapered so the fittings will get tight when they are threaded together about half way. Tighten firmly with a wrench or large channel-lock pliers.

13. Install the pipe grounding clamp (ref. 5) onto the upper portion of the 3/4" sweat to 3/4" male threaded copper adapter (ref. 6). This is called a "grounding clamp" in the electrical trade, but is actually being used here to make the RF connection to the copper antenna pipe.

14. Fasten the completed loading coil assembly to the 1 1/2" PVC pipe section (ref. 9) oriented with the tapped end of the coil down. Use two plastic wire ties (ref. 8) around the loading coil pipe and the 1 1/2" PVC pipe as illustrated. Position the tie wraps just inside the caps as illustrated. If your wire ties aren't long enough, you can daisy chain two or more to get the required length. Tighten the wire ties as much as you can with pliers. Apply a dab of PVC cement to both wire ties where they contact the 1 1/2" PVC pipe to prevent them from slipping.

15. Cut the 12" top coil end wire just long enough to comfortably reach the "ground clamp" (ref. 5) without straining. Scrape (if necessary) and tin the end of the wire. Insert the end of the wire into the ground clamp and tighten the wire clamping screw firmly.

Mounting The Weatherproof Box

Since the exact mounting position and dimensions are determined by the size and shape of your chosen weatherproof, the following steps are written in general terms.

Here are some important points to keep in mind.

- The transmitter should be mounted no higher than the bottom of the loading coil winding. This will minimize capacitive coupling between the coil and the transmitter board.

- The antenna and ground leads that run from the transmitter to the coil and the metal pipe mast, respectively, should be kept as short as possible for Part 15 compliance. Generally, this limits the choice of transmitter orientation inside the box to the vertical position with the transmitter rear panel facing up, as illustrated.

- The component side of the transmitter circuit board must be accessible for setting the frequency switches and adjusting the trimmer capacitor. Again, the transmitter orientation shown in the illustration is good for accessing the board.

- The weatherproof box should be no larger than necessary to reduce wind resistance and stress on the box mounting points. For a heavier box, you might consider using two U-shaped pipe mounts to attach the box more securely.

Now on with mounting the box:

1. Drill holes in the box for the two mounting screws (ref. 13). Exact position is not important, but they should be spaced far apart and should be on the vertical centre line of the box.

2. Drill holes in the box large enough to pass the power and audio cable plugs into the box. These holes should be offset horizontally from the box centre line enough to clear the mast pipe and must be positioned upward from the transmitter enclosure rear panel in its final position. See illustration. Note: if your audio source is already monophonic, you need only one audio cable plugged into either audio jack on the transmitter. If your source is stereo, you will need both left and right audio cables.

3. Drill a separate hole large enough to pass the antenna and ground wires out of the box.

4. Temporarily thread the top end of the antenna mast pipe (ref. 12) into the threaded PVC adapter (ref. 14) and tighten firmly.

5. Hold the box in its final position against the mast pipe and mark the locations on the pipe for the two mounting screws (ref. 13). Drill holes in the mast pipe at the marked locations. Use a drill sized to just clear the diameter of the screws at the valleys of their threads. Run the screws in and out of the holes a couple times to form the threads in the pipe sections.

6. With the same drill bit used in the previous step, drill a hole in the mast pipe for the self-threading ground screw (ref. 13) approximately as shown in the illustration. Run the screw in and out of the hole a couple times to form the threads in the pipe.

7. Attach the box to the mast pipe with two self-threading screws (ref. 13) through the mounting holes just prepared.

8. Attach the mating halves of the adhesive Velcro strips (ref. 10) to the bottom of the transmitter enclosure and to the inside of the weatherproof box, respectively as illustrated. Remove the top cover from the transmitter for later access to the switches and trimmer capacitor for final tuning. You may elect to just leave the cover off in the final installation.

9. Route the antenna and ground wires from the transmitter rear panel out through the hole in the box that you previously drilled for them. Cut the black ground wire to the minimum length that will comfortably reach the ground screw on the mast pipe, allowing an extra 3/4" for the connection. Strip 3/4" of insulation from the wire. Lightly twist the conductor strands together, and tin the exposed wire with solder. Don't connect the ground wire to the mast pipe yet.

10. Cut the white antenna wire to the minimum length that will comfortably reach the uppermost tap on the coil (not the upper coil end wire), allowing an extra 1/4" for the connection. Strip 1/4" of insulation from the wire. Lightly twist the conductor strands together, and tin the exposed wire with solder. Don't connect the antenna wire to the coil yet. You will do that later after selecting the proper tap in the tuning procedure.

11. Remove the antenna assembly from the mast pipe by unscrewing at the antenna assembly/mast pipe fitting. Lay the antenna assembly aside while you install the mast pipe in its final location.

Installing The Mast Pipe

Install the mast pipe (ref. 12) securely in its final position making sure that the threaded end with the ground screw hole is at the top. How you mount the mast pipe is up to you. Some suggestions:

- If the mast pipe is fairly short, dig a hole about 3 ft deep and 1ft in diameter. Place the mast pipe in the hole. Mix a bag or two of concrete and pour around the pipe in the hole. Support the pipe vertically (check with a level) until the concrete sets.

- A longer mast pipe may be installed on the side of a building. You can use TV antenna mast wall mounts or you can fabricate wood or metal wall standoff supports and use U shaped pipe mounts or U bolts. Wood supports can be fabricated from 2 x 4 wood stud stock. Metal supports can be fabricated from universal angle iron stock and bolts. The pipe should extend all the way to ground level to provide the necessary signal ground path and added support.

Grounding The Mast Pipe

Grounding is very important to the performance of your antenna. The mast pipe needs to be well grounded to minimize antenna ground loss. High resistance to ground will cause most of your signal to be dissipated in the ground resistance. Ground resistance drops when you are able to connect to a conductor that has a large area buried in moist ground.

A metal cold water pipe that has a good conductive path underground can sometimes provide a very good ground, but presence of corrosion, gaskets, poorly conducting fittings or plastic pipe sections can severely affect the conduction path.

If your soil around the mast is relatively rock free, you will get good results with several 8-foot long electrical grounding rods driven vertically into the soil around the base of the mast. You will need to connect the tops of the rods to the mast with heavy copper wires (#14 or #12 are practical sizes). Use one or more grounding clamps above ground level at the base of the mast pipe to connect the ground wires. The ground rods are made of steel clad with

an outer jacket of copper. They are available from home improvement stores and electrical supply dealers.

Burying a number of long bare copper wires at least 6" in a radial pattern around the base of the mast is a popular solution, especially when your soil is too rocky for ground rods. Use as many wires as you can manage and make them as long as possible. Use un-insulated wire that is #14 gauge or heavier. Solid un-insulated wire is available in various size rolls from home improvement store and electrical supply dealers. You can rent a powered wire trencher from your local tool rental store. They cut a slot in the ground with a bladed wheel. You can lay a lot of wire in one day with a trencher. The wires need to be bonded together at the mast and connected to the mast. You can use one or more grounding clamps at the base of the mast pipe above ground level.

Mounting The Antenna And Transmitter To The Top of the Mast Pipe

1. Screw the antenna assembly onto the top of the mast pipe and tighten firmly.

2. Attach the black ground wire to the mast pipe by forming the wire around the ground screw and then tightening the screw firmly down on the wire to make good contact.

3. Slide the 1/2" antenna pipe (ref. 2) back into the slotted 3/4" pipe (ref. 4) for a distance of 7" so the line labelled "mid" is even with the top of the 3/4" pipe, and tighten the two hose clamps (ref. 3) sufficiently to keep the antenna pipe from slipping downward.

Tuning

Proper tuning of your antenna is <u>critical</u> to achieving maximum performance. The antenna has a very sharp resonance point. You must follow the tuning instructions carefully. Tuning must be done with the antenna installed in its permanent location.

1. Route the audio and power cables up to the transmitter, pass them through the holes in the transmitter box, and plug them into the transmitter jacks.

2. Apply power to the transmitter and connect the audio cables to an audio source.

3. Loosen the two hose clamps enough to be able to work the 1/2" pipe up and down for adjustments, but not so loose that it slides downward on its own. Start at the midpoint of adjustment range, which is the point where the 1/2" pipe is inserted into the top end of the 3/4" pipe for a length of 7". The range of adjustment is plus or minus 4" from the midpoint. Never raise the antenna to a point where less than 3' is inserted into the top of the 3/4" pipe, or it will not be supported properly by the hose clamps.

4. Choose your desired operating frequency in the range between 1500 kHz and 1700 kHz. Pick a frequency that is unused in your area. Set the two 4-position DIP switch, , to your chosen frequency according to the chart in the manual. Set the trimmer capacitor, to its <u>minimum</u> setting (rotate until the half moon shaped metal plate on the top faces the front side (control side) of the transmitter circuit board.

5. Holding the short antenna wire lead coming from the transmitter antenna plug, touch the wire to each successive tap, moving downward along the taps (including the bottom coil end wire) until you find the tap that gives the best transmitter range.

6. Fine tune the antenna by working the 1/2" pipe antenna up or down about a half inch at a time until you find the position that gives the best transmitter range.

7. Solder the transmitter antenna lead to the selected tap. All other taps above and below your selected tap will remain unconnected. The portion of the coil between the selected tap and the top end wire now has the required inductance to tune to your selected frequency. The portion of the coil below your selected tap is electrically open-circuited and does not contribute to the coil inductance.

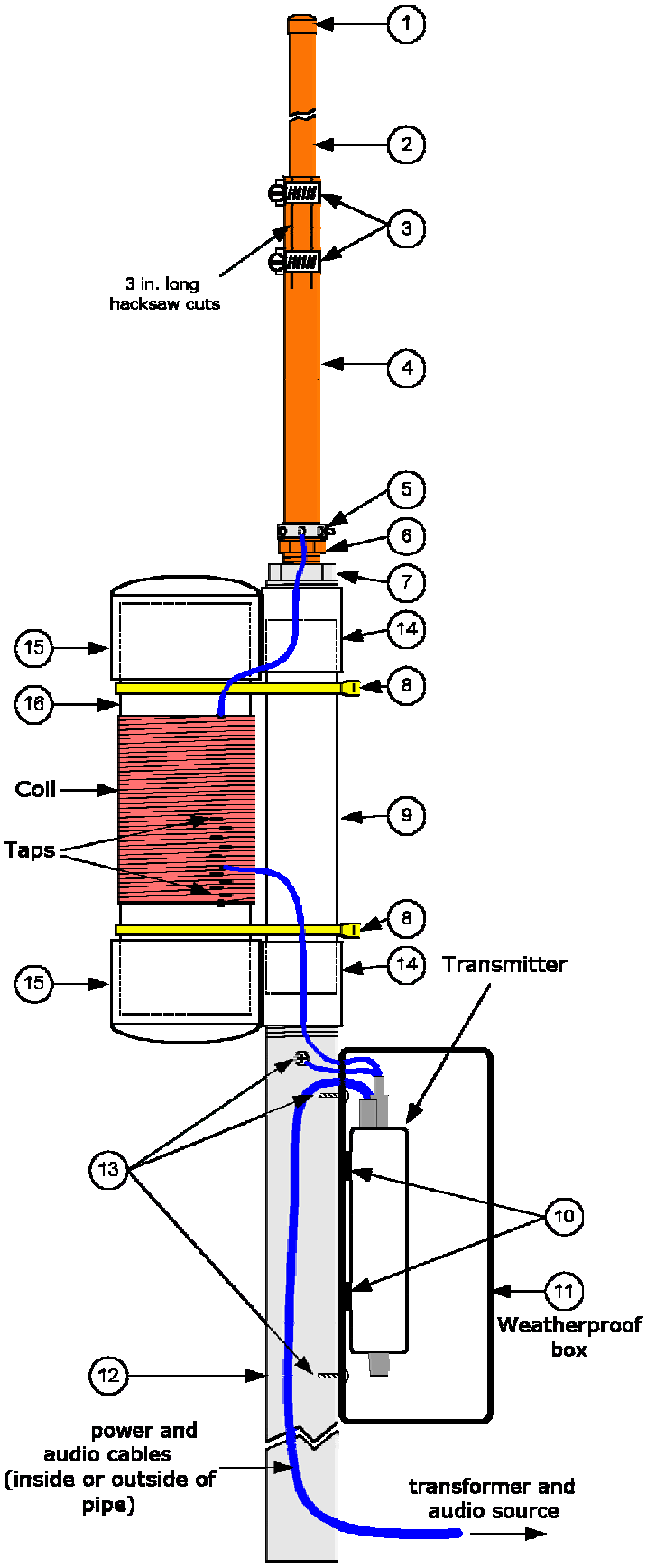
8. Adjust the GAIN, MODULATION, and COMPRESSION controls to your preference according to the instructions in the manual.

Sealing The Box Against Moisture

Apply silicone adhesive liberally around all wires where they enter the box to block any moisture from entering the box. This is an important step. Any water that gets onto the circuit board will quickly damage the board. Attach the box cover.

Parts List

Ref.	Qty	Description
1	1.	1/2" copper pipe cap
2	98 in.	1/2".copper pipe (Type L)
3	2	3/4" hose clamps
4	10 in.	3/4" copper pipe (Type M)
5	1	Pipe grounding clamp to fit 3/4" pipe
6	1	3/4" sweat to 3/4" male threaded copper adapter
7	1	1 1/2" male threaded to 3/4" female threaded galvanized iron reducing bushing
8	2	large plastic wire tie, also known as "tie wrap"
9	10 in.	1 1/2" white schedule 40 PVC pipe
10	2	3" long adhesive-backed Velcro strips
11	1	Waterproof box: plastic or metal outdoor electrical box. Min inside dimensions: 7" x 6.5" x 2"
12	(see note 1)	1 1/2" rigid metal conduit
13	3	#10 x 1" self-tapping stainless steel screw
14	2	1 1/2" slip to 1 1/2" female threaded white schedule 40 PVC adapter
15	2	3" white schedule 40 PVC cap
16	11 in.	3" white schedule 40 PVC pipe
-	1	Small can PVC solvent cement, medium consistency
-	1	Small can PVC solvent cleaner
-	1	1 lb spool #16 AWG gauge magnet wire


1
2
3
3 in. long
hacksaw cuts
4
5
6
7
14
15
8
16
Coil
9
Taps
8
14
15
Transmitter
13
10
11
Weatherproof
box
12
power and
audio cables
(inside or outside of
pipe)
transformer and
audio source