HALF-WAVE VERTICAL DIPOLE

These plans describe a vertical half-wave dipole designed for transmission of FM broadcast band signals. Materials used in its construction permit operation at power levels up to 100 watts. The same principles apply however to higher power antennas - only the diameter of the materials need to be changed. Please read these entire plans before beginning assembly.

CHARACTERISTICS

The feed impedance of a single diople is about 75 ohms. It has an omni-directional power gain of 1 when installed on a non-metalic support. Up to 8 units (bays) may be stacked to increase the effective radiated power. A system with more than 4 bays tends to skip over nearby areas limiting coverage close to the antenna site. A 4-bay system is therefore the recommended limit. A single-bay, and a 2-bay or a 4-bay system is easiest for impedance matching. A specially designed power divider is required for matching an odd number of units.

Each additional antenna increases the effective power. A 2-bay has a power gain of 2, a 4-bay gives 4. The field gain increases as the square-root of the power gain. In other words the signal strength increases at a given distance by 1.4 times for a power gain of 2 and 2 times for a power gain of 4.

When installed on a non-metallic support, such as a wooden pole, the radiation pattern is very nearly circular - nearly the same in all directions. Nearby objects, especially solid and dense objects affect the radiation pattern and tuning of any antenna. These objects include brick, cement, or rock buildings, trees, metal towers or tanks, power lines, and even human bodies.

The pattern becomes "cardioid" (heart shaped) when the antenna is installed on a metal tower or TV mast. Coverage directly behind the support becomes "shadowed". The distance to a given signal strength in the shadow is about 60% to 80% of what it would be for a circular pattern. What is lost in the shadow area is redirected to the front and sides of the support however. Distance in those directions may increase by as much as 20% to 40%..

The larger the tower's cross section, the greater the shadow area. A TV mast exhibits a very narrow shadow area. See the illustration "Typical Coverage Pattern". It assumes the antenna is at least 10 feet up a TV mast, there are no obstructions, and all nearby objects are at least 25 feet away.

A half-wave dipole exhibits a feed impedance of about 75 ohms. Nearby objects and a metal support or mast absorb or reflect some of the radiated energy. This has the effect of changing the feed impedance and tuning. The antenna is also said to be "balanced". This means neither of the two antenna elements is referenced (connected) to "ground". Coaxial cable on the other hand is "unbalanced" because its shield is usually connected to "ground".

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HALF-WAVE VERTICAL DIPOLE, Continued

A conductor (pipe, wire, coax, etc) appears resonate if it is cut to a quarter-wave length of a frequency. This characteristic may be used to make impedance matching "transformers", isolation "transformers", and 2nd harmonic traps - just to name a few. Both impedance matching and isolation are used with this antenna design.

The physical length of a "wavelength" is dependent on the wave medium. Waves travel at the speed of light through space but move slower through other materials. A wave travels along a very thin wire about the same as it would through space, but moves slower along a large diameter wire, or an enclosed wire. A wavelength on 3/4" copper pipe is therefore shorter than that wavelength on a thin wire or in space. The same is true for enclosed wire such as coaxial cable. The difference in speed is called the "Velocity Factor" or simply V.F.

Here is how it looks mathematically:

11812 divided by frequency (MHz) = Wavelength in inches (space)

2953 divided by frequency (MHz) = 1/4 wavelength in inches (space)

Velocity factor of 3/4" copper pipe = .98 (approximate)

Velocity factor of "foam" type coax cable = .75 (Radio shack type)

Velocity factor of "poly" type coax cable = .66

Therefore:

2953 / f(MHz) x V.F. = 1/4 wavelength in medium other than "space"

When two antennas are connected together the resultant feed impedance is halved. Since the half-wave dipole's impedance is about 75 ohms, two of them would result in a 37.5 ohm impedance. Since they don't make a 37.5 ohm coax we have to "transform" this to a standard coax impedance. The formula for finding the required transformer impedance is: (Symbol for impedance is "Z")

Transformer Z = Square-root of (coax Z x feed Z)

If we select 75 ohm coax, and have a 37.5 ohm feed impedance, then:

75 x 37.5 = 2812.5 and the square root of 2812.5 = 53 (ohms)

This is close enough (within 10%) of 50 ohms that we can use 50 ohm coax (RG-58 or RG-8) for our matching transformer. To see how this is connected into the system see cable (M) in the "Installation of 2 dipoles" illustration.

HALF-WAVE VERTICAL DIPOLE (Continued)

ASSEMBLY (See illustration page)

The support boom and internal coax furnished with the kit give an SWR of 1.5 or less to 1 over the entire FM band. An SWR of 1.5:1 is usually satisfactory for low power operation. If you desire a lower SWR you may shorten the coax and boom if you like. The internal coax length for a specific frequency should be:

2953 divided by f (MHz) times the cable's velocity factor (.75).

Example lengths are: (boom length is 5 inches shorter)

88 MHz 25.0 inches
98 MHz 22.6 inches
108 MHz 20.5 inches

(1) Determine the proper length of the internal coax and boom for your intended frequency. Cut the boom and coax to the required length if desired. See "Preparation of RG-59/U". Prepare the free end of the internal coax cable.

(2) Install the PVC "T" on the end of the boom. Rotate the "T" so it's in alignment with the mounting stub (just laying the whole thing flat on a table should do it). Assure the pipe doesn't extend all the way into the "T" - it should stop just at the end of the hole (see drawing). Tighten the PVC nut slightly to hold it in place. Pull the coax center conductor out the hole on the side of the "T" which faces the same direction as the coax connector (down in the drawing). Pull the braid out the other hole (up in the drawing).

(3) Slip one of the PVC nuts onto an antenna element. Follow it with a metal lock ring and beveled plastic washer (compression ring). These slide onto the pipe about 1-1/2" (to the small hole).

(4) Twist the coax braid so it's essentially a single piece of stranded wire. Bend its end slightly to form a kind of "hook". Slip this into the open end of the antenna element pipe and out of the little hole in the pipe. Push the metal lock ring and PVC ring right up to the wire (hole).

(5) Slip the pipe into the "T" while pulling on the braid. The object is to keep the braid inside of the "T" as short as possible. Wrap the braid around the pipe in a clock-wise direction. Push the PVC nut down over the braid, thread it on to the "T". Tighten the nut CAREFULLY ....DO NOT LET THE PIPE TURN ALSO. If the pipe turns it could twist and break the wire. If done properly this should press the braid against the metal lock ring. The lock ring in turn "bites" into the pipe to make connection.

HALF-WAVE VERTICAL DIPOLE (Continued)

(6) To install the other antenna element just repeat steps 3, 4, and 5 above - only this time use the coax's center conductor.

(7) Re-tighten all nuts while taking care not to let any of the pipes turn while tightening.

(8) Check your work with an Ohmmeter: (a) You should have continuity between the lower element and the center pin of the coax connector. (b) You should have continuity between the boom and the upper element. (c) You SHOULD NOT HAVE CONTINUITY between the upper and lower elements themselves.

INSTALLATION

Generally, the higher the antenna above ground the better. The practical limitations are (a) the allowable height of your tower or mast, and (b) the coax power loss between the transmitter and the antenna. The transmission line should be kept under 50 feet if you use RG-59, under 100 feet if you use lower loss 75 ohm coax. You may use 50 ohm coax such as RG-58 or RG-8 if you have to. However, the resultant SWR will be 1.5:1 minimum.

CAUTION

Installation may require working at heights over 10 feet. This may also require a very tall ladder. DO NOT WORK ALONE ! Be careful how you set up your ladder. Use a safety belt or rope to keep you from falling. Be careful not to have your tower, TV mast, or other support where it could fall against or touch electrical or telephone lines. If mounting the antenna system on a TV mast it may be possible to do most of the work on the ground - then stand the whole thing up later (limited to about 15 feet). BE CAREFUL!!!!

Single-Bay system:

Mount the antenna as shown in the illustration "Typical mounting of dipole". The antenna should be 10 feet or more above other objects, and the roof of the support building. "U" bolts are provided with the kit for attaching the antenna to a standard TV mast or similar sized portion of a tower. Be careful not to tighten the bolts too much, you don't want to collapse the copper fitting or pipe.

You may "preset" the lengths of the sliding tuning stubs if you wish. Very gently tighten the tuning stub locking screw...you don't want to dent the sliding 1/2" copper pipe. If you dent it, it may not slide in and out any more. Typical length of each tuning stub:

88 MHz = 7"
100 MHz = 3"
108 MHz = 0"

Attach your transmission line and go to "TESTING".

HALF-WAVE VERTICAL DIPOLE (Continued)

Two-Bay System: (See "Installation of 2 dipoles")

Installation is the same as the Single-Bay system except you now must consider (a) spacing between antennas, (b) vertical alignment, (c) phase relationships, and (d) impedance matching.

The antennae must be in vertical alignment. Connect a long string to the upper element of the top-most antenna. Tie a small weight to the bottom of the string. This makes a "plumb-bob" - it hangs straight down. Each of your antennae should be parallel with the string, in other words, each antenna is DIRECTLY above or below the other. The coax connector must always be pointing DOWN (this puts the antenna element connected to the braid...UP).

The two antennae must be connected exactly one electrical wavelength apart. This is to preserve the phase relationship between the two. When the antennae are fed "in phase" their radiation fields add. If they are "out-of phase" radiation fields cancel. The interconnecting cable (W) is a 75 ohm coax cut to the required length. Its length (in inches), where the Velocity Factor is .75, is:

11812 divided by f(MHz) times the Velocity Factor = Length of (W)

Examples: 100.6" for 88 MHz, 88.6" for 100 MHz, 82" at 108 MHz.

The top end of the (W) section connects to the top antenna with a coax connector. The bottom of the (W) section has a "T" connector which connects to the bottom antenna. A matching section (M) is connected between the "T" and the transmission line (C).

The space between antenna centers (S) should be about .8 of a wavelength. The transmission line by virtue of its velocity factor is .75 - close enough for satisfactory operation. If you want to be VERY precise however you can add a little more line. This can be done by adding EQUAL lengths of the same type coax to EACH antenna BEFORE connecting to the (W) section.

Matching section (M) is made from 50 ohm coax. Its length is:

2953 divided by f(MHz) x V.F.= length of (M) in inches.

Know the V.F. for your 50 ohm coax, .66 or .75!

Four-Bay system:

To start, simply install 2 of the 2-bay systems, each with its own (W) and (M) sections, but WITHOUT transmission line (C). The spacing between each antenna is just as before, about .75 to .8 wavelength. When connecting the (W) section to the lower 2-bays put the coax "T" to bay #3. The two (M) sections should be then pointed at each other. Assure each is in vertical alignment (one above the other). Make one additional (M) section.

Now measure the distance between the ends of the two (M) sections. Cut two 75 ohm cables to any length which is just a little longer than half that distance. Both must be the SAME length. Fit them with connectors. Connect one to the upper (M) section, the other to the lower (M) section. Connect the free ends of both cables to another coax "T". Now connect your extra (M) section to that "T". Your main transmission line (C) connects to the end of this (M) section.

Remember, each of the 2-bay systems was arranged so that the end of the (M) section would match a 75 ohm line. Here we connected to systems together, each at 75 ohms, while maintaining the phase relationships. The two added together gave us 37.5 ohms again requiring another (M) section to bring us back to the 75 ohm transmission line (C).

Multiple-Bay Systems:

In a multiple bay system each bay tends to affect the tuning of the others. It is wise therefore to first tune each antenna individually. All the others are disconnected while you do this. Each antenna by itself has a feed impedance of 75 ohms so the (M) section is not used at this point. You simply connect the end of your main transmission line (C) to the antenna being tuned. If you need more length you can use the (W) section (it's also 75 ohms). After ALL bays have been initially tuned they can all be connected together as one system. The tuning procedure is again applied to "touch-up" the system as a whole.

TUNING

An SWR meter is connected between the transmitter end of the transmission line (C) and the transmitter itself. You need only enough transmitter power to calibrate the SWR meter. Your meter is set to the calibrate position, power is applied, and the calibration knob is adjusted to the "set" line (usually full-scale) on the meter. Then switch to the "SWR" position. After each major change in tuning the meter may have to be recalibrated.

Tune the antenna by sliding the 1/2" copper pipe tuning stubs in or out. "IN" increases the resonant frequency of the antenna, "OUT" decreases it. Both stubs should be about the same length. If anything, the upper stub can be up to an inch longer. Move the stubs about 1/2 to 1" and then check the meter. Continue in this manner until you have the lowest possible reading on your SWR meter. You should consider any reading under 1.5 as satisfactory, under 1.3 as very good, and under 1.2 as excellent.

Move away from the antenna after each tuning adjustment. If your body (or someone that's helping you) is too close it will affect your meter readings.

THE FINISHING TOUCH

The antenna is somewhat weather proof but you may take some added precautions if you want. A little silicone sealant, such as used in clear bathtub caulking may be used on the threads of the PVC "T". Looking at the "Wiring detail" illustration...you can also put some silicone sealant, or silicone grease in the PVC nut between the nut and where the wires make contact with the metal locking ring. Some sealant may also be used where the 1/2" tuning stubs slide into the 3/4" bushings. A small amount of silicone grease on the threads of your coax fittings will help keep out moisture.

The copper pipe can look very nice when highly polished but it won't stay that way unless it has a protective coating. Polish with copper cleaner, a plastic pot scrubber, or very fine steel wool. Wash thoroughly with detergent and water. Dry completely. Spray with a clear lacquer.

If you don't care if anyone sees your antenna, or if you want to make it difficult to see, paint it. A flat black or blue (to match the sky) will help make it "invisible". Use a non-metalic lacquer or a latex paint. DO NOT use metal or lead based paints. Painting should not affect the antenna's tuning or performance, as long as you paint it AFTER it's tuned.

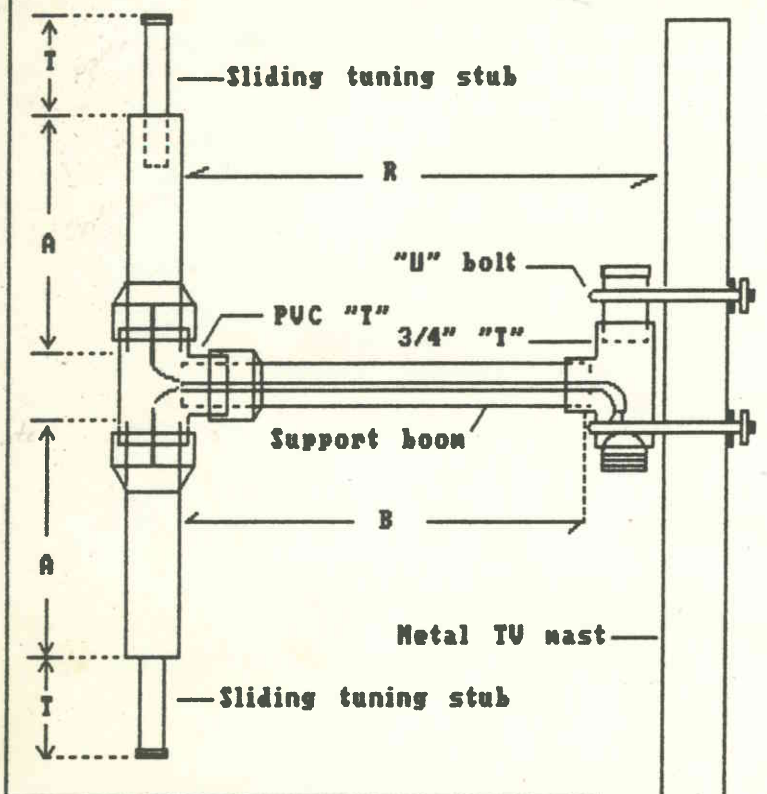
PARTS FURNSIHED WITH EACH HALF-WAVE DIPOLE KIT

1 - 3/4" PVC compression "T"
2 - presoldered 3/4" copper antenna elements
2 - presoldered 1/2" copper tuning stubs
1 - presoldered support boom
1 - length of RG-59/U with SO-239 connector (V.F. of .75)
2 - "U" bolts with washers and nuts

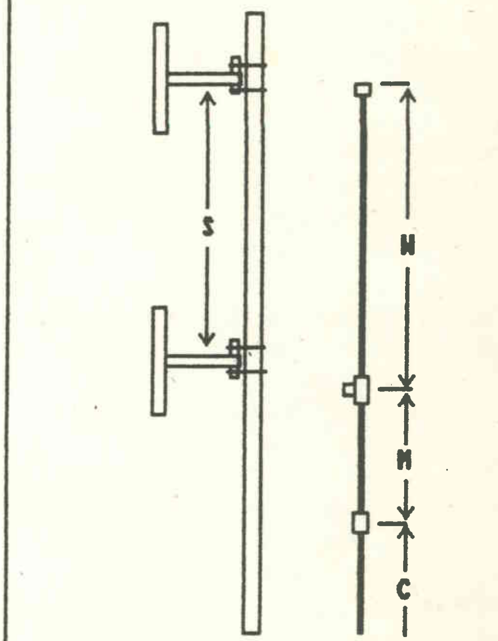
Parts available from:

Panaxis Productions
PO Box 130
Paradise, CA 95969

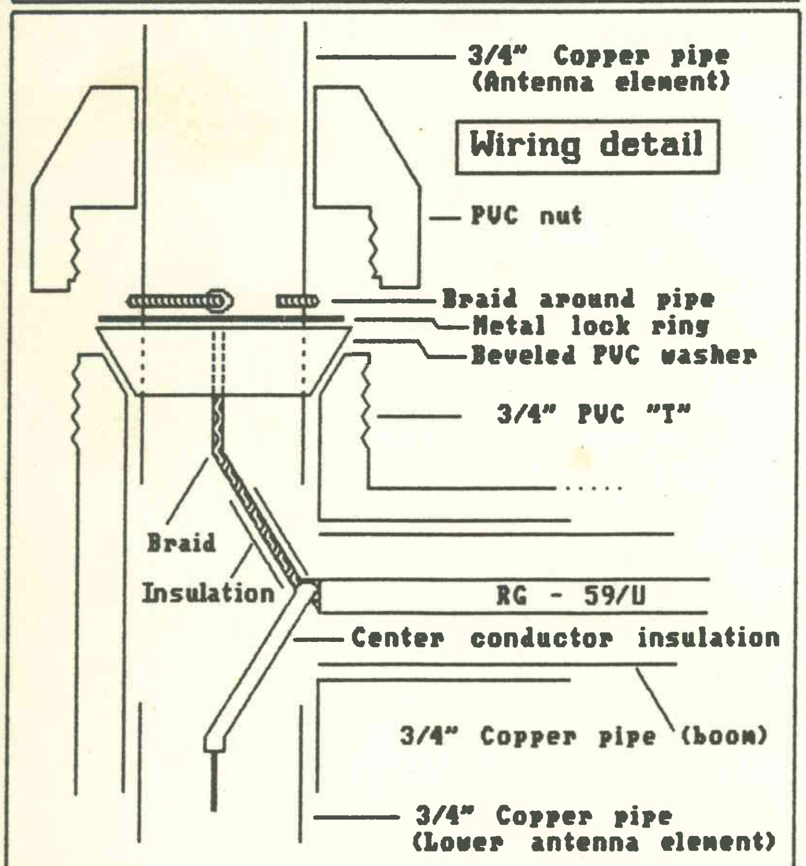
HALF-WAVE VERTICAL DIPOLE



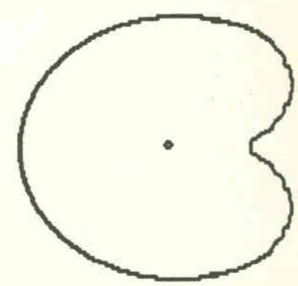
Typical mounting of dipole



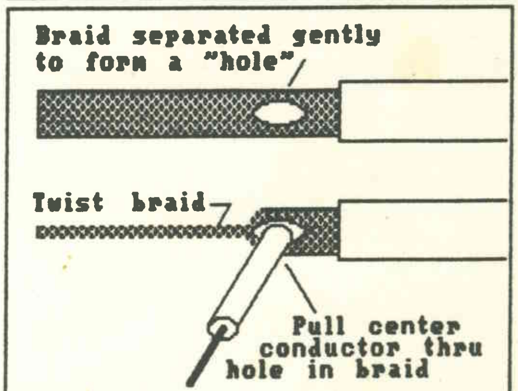
Installation of 2 dipoles



Wiring detail



Typical coverage pattern



Preparation of RG-59/U