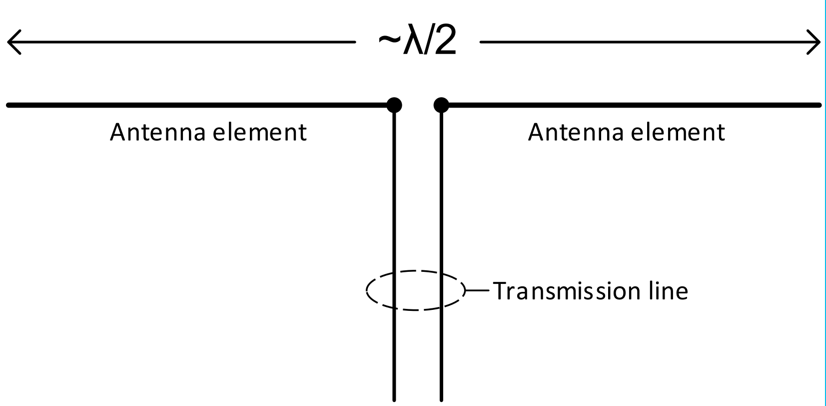
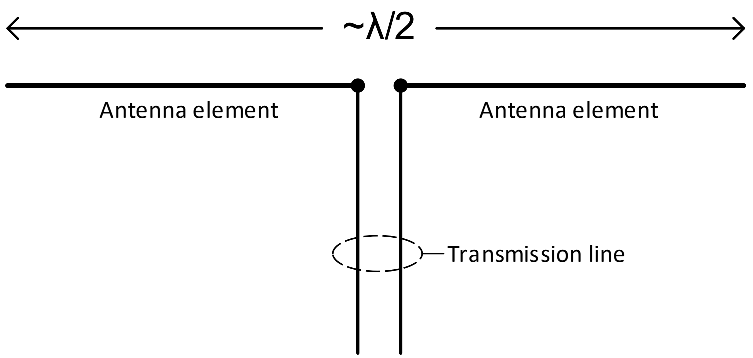


The half-wave dipole antenna

Ron Hranac

What is a dipole antenna?

- A typical dipole antenna is about a half-wavelength (λ/2) long at its intended frequency of operation.



What is a dipole antenna?

- Dipoles form the basis for several other antennas, such as Yagi-Uda (“Yagi”) and log periodic dipole array (LPDA) antennas.

What is a dipole antenna?

What about the name?

di – two

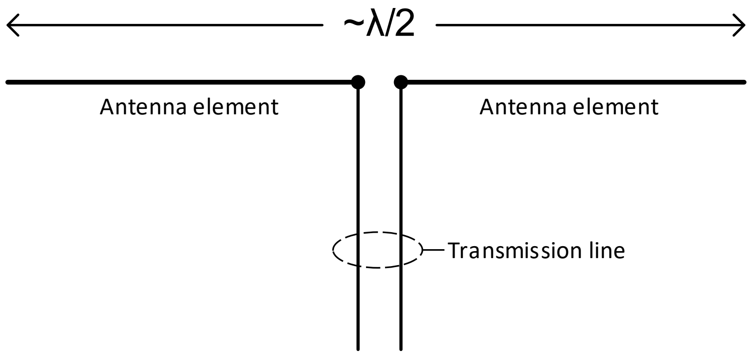
pole – electrical polarity (describes the opposite voltages on each half of the antenna, resulting in two electrical halves)

What is a dipole antenna?

- The half-wave dipole antenna has long been used for signal leakage measurements by cable operators, and is referenced in the FCC’s signal leakage requirements.
- The dipole antenna most familiar to cable operators is a linear doublet that has a physical end-to-end length equal to slightly less than one-half of a wavelength at the design frequency.

What is a dipole antenna?

- A half-wave dipole comprises two conductive elements in the same plane, fed at the center by a transmission line.*
- The transmission line can be a *balanced* transmission line (e.g., twinlead or window line), or an *unbalanced* transmission line such as coaxial cable.



* Some dipoles are fed off-center, but we're not going to discuss those in this session.

What is a dipole antenna?

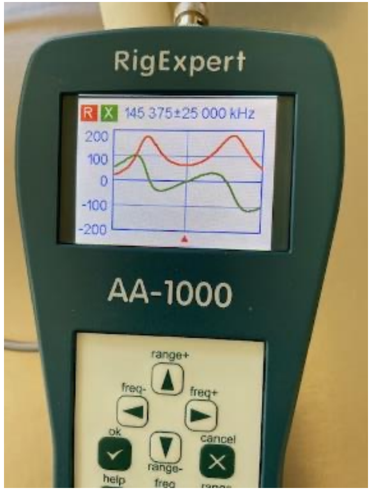
When fed by coaxial cable, a balun is typically used at the antenna's terminals to accommodate the transition from the unbalanced transmission line to the (balanced) dipole antenna. Some examples:

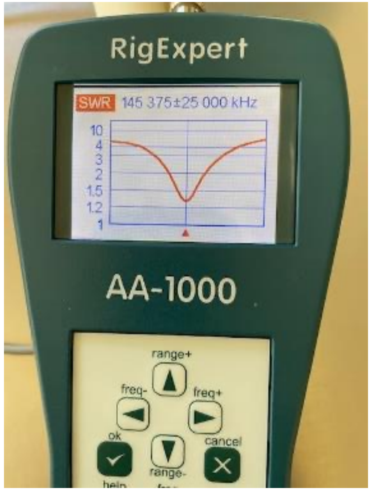
- λ/4 sleeve balun
- Transformer balun
- Coiled cable (choke) balun
- Ferrite bead(s) balun

Dipole antenna resonance

From the *ARRL Antenna Book, 25th Ed.*:
“If the dipole is resonant, the instantaneous waveforms of the voltage and current are exactly in phase. This means that the antenna’s feed point impedance is purely resistive with no reactance.”

To achieve resonance, a half-wave dipole antenna’s physical length must be a few percent shorter than a free-space half-wavelength at the frequency of operation.





Half-wave dipole antenna characteristics

Feedpoint impedance (free-space): ≈73 ohms

Half-wave dipole antenna characteristics

Feedpoint impedance (free-space): ≈73 ohms

Feedpoint impedance (real-world): It depends.

- Over real earth and with common element length-to-diameter ratios used in most dipoles, a half-wave dipole antenna's impedance can vary from a low of around 20 ohms up to 100 ohms or more.

- The antenna height above ground and its proximity to other objects have a significant effect. The resulting reflections – depending on distance (in wavelengths) and the quality of the reflecting surface(s) – can change the antenna's impedance and resonant frequency.

Half-wave dipole antenna characteristics

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Feedpoint impedance (real-world): It depends

Gain (free-space): 1.64 [in decibels: $10\log_{10}(1.64) = 2.15$ dBi]

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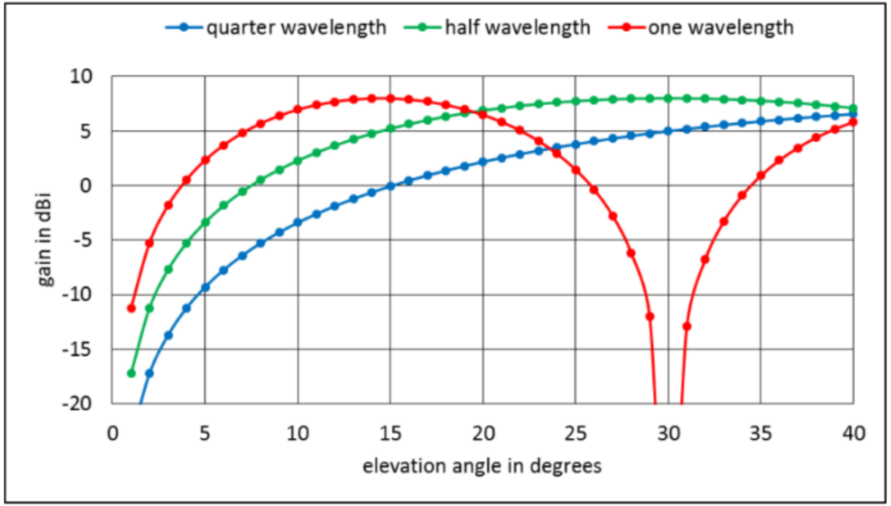
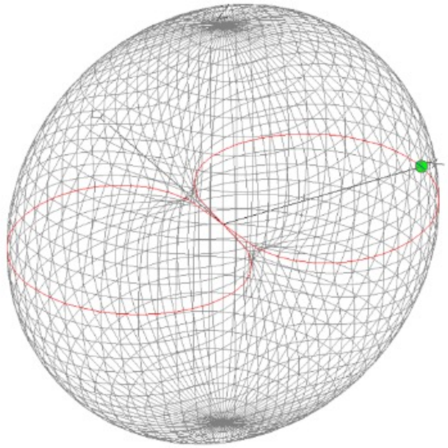


Graphic source: Carl Luetzelschwab, K9LA

Calculated results for a 14 MHz half-wave dipole modeled over average earth conditions, for antenna heights of λ/4, λ/2, and λ.

Half-wave dipole antenna characteristics



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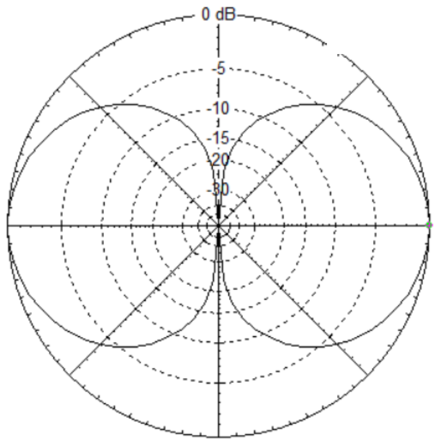
Radiation pattern (free-space):



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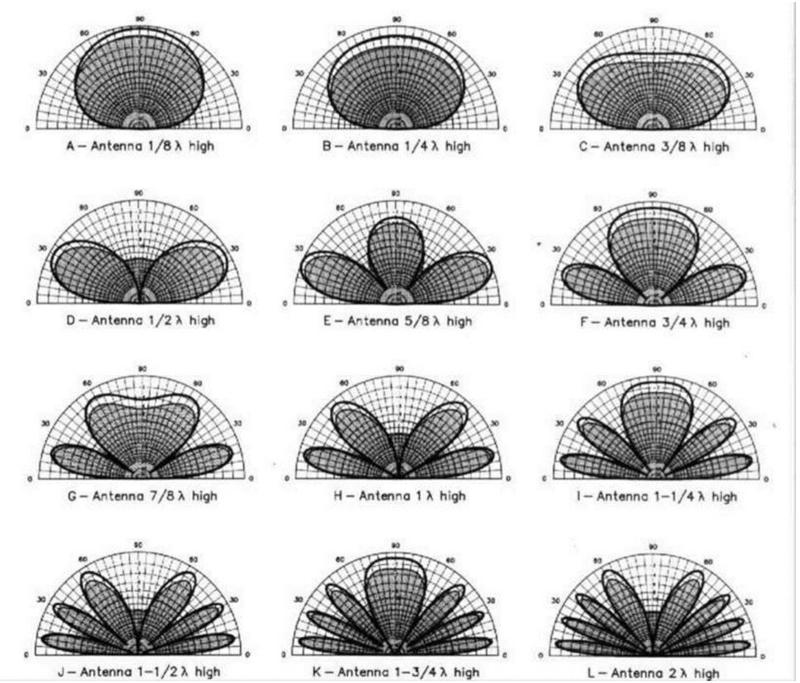
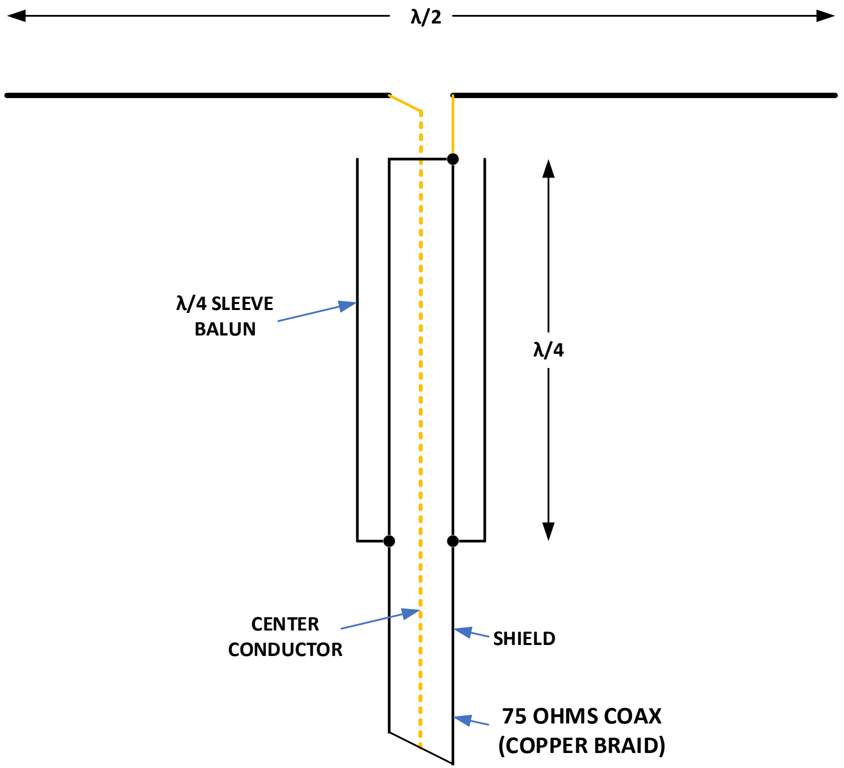


Graphic source: ARRL

Project time: Build your own λ/2 dipole

Let's make a home-brew half-wave dipole antenna!

- For this project, the antenna will be crafted for use on 133.2625 MHz.
- The balun will be a λ/4 sleeve balun (see figure), although other types of baluns could be used.



Project time: Build your own λ/2 dipole

Crunching the numbers

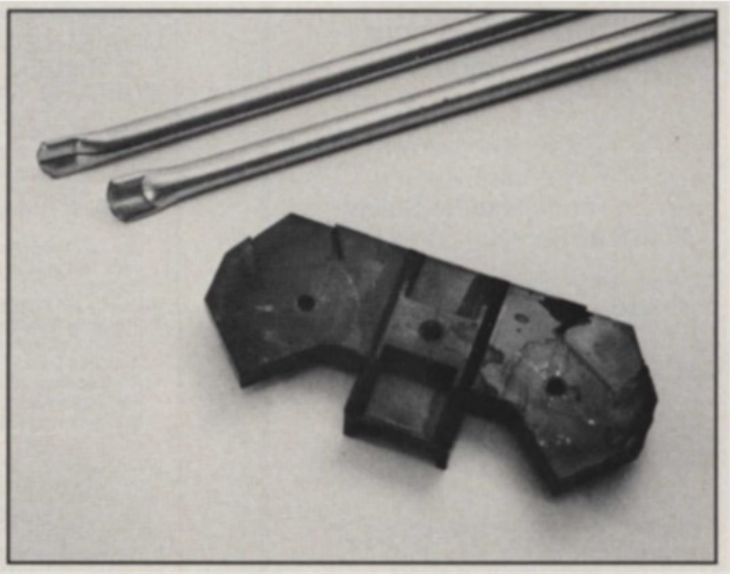
- Frequency: 133.2625 MHz
- Free-space $\lambda/2_{inches}$: $5901.43/f_{MHz}$ = 44.28 inches
- Dipole length: **($5901.43/f_{MHz}$) × K**, where K for our project is 0.948*
- The calculated end-to-end length is 41.98 inches (we'll round up to 42 inches) for the element diameter being used.

* To achieve resonance a dipole's [or monopole's] physical length must be shortened from the free-space value by a few percent in order to bring the reactance to zero. The antenna element length is affected by the ratio of the half-wavelength-to-element diameter. To account for the element half-wavelength-to-diameter ratio, a multiplying factor called "K" must be applied to the free-space quarter- or half-wavelength calculation. The K factor can be taken from a chart in the latest edition of the *ARRL Antenna Book*, or calculated mathematically.

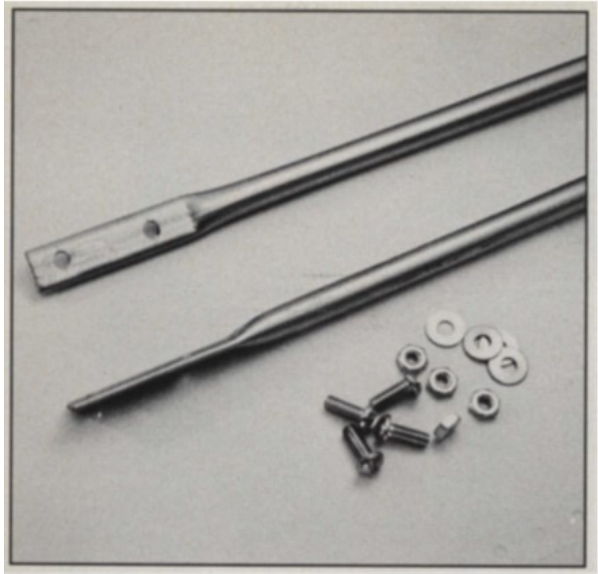
Build your own dipole: Parts list

Quantity	Item
1	Old TV antenna
15 feet	Copper-braid Series 59 coaxial cable
2 feet	Copper-braid RG-8 coaxial cable
2 inches	Small piece of hobby heat shrink tubing
2	Crimp-type ring wire terminals
1	Wooden dowel (old mop or broom handle)
Assortment	Machine screws, washers, nuts to fit 1/8 inch holes
1	F connector
	Black tie wraps
	Safety glasses, hand tools, soldering iron, solder, drill, drill bits, heat gun or blow dryer, tape measure, tubing cutter

Build your own dipole

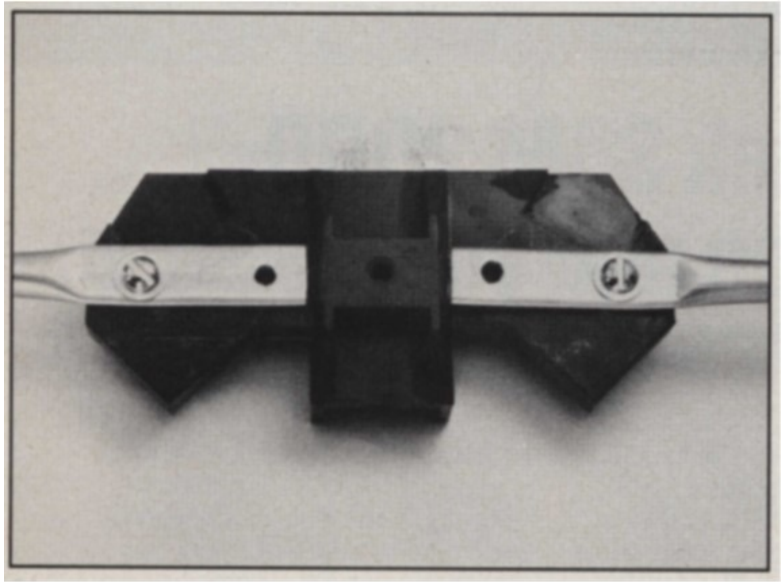


Drill out the rivets that hold one of the plastic brackets and pair of antenna elements to the TV antenna's boom. The bracket will be the dipole's center insulator, and the two TV antenna elements will become the dipole's elements.

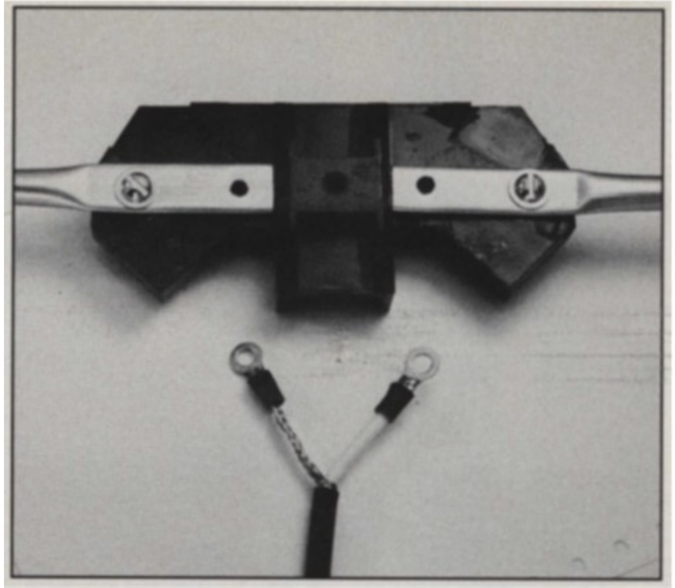


Flatten about 1-3/4 inch of one end of each of the two TV antenna elements in a bench vise. Drill two 1/8 inch holes about an inch apart in the flattened areas.

Build your own dipole

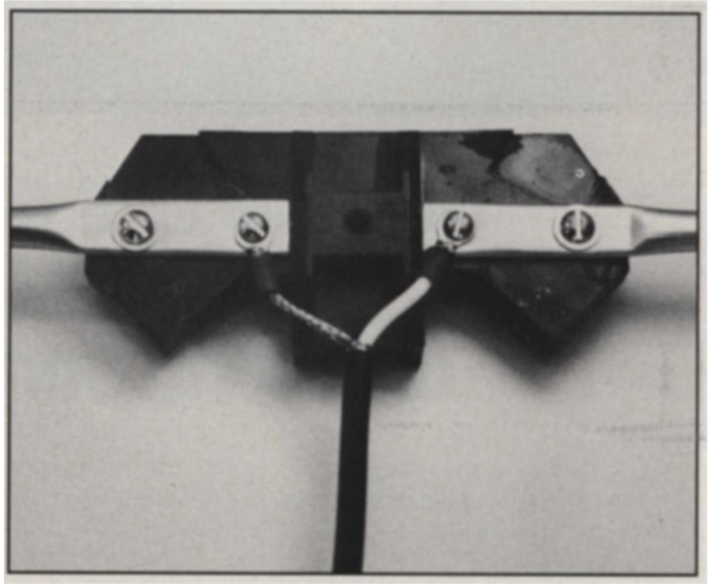


Attach the elements to the plastic bracket using only the outer holes. The inner holes will be used to attach the transmission line to the elements. For this project, a 15 ft. length of copper braid Series 59 coax was used.

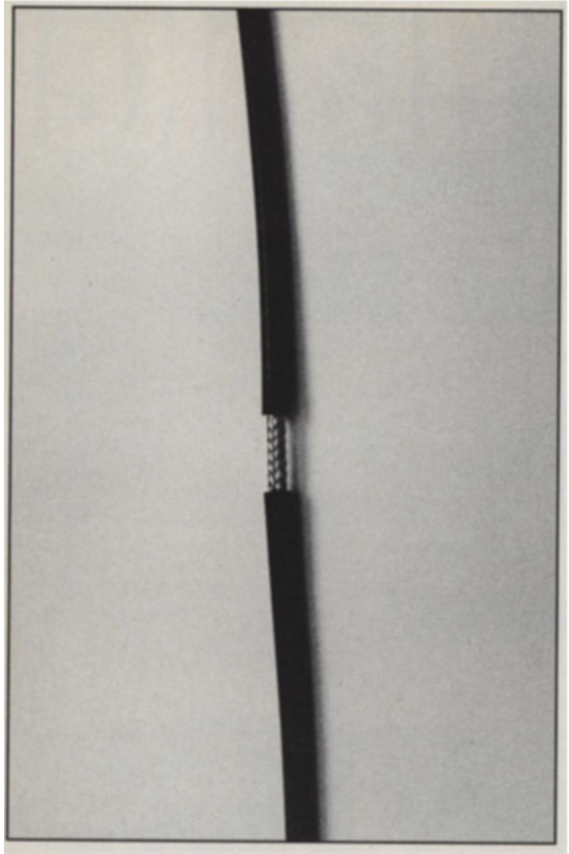


Remove about 1-1/2 inches of jacket from one end of the transmission line. Remove 1/4 inch of dielectric from the center conductor, then crimp and solder the wire terminals to the shield and center conductor.

Build your own dipole

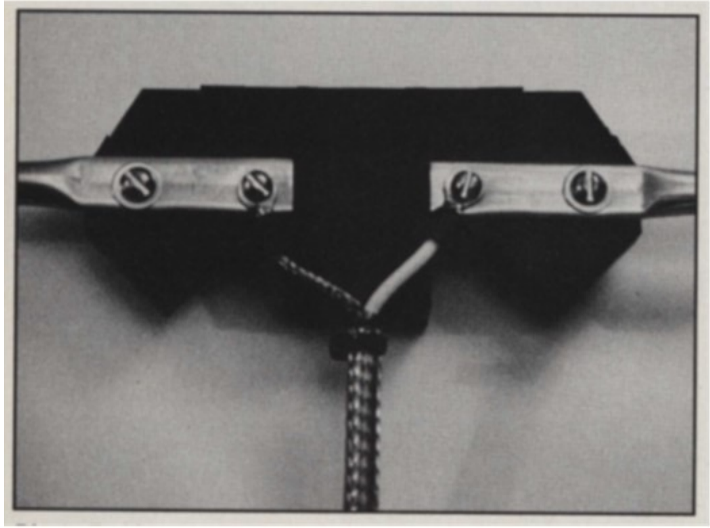


Attach the transmission line to the elements using suitable hardware. Make sure the screws are long enough to pass through the bracket. Then use a tubing cutter to trim the lengths of the elements so the end-to-end dipole length is the calculated value (42 inches for this project).

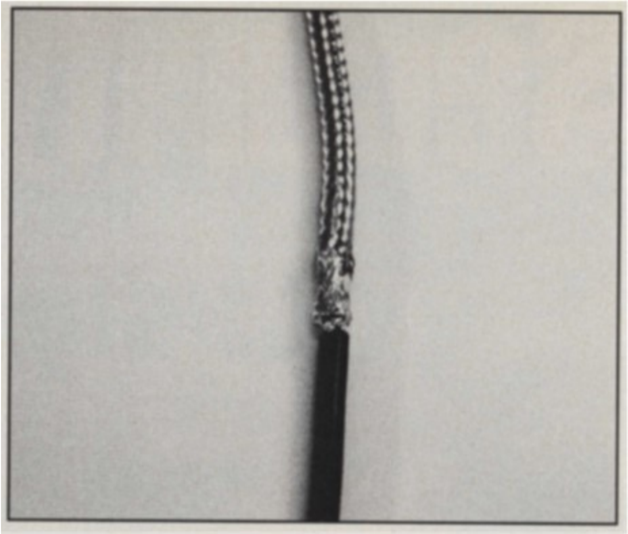


Measure about 21 inches down from the top end of the coax (from the end of the jacket where the center conductor and shield separate). Carefully remove about 3/4 inch of jacket from the coax.

Build your own dipole

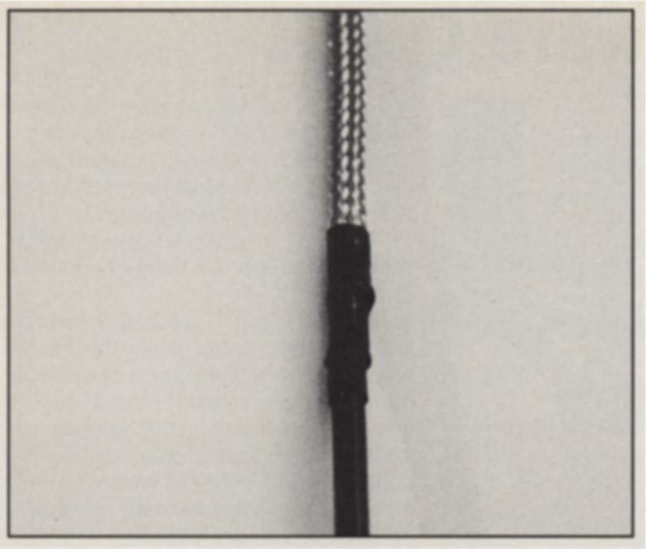


Slip a couple feet of copper shield from a piece of RG-8 coax over the antenna feedline, until the upper end of the larger shield is about flush with the end of the transmission line's coax. Secure the larger shield to the transmission line with a tie wrap, making sure the larger shield does not touch the smaller cable's exposed shield.

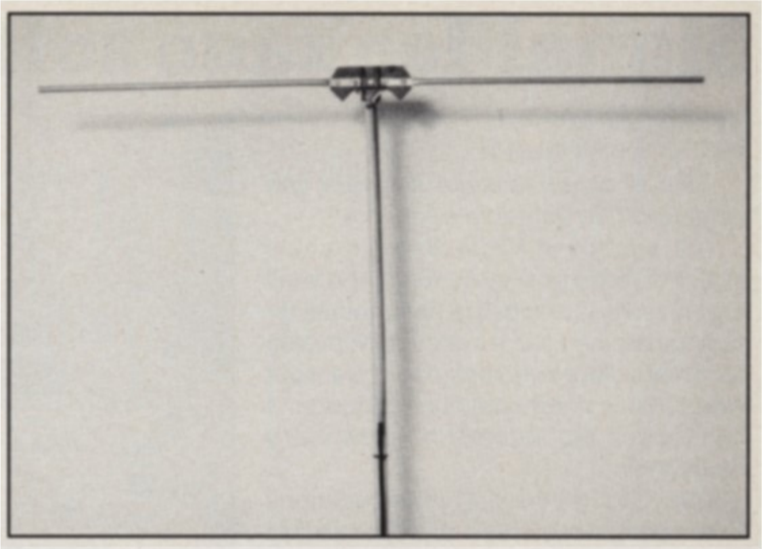


Trim the lower end of the RG-8's shield to line up with the transmission line's exposed shield. Carefully solder the larger shield to the transmission line's shield (I've sometimes used several small tie wraps to do this instead of soldering).

Build your own dipole

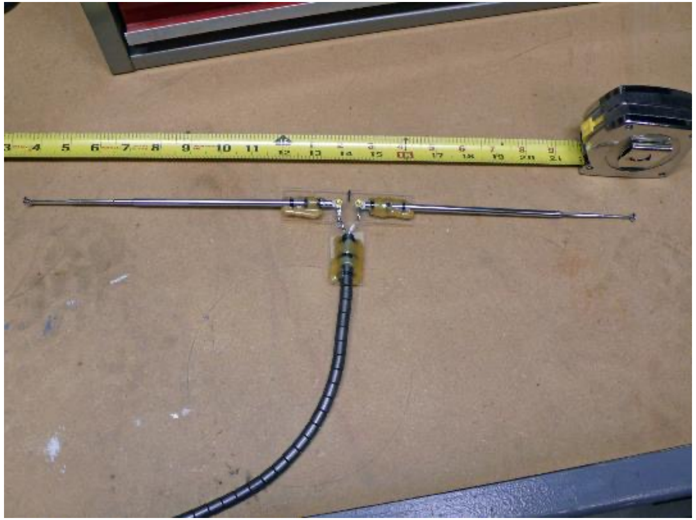


Install a short length of heat shrink tubing over the soldered (or tie-wrapped) connection, and shrink with a heat gun or blow dryer.

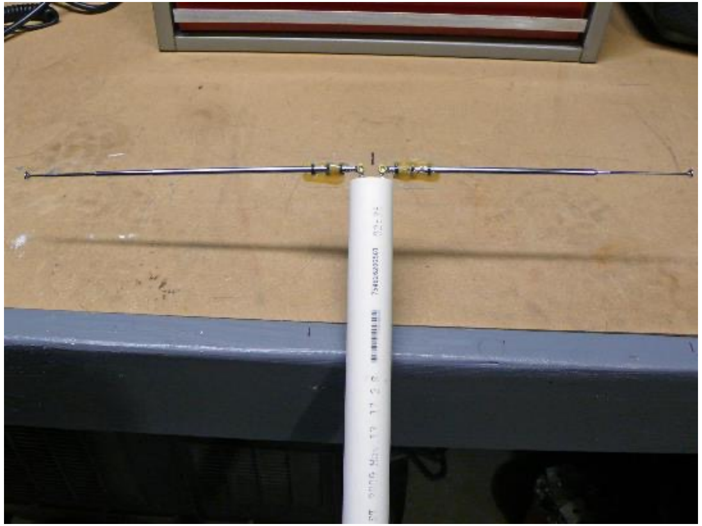


Attach the plastic bracket to the end of a wooden dowel (an old broom or mop handle will work). Tie wrap the feedline to the wooden pole in a couple places, then install an F connector on the other end of the transmission line.

More home-brew dipoles

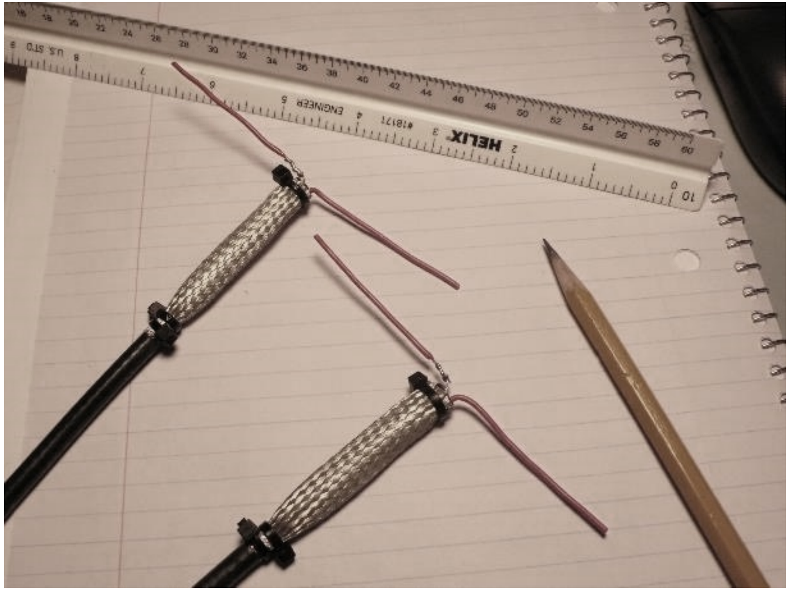


Center insulator: acrylic sheet (0.1 inch thickness)
Elements: telescoping antennas
Feedline: Mini 75 ohm coax, about 5 feet
Balun: #43 mix ferrite beads



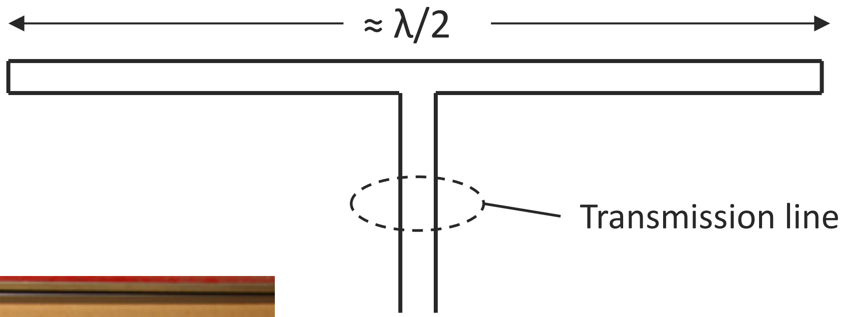
Mast: 1-inch PVC pipe (Sch. 40) with notches cut in top to fit center insulator; length is about 3-1/2 feet.

More home-brew dipoles



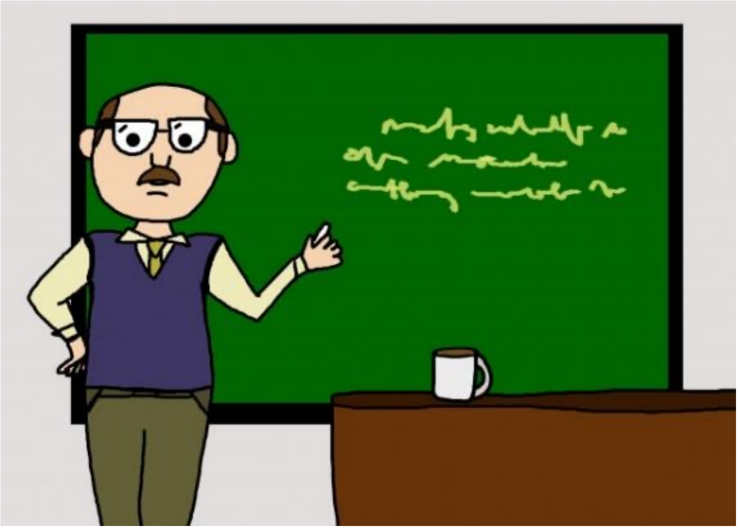
Center insulator: None
Elements: Small gauge insulated wire
Feedline: Series 59 copper braid coax
Balun: λ/4 sleeve balun

Folded dipole



Element: 300 ohms twinlead, ends soldered together, fed in center of “bottom” element
Feedline: Suitable length of Series 6 or Series 59 drop cable
Balun: Cable TV matching transformer (300 ohms-to-75 ohms)

Summary



- The half-wave dipole antenna has played a role in the RF side of the cable industry for decades.
  - Many are familiar with its use for signal leakage detection and measurements.
  - The half-wave dipole antenna also forms the basis for other types of antennas, such as Yagi-Uda and log periodic dipole array antennas used at many headends and antenna sites.
- Feel creative? One can easily make a home-brew half-wave dipole antenna.

Resources:

- *ARRL Antenna Book, 25th Ed.* (American Radio Relay League)
- *Antennas, 2nd Ed.*, by J. Kraus (McGraw Hill)