

HORIZONTAL DIPOLE — EVERYBODY'S FAVORITE

THE HORIZONTAL DIPOLE is a simple effective antenna. Antenna wire and accessories required for construction are inexpensive and readily available. In fact make do replacements from surplus sources cost even less, or may be available for free.

It is the length of the dipole antenna that makes for efficient use as a receptor of an incoming radio wave. When used as a transmitting antenna, it radiates efficiently and, at the same time, displays a proper impedance match to the output of the transmitter.

Dipoles are of critical length when used as transmitting antennae because of the need for proper match. Length and match insure ideal characteristics for reception as well. It is true that length and match are less critical if the antenna is to be used for receive only, because of the high sensitivity of modern receivers. For example, an antenna cut to length on one of the lower-frequency short-wave broadcast bands, will also receive well on other international broadcast bands. However, a dipole cut to length and properly oriented may be of considerable help in receiving some favorite, but very weak station.

Dipole Length. The physical length of the antenna is related to the wave-length of the signal frequency to be received or transmitted. Frequency in megaHertz, and wavelength in meters are related as follows:

$$\text{Wavelength (Meters)} = \frac{300}{\text{freq. (MHz)}}$$

For example, the wavelength of a 3.75 mHz signal frequency would be:

$$\text{Wavelength} = \frac{300}{3.75} = 80 \text{ meters}$$

A dipole is a half-wavelength antenna and, therefore, its theoretical length would be one-half of this value, or 40-meters long. In practice, however, there are capacitive end-effects which cause a dipole that is cut to exactly the so-called "free-space" wave-length to be resonant on a lower frequency than the calculated value. In fact, to make the antenna an exact "electrical" half-wavelength long, it is necessary to shorten the physical length by 5-percent. Hence the dipole length for 3.75 MHz resonance would be:

$$\text{Dipole Half-Wavelength} = 0.95 \times 40 = 38 \text{ meters}$$

Since the dipole antenna is fed at the center and separated into two quarter-wavelength segments as shown in Fig. 1, each side of the antenna would be 19 (38 ÷ 2) meters long.

Physical antenna length for each quarter-wave segment of the dipole can be obtained by multiplying the 19 meters times the meters-to-feet conversion constant of 3.2808, obtaining a value of 62.34 feet.

A conversion from metric to linear length results in a very simple equation than can be used to determine the length of the quarter-wavelength segment of a dipole:

$$\text{Length in Feet} = 234/f(\text{MHz})$$

A hand calculator is an aid if you wish to make your own antenna calculations.

Dipole Dimension Charts. Quarter-wave segment lengths for each of the Amateur bands, 10 through 160 Meters, are given in Table 1. For example, each quarter-wave segment of a dipole antenna cut to 14.2 MHz in the 20-Meter band should have a length of 16.48 feet. Table 4 gives dimensions for dipole quarter-

Table 1—Here are the dimensions for cutting half-wave dipoles for the various Amateur frequencies below 30 MHz. The number given represents one-half the total antenna length.

FREQUENCY IN MHz	DIPOLE $\lambda/4$ IN FEET	FREQUENCY IN MHz	DIPOLE $\lambda/4$ IN FEET
160 METERS		20 METERS	
1.81	129.28	7.200	32.50
1.83	127.86	7.225	32.39
1.85	126.49	7.250	32.28
1.87	125.13	7.275	32.17
1.89	123.80	20 METERS	
1.91	122.51	14.025	16.69
1.93	121.24	14.050	16.66
1.95	120.00	14.075	16.63
1.97	118.78	14.100	16.60
1.99	117.59	14.125	16.57
80 METERS		14.150	16.54
3.525	66.38	14.175	16.51
3.550	65.92	14.200	16.48
3.575	65.45	14.225	16.45
3.600	65.00	14.250	16.42
3.625	64.55	14.275	16.39
3.650	64.11	14.300	16.36
3.675	63.67	14.325	16.33
3.700	63.24	15 METERS	
3.725	62.82	21.05	11.12
3.750	62.40	21.10	11.09
3.775	61.99	21.15	11.06
3.800	61.58	21.20	11.04
3.825	61.18	21.25	11.01
3.850	60.78	21.30	11.98
3.875	60.39	21.35	10.96
3.900	60.00	21.40	10.94
3.925	59.62	10 METERS	
3.950	59.24	28.2	8.30
3.975	58.87	28.4	8.24
40 METERS		28.6	8.18
7.025	33.31	28.8	8.13
7.050	33.19	29.0	8.07
7.075	33.07	29.2	8.01
7.100	32.96	29.4	7.96
7.125	32.84	29.6	7.91
7.150	32.73		
7.175	32.61		

wave segments for reception on the various shortwave broadcast bands. Dipole lengths for the various WWV frequencies are given in Table 3.

Lengths are given to a decimal part of one foot in the tables. In addition, Table 2 permits you to make an approximation in inches. In fact, when erecting an antenna for use with a transmitter, there are other variables, such as proximity to ground and metallic surfaces, as well as antenna element diameter that influence the exact resonant frequency. Therefore, cutting an antenna within an inch or two of indicated value is satisfactory. For example, in cutting the dipole for 14.2 MHz use, a practical value is 16-feet, 6-inches. Note from Table 2 that the six-inch figure is appropriate for a decimal part falling between 0.55 and 0.65.

It has been my experience in cutting antennas, that it is preferable to cut elements somewhat on the long

side, permitting you to trim down the antenna to a specific resonant frequency after initial tests have been made. Of course, antennas for receive-only use are not nearly so critical as to their length. Consequently, in Table 4, one dimension is given for operation over the specific shortwave broadcast band.

Of course, it should be stressed that an inch or two of length has a much more decided effect on the resonant frequency on a higher frequency Amateur band as compared to a lower one. Thus, you should be more careful in cutting the dipole for 10 or 15 Meters, as compared to the cut for 80 or 160 Meters. For example, a differential of 3-inches on 10 Meters might result in a frequency change of approximately 1 megahertz, while a similar differential on 80 Meters corresponds to a frequency shift of only 20-25 kilohertz.

Dipole Directivity. The horizontal dipole is directional. As a transmitting antenna, it sends out

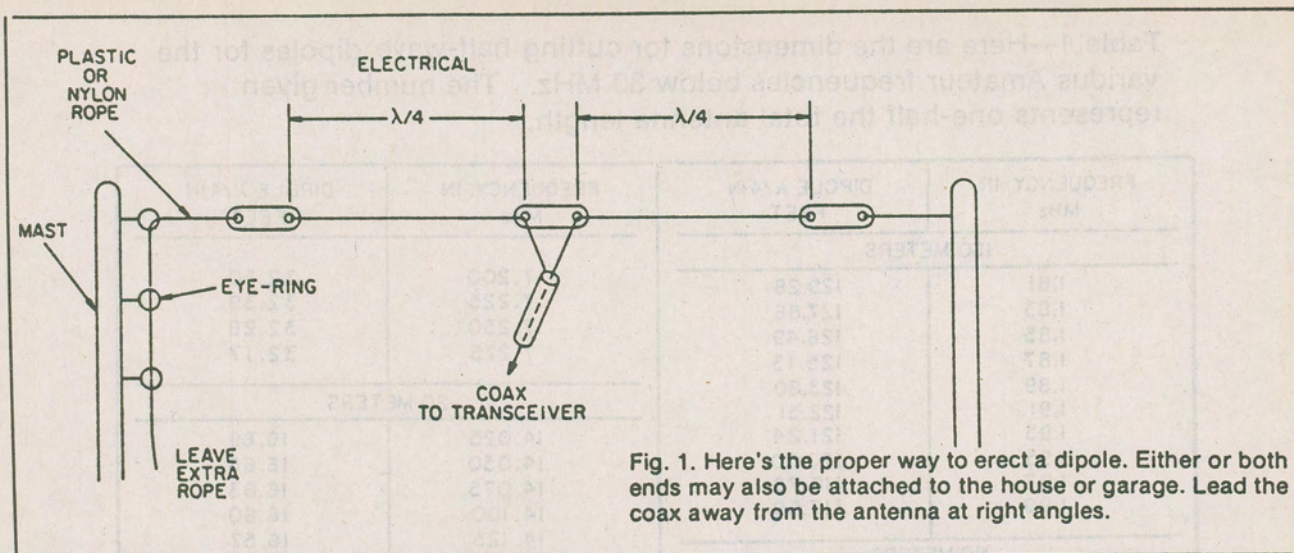


Fig. 1. Here's the proper way to erect a dipole. Either or both ends may also be attached to the house or garage. Lead the coax away from the antenna at right angles.

maximum radio energy (radiation) in the two directions broadside (perpendicular) to the antenna wires (Fig.2). As a receiving antenna, it displays maximum sensitivity to radio signals arriving from the same two directions. Radiation and sensitivity taper off at angles away from the perpendicular, declining to a minimum in the direction along the line (parallel) of the antenna wire. The response pattern of Fig. 2 is a theoretical one. The antenna does radiate energy at other angles and is sensitive to incoming signals as well. The extent of the differential depends upon a number of variables including type of antenna, proximity of ground, nearby metallic structures, propagation conditions, transmission line system, etc. It is a fact though, that maximum radiation and sensitivity occur perpendicular to the antenna wire and minimum in the direction of the antenna wire. The figure-eight pattern is itself rather broad, and it is only at angles near to the angle of the antenna wire that the response is sharply down.

DECIMAL PART OF ONE FOOT	INCHES (APPROXIMATE)
0-.05	0
.05-.10	1
.10-.15	2
.15-.25	3
.25-.35	4
.35-.45	5
.45-.55	6
.55-.65	7
.65-.75	8
.75-.85	9
.85-.90	10
.90-.95	11
.95-1.0	12

Table 2—Use this table to convert the decimal portion of the feet measurement given in Table 1, to inches. Always cut your antenna a bit longer at first. It's easier to trim it down than to add length later.

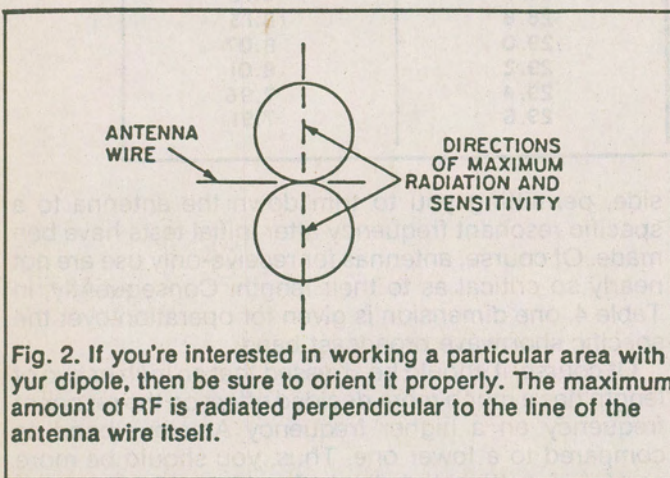


Fig. 2. If you're interested in working a particular area with your dipole, then be sure to orient it properly. The maximum amount of RF is radiated perpendicular to the line of the antenna wire itself.

In practice then, it is a good idea, if possible, to erect the dipole antenna with an orientation that places it broadside to the direction toward which you wish to radiate maximum signal or display maximum sensitivity. If your intent is to minimize the pickup of an interfering signal, you should point the dipole antenna wire in that direction.

Dipole Antenna Components. Essential components of the dipole antenna are: antenna wire, dipole center connector, end insulators, support rope, transmission line, and other accessories as needed.

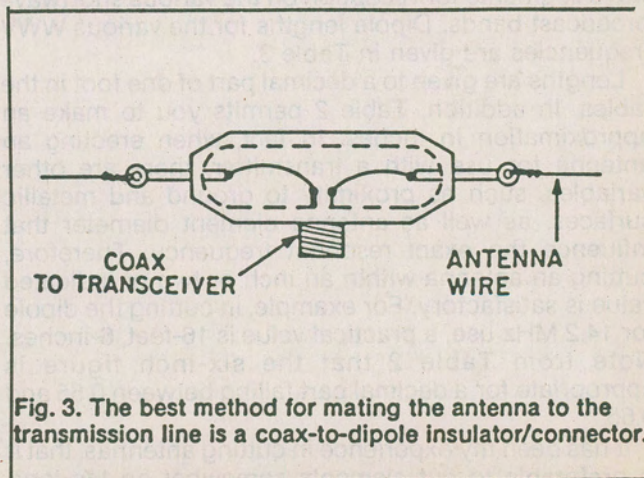


Fig. 3. The best method for mating the antenna to the transmission line is a coax-to-dipole insulator/connector.

Table 3—For receive-only operation, the dipole is still a very good choice. Here are the optimum lengths for broadband operation. Remember to orient the antenna for the area you wish to listen to specifically.

BAND METERS	FREQUENCY IN MHZ	DIPOLE $\lambda/4$ IN FEET
120	2.3-2.495	97.5
90	3.2-3.4	70.9
75	3.8-4.0	60.0
60	4.75-5.06	46.8
49	5.95-6.2	38.36
41	7.1-7.3	32.5
31	9.5-9.775	24.4
25	11.7-11.975	19.8
19	15.1-15.45	15.3
16	17.7-17.9	13.15
13	21.45-21.75	10.8

The antenna wire can be the popular 7-strand #22 type, which is common and inexpensive. When it can be found at low cost, our personal preference is for #14 or #16 solid, insulated wire. A good-quality, insulated wire gives you added safety and weather protection. Insulation in no way interferes with the radiation or pick-up of signal.

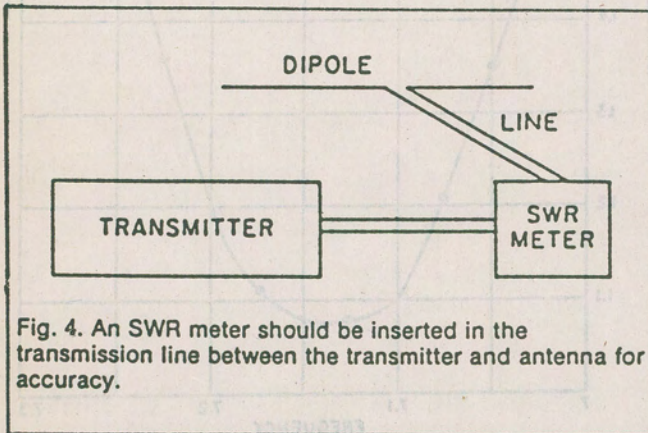


Fig. 4. An SWR meter should be inserted in the transmission line between the transmitter and antenna for accuracy.

Available end insulators are usually made of porcelain and are 1.75 to 3-inches long. They are oval-shaped or rectangular, some having a ribbed construction. Two holes are provided, one for the antenna wire itself and the other for the support line. Support line can be nylon rope or strong plastic clothes-line with a nonmetallic core. To make it easy to lower the antenna, for cleaning or experimentation, the support line at one end can be fed down through eyebolts to ground level, as shown in Fig. 1.

A coax-to-dipole connector, Fig 3, is the ideal method of linking the dipole antenna to the coaxial transmission line. This connector provides a durable and reasonably weather-proofed connection providing for convenient connection and detachment of transmission line. An alternative plan is to use an end insulator at the center. The two conductors of the transmission line can be attached firmly, soldered and taped to the antenna wire on each side of the center insulator.

There are various support means for horizontal dipole antennas. The variety of TV-antenna hardware such as chimney, side-wall and roof mounts, permit

easy attachment to a house or garage. Support itself can be a 5 or 10-foot section of TV mast. Free-standing and guyed masts are available for ground-mounted supports. A telescoping TV mast is versatile because of its ease of erection and let-down. Guying is required. Guy rings are spaced approximately every 10-feet along such a telescoping mast.

Use good quality coaxial line, either 50-ohm or 70-ohm. Preferred types are RG-58A/U (50 ohms) or RG-59A/U (70 ohms) for low power applications. RG-8A/U is recommended for higher-powered applications, and installations where a long feed line, from antenna to transmitter is necessary.

FREQUENCY IN MHZ	DIPOLE $\lambda/4$ IN FEET
2.5	93.6
5	46.8
10	23.4
15	15.6
20	11.7
25	9.36

Table 4—Here are the dimensions needed to cut a dipole for WWV time station frequencies. WWV is an excellent source for receiver frequency calibration as well as the correct time. WWV's transmitters can be heard world-wide, 24-hours every day.

Erection of Dipole. Plan your installation according to length, height, and directional orientation. You must consider the space required by the antenna, and where the line must be brought into the house.

Safety and performance are important criteria. For safety reasons, keep the antenna clear of power lines. Be certain that if the antenna falls when erected, or while under erection, it cannot fall across electrical wires. Make certain that under no circumstances, can mast or wire come in contact with power lines if you lose control of the mast or antenna. Keeping clear of power lines also improves the antenna performance. You will pick up less power lines noise on receive. On transmit, you will radiate the least signal into the power

lines, minimizing loss and possible interference with home entertainment units such as television receivers and high-fidelity amplifiers.

Orient the antenna to best meet your needs. If you wish to radiate maximum signal east and west, orient the antenna wire north and south. In a built-up area, it is not always possible to find an ideal mounting situation. However, within reason, it is not necessary that the two antenna ends be the same exact height above ground. Neither must the two quarter-wave segments of the dipole be in an exact line. Stay as close as you can to the idealized situation, but don't worry if you must make limited departures. The antenna will still perform well if you are reasonable in the changes you make.

f(mHz)	SWR
7.005	1.65:1
7.025	1.5:1
7.050	1.35:1
7.075	1.21:1
7.100	1.1:1
7.125	1.08:1
7.150	1.08:1
7.175	1.11:1
7.200	1.2:1
7.225	1.36:1
7.250	1.51:1
7.275	1.75:1
7.295	2.2:1

Table 5—Measuring SWR vs. frequency and plotting the results will help you determine the exact resonant frequency by converting these plot points into a sample graph as in Fig. 5.

Receive Only. The same general considerations must be made in the erection a receive-only antenna, with the exception that power handling capability and transmitter matching are no longer factors of concern. Thus the antenna need not be cut as precisely. The two-wire transmission line can be made of lamp cord or, preferably, a good quality 300-ohm TV ribbon line. A combination of dipole antenna and TV line makes a good combination for short-wave listening on the international broadcast and radio amateur bands. A receiving dipole cut for 35-feet on each segment is a reasonable antenna for all-band listening. However, if you want peak performance on some particular band. Orient this antenna with its figure-eight reaching out in the favored direction.

Tuning With An SWR Meter. An SWR meter connected between transmitter and transmission line, Fig.4, can be used to measure the resonant frequency of a dipole. To go a step further, the antenna can now be trimmed or extended if it does not resonate to the desired frequency. The results can be observed by the SWR Meter, as the antenna resonant frequency is moved up or down the band. Since it is easier to trim off

rather than to add on wire length, cut the initial antenna wire longer than the specified value for the particular frequency, in order to catch up with any variables that might influence resonance. A practical example will demonstrate an acceptable procedure.

Assume an antenna is to be cut for 7150 kHz in the 40 Meter amateur band. Table 1 indicates a dipole length of 32.73 feet. This suggests a dipole length of 32-feet, 9 inches. Cut each dipole element to 33-feet, which would be for a resonant frequency of 7100 kHz. Erect the antenna on a temporary basis.

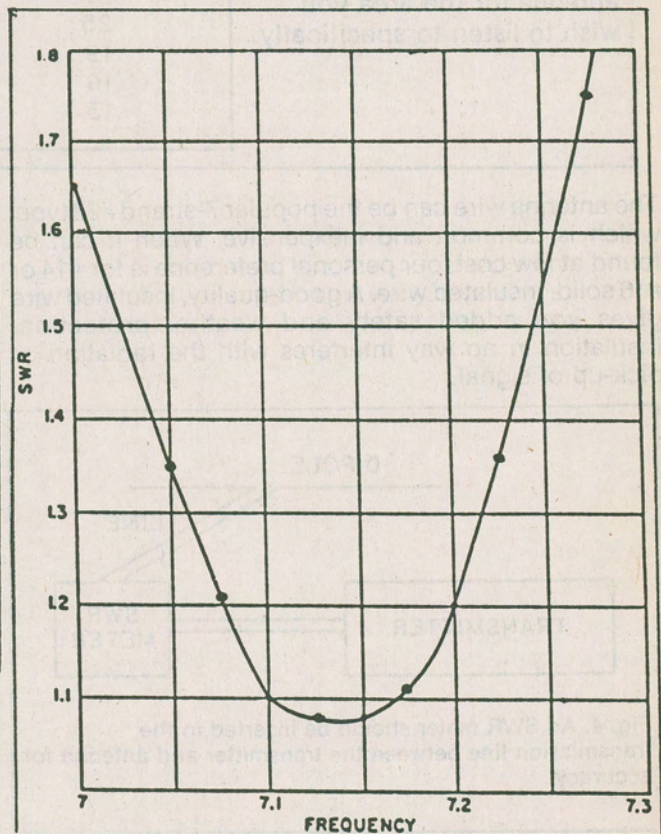


Fig. 5. Plotting the points recorded in Table 5 of measurements made of our experimental dipole for 40 meters pinpoints the antenna's resonant frequency. Even though the curve is rather steep, we manage to achieve an SWR under 2.0:1 for just about the entire band.

Measure the SWR every 25 kHz between 7025 and 7225. Set the readings down in a table form of frequency vs. SWR. Determine the precise frequency at which the SWR reading is minimum. This would be the resonant frequency of the dipole. In our example, it was exactly 7050 kHz.

Inasmuch as the resonant frequency reading is low, you can now trim the antenna to attain the desired resonance. Be careful not to trim off too much. According to Table 1, each trimmed inch corresponds to a frequency change of approximately 20-25 kHz. In our example, we trimmed off six-inches, and increased the resonant frequency to 7141 kHz. If your SWR reading is low, and the resonant indication falls near to 7150, let well enough alone.

The plot of our experimental antenna is shown in Fig. 5. Note that even at the band edges, the SWR reading is

Horizontal Dipole Antenna

reasonable. In the range between 7050 and 7250 kiloHertz, the SWR meter indicated almost ideal performance.

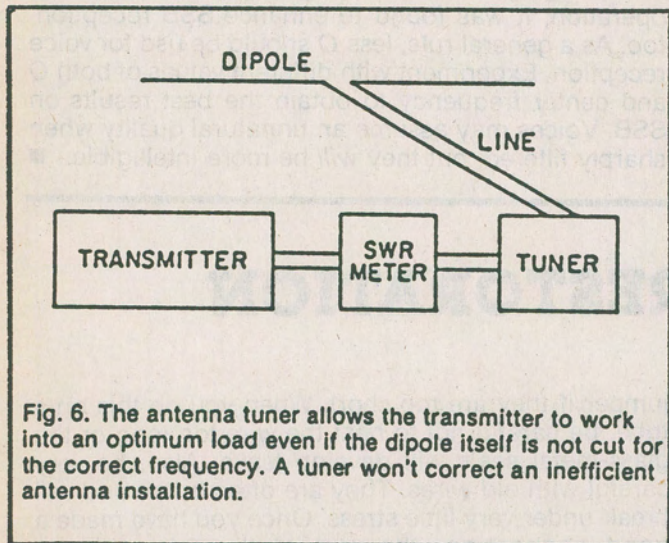


Fig. 6. The antenna tuner allows the transmitter to work into an optimum load even if the dipole itself is not cut for the correct frequency. A tuner won't correct an inefficient antenna installation.

Antenna Tuners at Work. The primary function of an antenna tuner, Fig. 6, is to provide a proper match between your antenna system and transmitter. In so doing, your transmitter sees a proper load and is able to operate at the optimum conditions of its design. The tuner does not alter the performance of the antenna or the SWR on its transmission line. Rather, it makes certain that an improper SWR does not result in unfavorable operation or possible damage to your transmitter. Primarily it is a transmitter protector.

However, a tuner has a number of secondary benefits that enhance antenna system experimentation and permits the use of the antenna systems that are not, in themselves, ideal for matching the standardized 50-ohm output of modern ham radio equipment. Again, it must be stressed that the tuner does not influence the performance of an antenna system. Rather, it acts as an interface between an antenna system and transmitter.

An additional secondary benefit is that it reduces harmonic and spurious signal radiation because it blocks the path between any such signals generated by your transmitter, and the radiating antenna. The tuner also rejects incoming signals that are on frequencies removed from the desired operating band. In effect, it reduces the sensitivity of the receiving system to image and other spurious frequency components.

A tuner makes the dimensioning of a horizontal dipole antenna less critical. It extends the frequency range of operation of the antenna that will provide an ideal match to be transmitter. For example, an 80-Meter dipole cut to 3750 kHz will be made operable over the entire 80 Meter band from 3500-4000 kHz. The electrical performance of the antenna will not differ greatly from an antenna cut precisely to some specific frequency on the band. Even though the SWR on the transmission line be rather high at the band extremes, the transmitter itself will look into an optimum load.

Conclusion. The horizontal dipole is indeed a versatile antenna, giving good performance at low cost. It should be dimensioned properly, and should be used with an SWR meter to evaluate its performance. A tuner insures proper match between dipole antenna system and transmitter, and also extends the operating bandwidth of the dipole in terms of proper matching to the transmitter. Let the dipole start you off in your first experimental activities with antenna systems. ■