43 — 15-40 Conical Vee With Balun

A uniformly lower SWR can be attained by using a balun in association with the conical style antenna (Fig. 57). The balun when used with the basic antenna of topic 42 provides lower and more uniform SWR readings over the two bands.

The presence of the balun has an influence on the resonant points. In general the antenna legs must be cut somewhat longer to establish the same resonant points. With the wideband balun used by the author, it was found that the leg lengths fell very near to the formula values of Chart 5. In fact, on occasion, optimum results were obtained by making leg lengths somewhat longer than calculated values. The leg length of 35′ 8″ was found optimum for two-band operation when the balun was added to the antenna of topic 42.

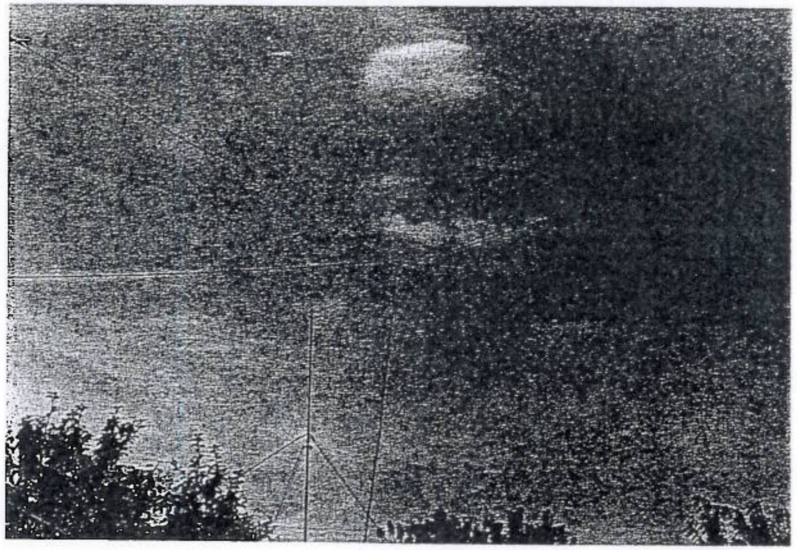


Fig. 58. Conical-vee antenna showing antenna wires, balun, transmission line, and center support mast.

The conical construction is shown in the photograph of Fig. 58. The two pairs of antenna wires connect to the balanced high-impedance side of the balun. A coaxial transmission line links the balun to the transmitter. Plastic clothesline supports the body of the balun and also establishes the proper angle between the two leg pairs. Three masts or high support points are needed. Refer to topics 1, 2, 16, 17, 40, 41, and 42.

44 — Short Horizontal Vee-Beam Antenna

The vee-beam antenna takes advantage of the directional characteristics of a long antenna wire. If two antenna wires are used jointly and have the proper included angle, the radiation lobes combine in such a manner that the antenna displays maximum directivity in a line that bisects the included angle (Fig. 59). To maintain this favorable combining of lobes, there must be a proper angle between legs. The longer the antenna legs are in wavelengths, the smaller is the included angle. Chart 6 relates leg length in odd multiples of a quarter wavelength to the optimum angle.

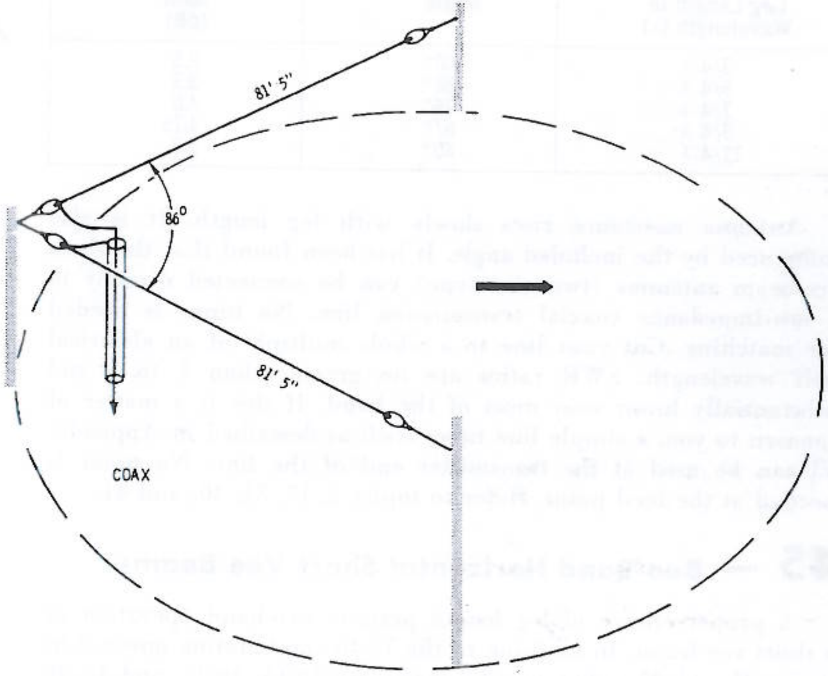


Fig. 59. Short vee beam for 20 meters.

Inasmuch as necessary mounting space, matching, and other considerations differ for a very-long vee antennas and shorter ones, the two basic constructions are covered separately in this book. An antenna with leg lengths shorter than 100′ or 11/4 wavelength, whichever is the shorter, is considered a short horizontal vee beam.

Cutting the legs down 6 percent from the formula values produced resonant points quite near the frequencies substituted in the above equations. Cut your transmission-line length to an even multiple of an electrical half wavelength. Refer to topics 1, 2, 16, and 17.

41 — 15-40 Three-Halves-Wavelength Vee

The frequency relationship between the 15- and 40-meter bands permits two-band operation, as a dipole on 40 and as a 3/2-wavelength antenna on 15 (Fig. 55). A wise choice of leg length permits good two-band operation. Such an antenna has a reasonably omnidirectional pattern on 40 and 15 meters plus a maximum 15-meter directivity in a line that bisects the included angle (Fig. 55).

In the practical antenna the optimum leg length was found to be 32′ 6″, producing a very low SWR on 40 meters and a somewhat higher value on 15, but no greater than 1.5 to 1 at any fre-

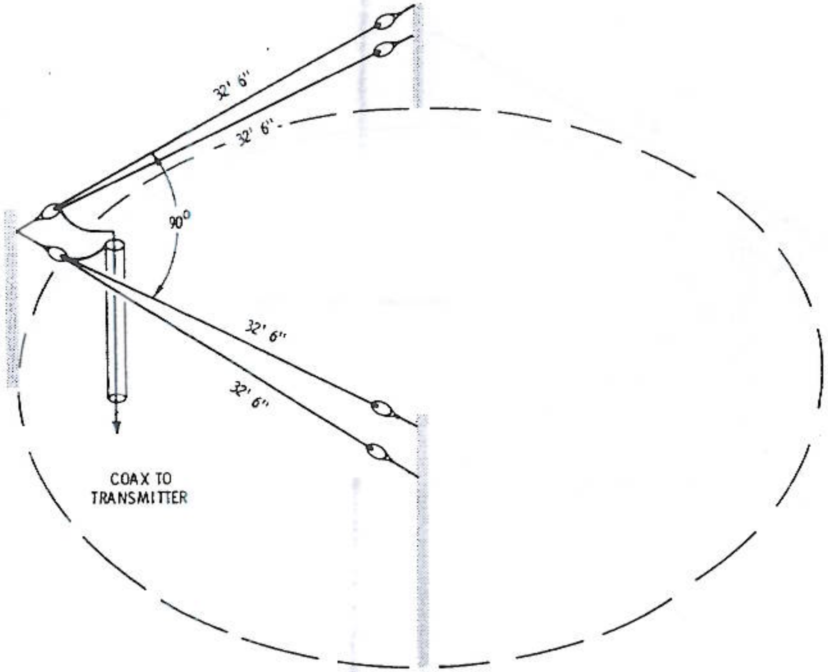


Fig. 56. 15-40 conical vee.

must be the leg length for a given resonant frequency. Leg shortening may only be 2 to 3 percent of the formula values using Chart 5, and in some cases leg length must be very near to the formula values. Refer to topics 1, 2, 17, 40, 41, and 44.

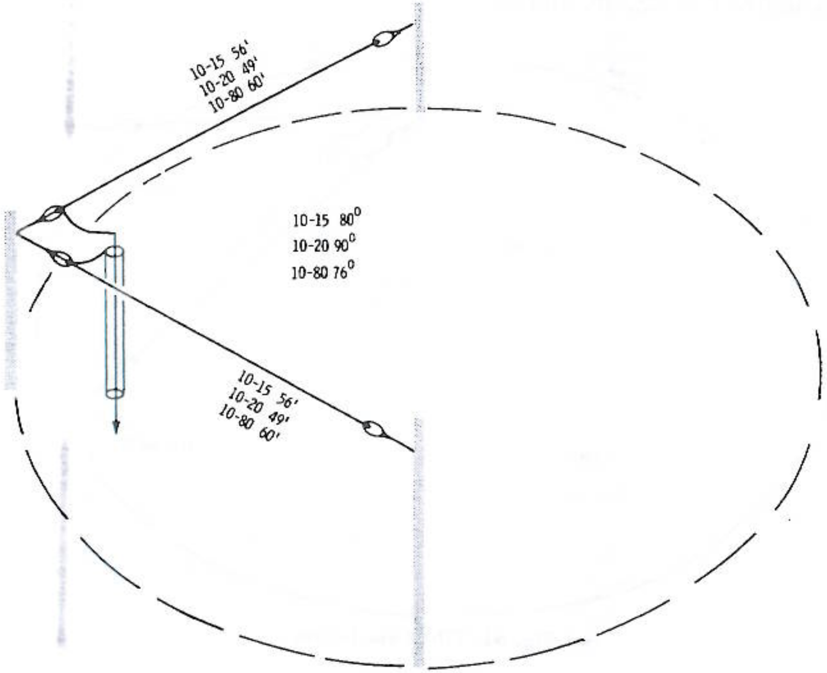


Fig. 60. Duo-band short vee beams.

46 — Tilted Short Vee Beams

The short vee beam has a reasonable omnidirectional characteristic with a maximum directivity in a line that bisects the angle between the two legs. Good low-angle radiation is obtained when a horizontal antenna has a one-wavelength height above ground (heights below 0.5 wavelength give only marginal performance). For low erection, some improvement in low-angle propagation can be obtained by tilting the vee-beam antenna so that the leg ends are below the center feed point (Fig. 61).

A short vee beam used successfully by the author had a feedpoint elevation of 40 feet and leg-end heights of 30 feet. Operation in this manner improved the low-angle DX characteristics of the antenna but harmed the omnidirectional characteristics. Results seemed to indicate that there was no great change in the hori-

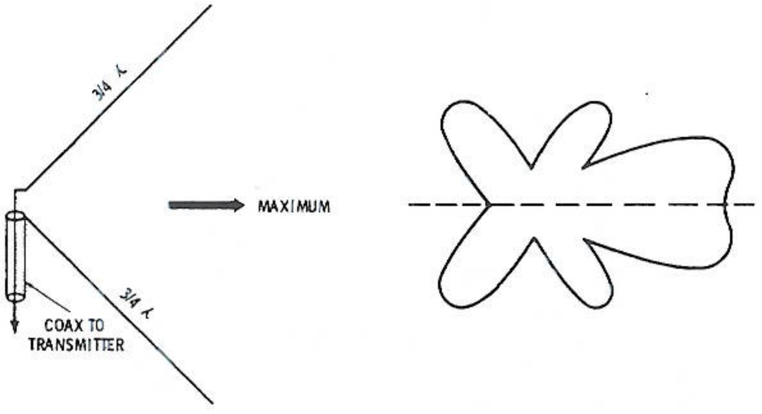
No changes in the physical length of the antenna need be made in changing bands; however, the tuner must be readjusted. Leg lengths correspond to the longest used for the antenna of topic 38 when operated as a 10-, 15-, or 20-meter antenna. The tuner also loads the antenna on 40 meters without requiring any additional length on the feed side or change in overall length of the long leg.

The tuner is adjusted on each band by first using a dummy load to find the transmitter settings that represent optimum operation into 50 ohms. Low power is supplied to the antenna system. The tuner switches and controls are now adjusted for a minimum standing-wave ratio. Proper settings are recorded in a notebook for ease in making band changes. Refer to topics 1, 2, 17, 22, 31, and 38.

40 — Three-Halves-Wavelength Horizontal Vee

The 3/2-wavelength antenna as covered in topic 17 has a low-impedance feed point at the center and 3/4-wavelength legs. Instead of the two lobes of a dipole the 3/2-wavelength antenna has four major and two minor lobes (Fig. 21). This antenna can be made more directive by appropriate forward tilting of the legs (Fig. 54).

When the legs are tilted forward horizontally, the antenna displays a maximum directivity along a line that bisects the



(A) Maximum-radiation direction. (B) Radiation pattern.

Fig. 54. Basic 3/4-wavelength vee.

band coverage of South America, and at the same time good stateside results would be possible. Refer to topics 1, 2, 7, 40, 44, and 45.

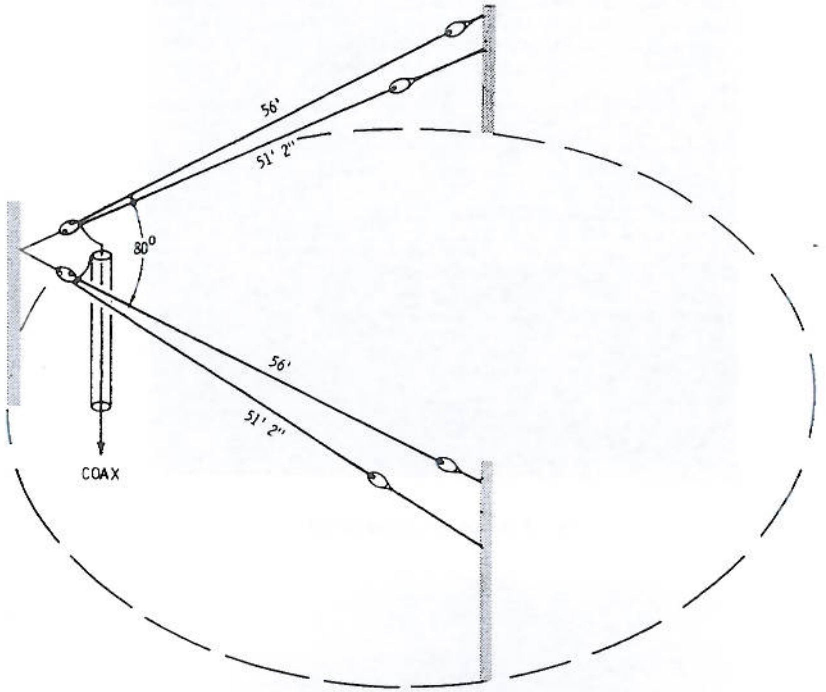


Fig. 62. 10-15-20 short vee beam.

48 — 10-15-20-40 One-Hundred Footer

In this antenna book we have arbitrarily selected 100 feet as the maximum length for a short vee beam. In fact, this easy-to-remember dimension is a good compromise value for 15- and 40-meter operation. On 40 meters, each leg is 3/4 wavelength long, while for 15-meter operation, the electrical length is 9/4 wavelengths long. On 15 meters the antenna resistance remains low enough to permit direct connection to a coaxial line (Fig. 64).

Formula values are:

$$(40)\ \text{Leg length} = \frac{738}{7.2} = 102.5\ \text{feet}$$

$$(15)\ \text{Leg length} = \frac{2214}{21.3} = 104\ \text{feet}$$

$$(20)\ \textbf{Long-leg length} = \frac{2706}{14.2} = 190'\,6''$$

$$(15)\ \textbf{Long-leg length} = \frac{4182}{21.35} = 195'$$

$$(10)\ \textbf{Long-leg length} = \frac{5658}{28.6} = 197'\,8''$$

Short-leg lengths can be cut using the values (Chart 1) of 16′ 6″, 11′, and 8′ 2″ for 20, 15, and 10 meters respectively.

Practical dimensions as constructed by the author are given in Fig. 51. By proper trimming of the long leg a very minimum standing-wave ratio can be obtained on a given frequency or operating segment of each band. However, the antenna is relatively noncritical as to the precise leg length once the overall length is brought reasonably near to a given band. Operation on 10 and 15 meters is possible with the same length for the long leg. Preferred transmission-line length is a whole multiple of an electrical half wavelength (multiple of 45′ 6″).

Operation on 40 meters requires some additional length on the feed end of the antenna (Fig. 52). Some length must be removed

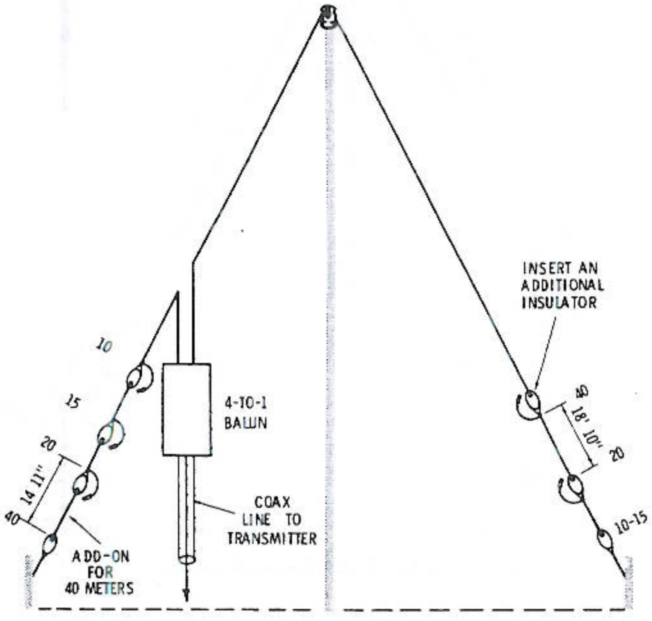


Fig. 52. Adding 40 meters to antenna of Fig. 51.

The practical compromise value is 100 feet. Suitable apex angles fall between 67 and 75 degrees.

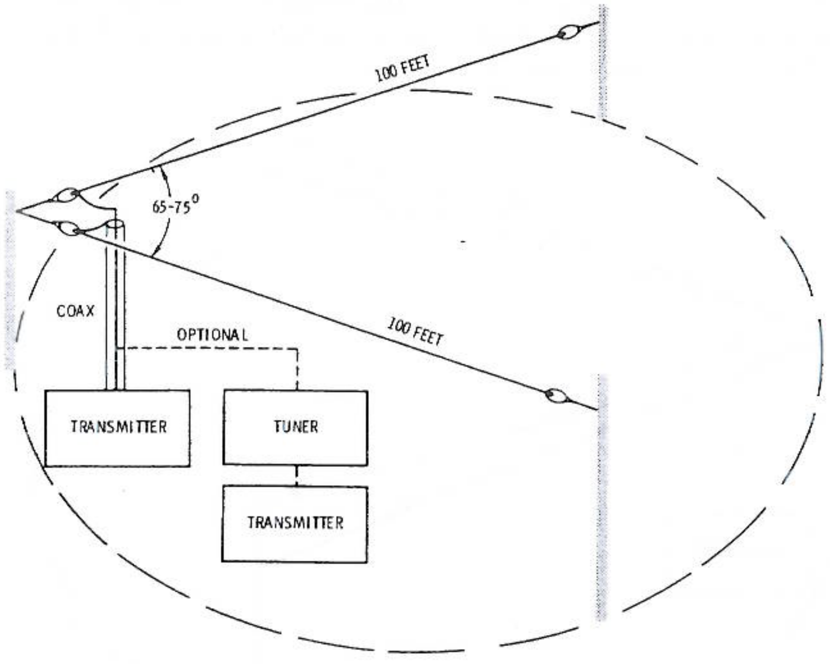


Fig. 64. Multiband 100-footer.

This short vee-beam antenna also functions on 10 and 20 meters. If a coaxial transmission line is cut rather carefully to a length that is a whole multiple of an electrical half wavelength on 10 meters, the SWR is low in the active sideband sections of the 10-, 15-, and 40-meter bands. Lower SWR ratings for 10- and 20-meter operation can be obtained with the use of the simple tuner described in Appendix VI. Refer to topics 1, 2, 7, 31, 35, 44, 45, and 48.

49 — 10-15-20-40 Short Vee Beam

Two pairs of vee-beam wires joined together at the feed point and spanning out to a separation of ten feet at the far end can provide multiband operation without the need for a tuner. This can be accomplished by cutting the two pairs of vee wires with differing lengths as shown in Fig. 65. The 100-foot vee provides

Coaxial-line feed can be used. However, the lowest possible standing-wave ratios are obtained over a greater span of frequencies when a 4-to-1 balun is employed.

When a long-wire vee antenna is end-fed, there is maximum radiation off the ends (Fig. 49). The longer the antenna is, the higher is its gain, the greater is its directivity parallel to the wires, and the greater is the relative radiation off the long-leg end as compared to the short-leg side. This type antenna combines the features of the single long-wire resonant antenna and the long-wire inverted-vee antenna (topics 22 and 33). In this case both the feed point and the leg ends are near ground level. Quite often it is possible to locate the feed end of this antenna very near the transmitter and only a very short length of transmission line is needed.

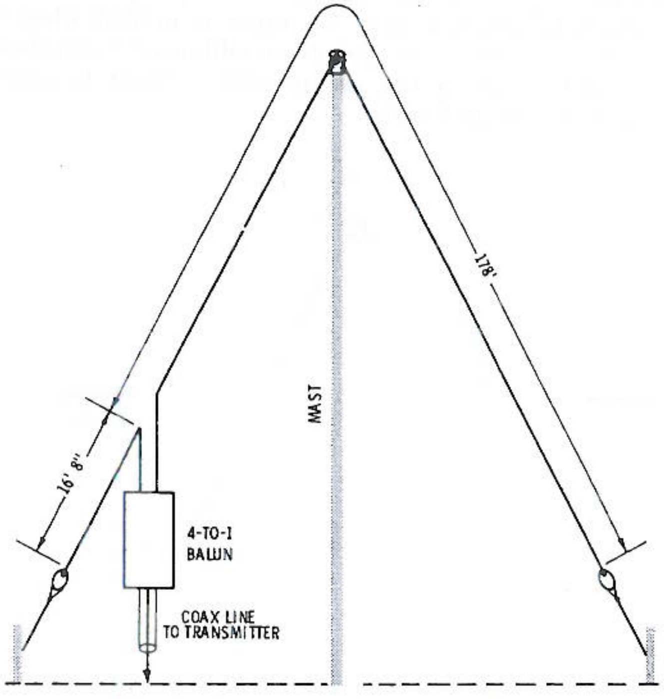


Fig. 50. Twenty-meter inverted-vee beam.

An example for 20 meter operation is given in Fig. 50. The long leg has been trimmed down from the calculated value for 11/4 wavelength:

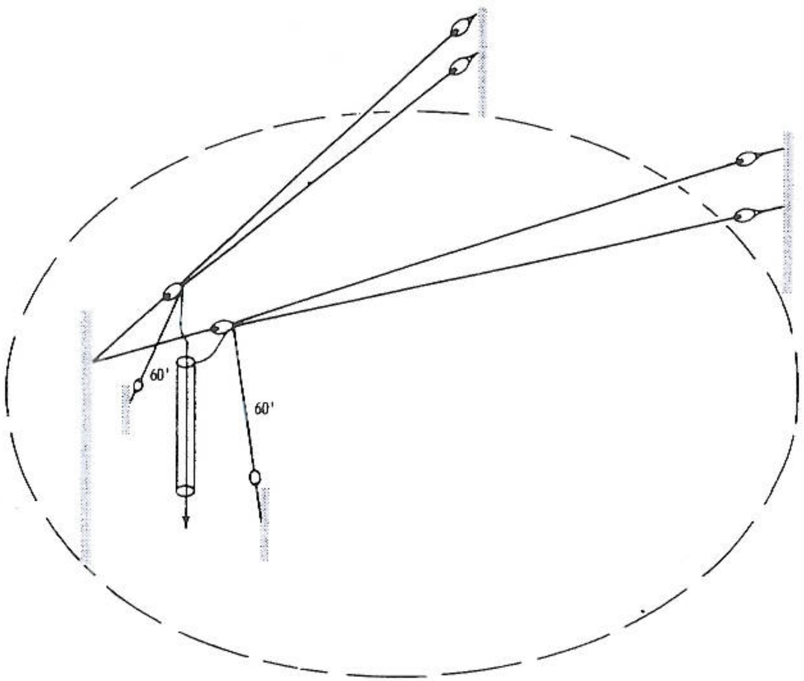


Fig. 66. Short vee-beam antenna of Fig. 65 with an attached 80-meter inverted dipole.

SECTION 5

Long Vee-Beam Antennas

51 — Long Horizontal Vee-Beam Antenna

In this book, the long horizontal vee-beam antenna is considered to have a leg length in excess of 100 feet, or three-quarters of a wavelength, whichever is the longer. As compared to the short vee beam there is a higher gain and a smaller angle between the two vee wires. Maximum radiation is again along the bisector line of the two wires. Orientation of a maximum lobe along this bisector line requires a proper angle as related to leg length. Chart 7 lists required angles and gain values as related to leg lengths.

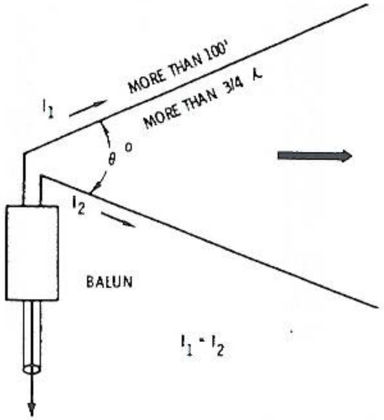


Fig. 67. The basic long vee-beam antenna.

A matching balun is recommended for the long vee beams. Ratios of 2 to 1 or 4 to 1 are suitable (Fig. 67). The unbalanced-to-balanced (balun) coils ensure equal currents in the two leg wires. This is an important consideration for the long vee beams if the maximum lobe is to be aligned precisely along the bisector direction. It is less of a consideration for the short vee beam because of the inherent broadness of the maximum lobe.

An example demonstrates the planning process. Assume that a 10-meter vee beam is to be erected with a possible gain of 10.7 dB. From Chart 7 the leg length is 39/4 wavelengths and the

80 meters, this becomes a half wavelength on 40 meters, and it will reflect a maximum impedance to the tuner.

Line tuners can of course be employed with a variety of antennas cut for single-band or multiband operation. The tuner permits such an antenna to be loaded as a random-wire type on other bands. Remember that random-wire loading means that the transmission line also becomes a part of the radiating system. In most instances the loading involves the inner conductor of the coaxial transmission line and whatever antenna wire is attached to this inner conductor. Thus, in determining the random-wire loading of another antenna type, the total radiating length is based on the total length of the transmission line and the active antenna leg. Refer to topics 1, 2, 17, 31, 32, 33, and 34.

36 — Resonant Antenna Plus Random-Wire Loading

The antenna of Fig. 46 can be used as an example of resonant antenna plus random-wire loading. Such an antenna loads readily on both 80 and 160 meters as a random-wire model with the antenna set for 20-meter operation (Fig. 48). Furthermore, it loads on 10 and 15 meters without requiring any jumper change. Even though the tuner is active, the antenna loads in normal fashion on 20 meters. On 80 and 160 meters, it loads as a random wire, with the inner conductor of the transmission line becoming part of the antenna. On 10, 15, and 40 meters the long leg is active, and there is some radiation from both the line and the short antenna leg. If you prefer to keep the SWR at a minimum on the transmission line, you can jump in the appropriate leg segments for each band.

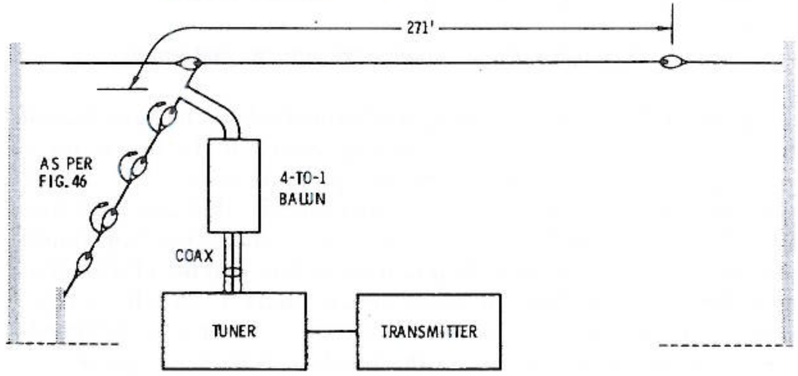


Fig. 48. Combination long-wire antenna and random-wire antenna with line tuner.

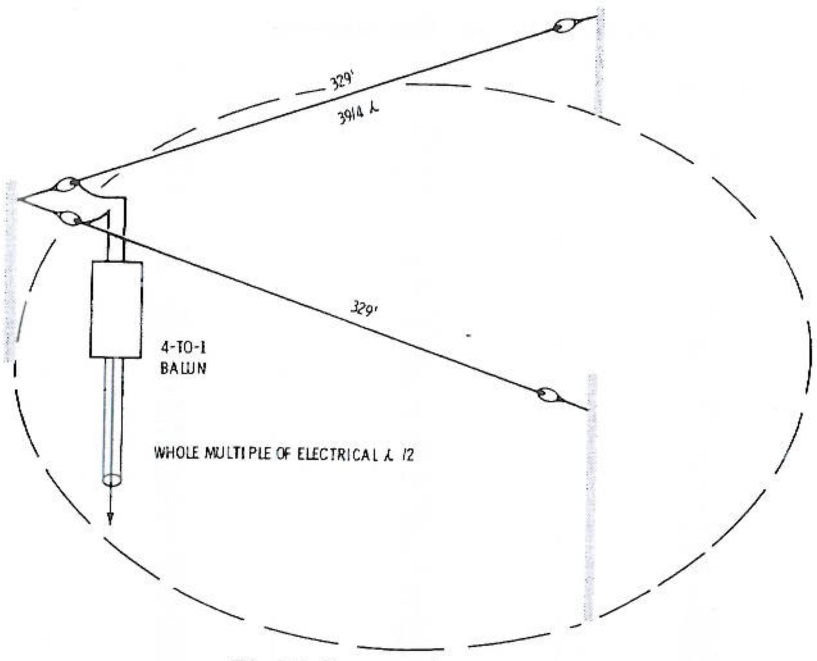
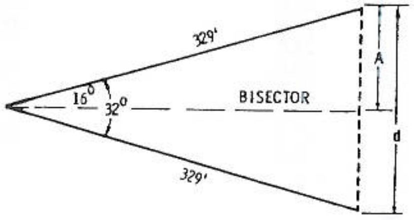


Fig. 68. Ten-meter long vee beam.

Fig. 69. Vee-beam angles and sides.



As in the case of the short vee beam, the lower the frequency of operation is, the longer the leg length must be, and the greater the erection space per a given gain. Antenna height too is a consideration and should be no less than one-half wavelength above ground. This means that for a 20-meter operation the vee-beam height should be no lower than 35 feet (approximately 0.5 wavelength), while the best low-angle results are obtained by using a 70-foot height (approximately one wavelength above ground).

Long-wire antennas are subject to precipitation static and static charges during driving rain or snow, and should be disconnected from equipment. Capability for complete disconnect and grounding is essential during thunderstorms. Refer to topics 1, 2, 17, and 44.

The length of the short leg can be calculated using the regular dipole equation. The long leg must be made some multiple of a quarter wavelength.

$$\text{Long leg} = \frac{246 \times n}{f\text{MHz}} \text{ feet}$$

$$\text{Short leg} = \frac{234}{f\text{MHz}} \text{ feet}$$

where,

n equals the number of quarter wavelengths.

The antenna legs must be trimmed carefully to find resonance and establish a feed-point impedance that can match the transmission-line system. Short sections should be trimmed off the quarter-wave segment to obtain resonance just as you trim an ordinary dipole. Because the long leg is so very long, it is possible to trim off larger pieces of the antenna wire in moving toward the desired resonant point.

For DXing the long-wire can be tilted slightly in the direction of the long leg (as shown in Fig. 45) to improve the low-angle radiation in the favored direction.

The arrangement and dimensions of a practical antenna are given in Fig. 46. The quarter-wave dipole segments are easy to set up and permit 10- through 40-meter operation. For 10-meters the first jumper is left open. For 15-meter operation, the first jumper is closed and the second jumper is opened. Twenty meter operation has the first two jumpers closed and the third jumper opened. For 40-meter operation, all jumpers are connected.

The long leg of the antenna is 9/4 wavelengths long on 40, 17/4 on 20, 25/4 on 15, and 33/4 on 10. Formula values are as follows:

$$(40)\ \text{Leg length} = \frac{2214}{7.2} = 307 \text{ feet}$$

$$(20)\ \text{Leg length} = \frac{4182}{14.2} = 294 \text{ feet}$$

$$(15)\ \text{Leg length} = \frac{6150}{21.3} = 288 \text{ feet}$$

$$(10)\ \text{Leg length} = \frac{8118}{28.6} = 283 \text{ feet}$$

After trimming, the practical lengths reduce to 297′ 7″, 271′, and 272′ 10″ respectively. Note that the same leg length can be

---

Note how closely this corresponds to the physical length for 10-meter operation in topic 51. Hence the practical leg length of 329 feet permits two-band operation. The recommended angle for the 15-meter cut is 37°. In the practical case a compromise angle of 34° was employed.

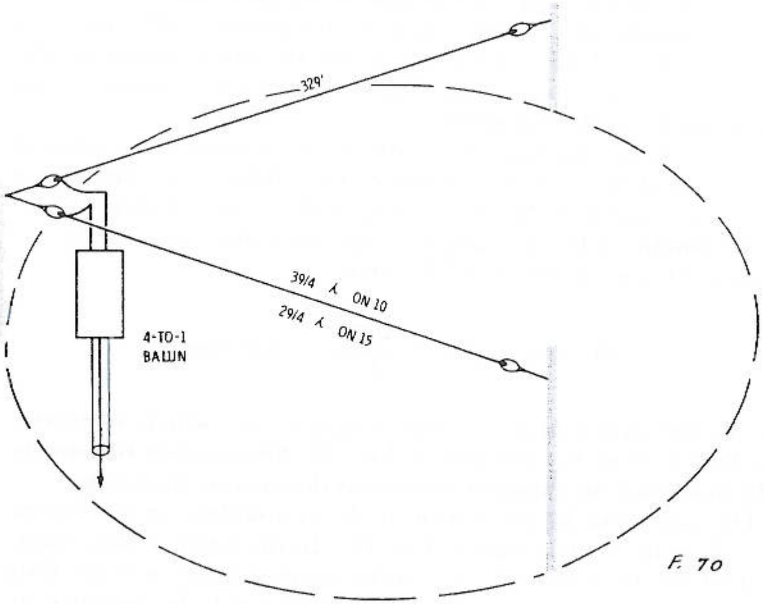


Fig. 70. Two-band long vee beam.

The separation between the leg ends is:

$$d = 2A = 2(329 \times 0.292) = 192 \text{ feet}$$

An attractive formula length for 15- and 20-meter operation is based on 31/4 for 15 meters and 21/4 for 20 meters.

$$(15)\ \text{Leg length} = \frac{7626}{21.3} = 358 \text{ feet}$$

$$(20)\ \text{Leg length} = \frac{5166}{14.3} = 361 \text{ feet}$$

Cut your leg wires 2 percent shorter than 360 feet and trim back to obtain desired resonances. Use a compromise angle of 38°. Refer to topics 1, 2, 17, 44, 45, and 51.

be trimmed carefully to establish resonance and to have the wave-distribution position a low-impedance at the feed point. Each leg should be made an odd multiple of a quarter wavelength long.

Note that the antenna of Fig. 44A is identical to that of Fig. 43. However it is end-fed rather than center-fed. In so doing, it becomes a single-band 15-meter antenna rather than a 10-15 combination. It is more directional (in the direction of the long leg) and, if one end is located near the transmitter, only a short length of transmission line is needed.

A 20-meter end-fed long-wire antenna is shown in Fig. 45. The long leg of the antenna has an electrical length of four and one-quarter wavelengths (17/4). Using Chart 5 this would calculate as:

$$\textbf{Long-leg length} = 4182/14.2 = 294'$$

$$\textbf{Short-leg length} = 234/14.2 = 16'\,5''$$

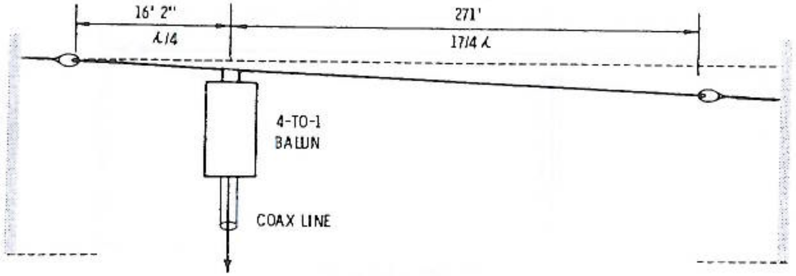
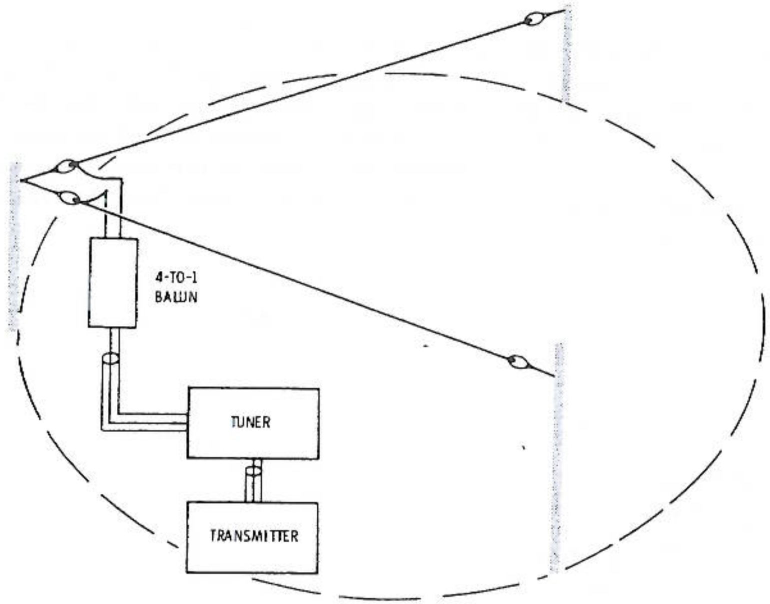


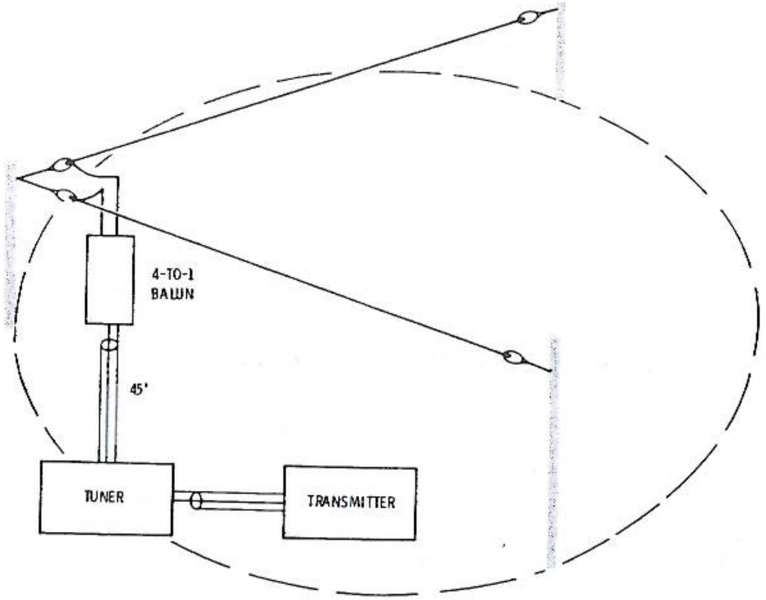
Fig. 45. Twenty-meter long-wire antenna with tilt.

As shown in Fig. 45 physical leg lengths are somewhat shorter. The best plan for determining leg lengths is to first cut them according to formula and then trim back slowly to find exact resonance. When close to resonance, the short leg should be trimmed inch by inch. Because the long leg is of much greater length, more wire must be trimmed off to produce the same change in resonant frequency. In trimming the antenna of Fig. 45 the long leg was cut back one foot at a time until resonance dropped into the band and then cut in 6-inch steps.

For effective low-angle radiation, the height of a horizontal antenna should be a half wavelength on the operating band. In recent years good results have been obtained by tilting long-wire antennas slightly in the direction of maximum propagation to obtain more favorable low-angle emission when the antenna height



(A) Tuner at the transmitter.



(B) Tuner at base of mast.

Fig. 71. Use of line tuner with vee-beam antenna.

selves nearer to the direction of the antenna wire as compared to the short-side lobes (Fig. 41B).

Some theoretical horizontal patterns are given in Fig. 42 for various long-wire electrical wavelengths. Note the increase in the number of lobes and end directivity as length is increased. In using such an antenna at practical heights above ground, the nulls are less sharp, and the pattern tends to fill in so that more uniform radiation results.

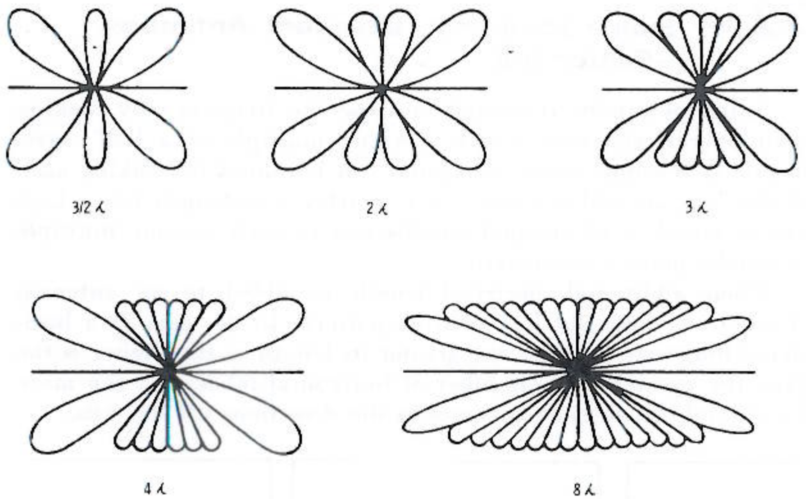


Fig. 42. Influence of long-wire length on horizontal pattern.

A practical long-wire antenna is shown in Fig. 43. Its dimensions are attractive because they permit 10- and 15-meter operation. Lengths are such that the antenna operates as a 2.5-wavelengths radiator on 15 and 3.5 wavelengths on 10. In the practical version, resonant frequencies were found to be 21.32 MHz on 15, and 28.4

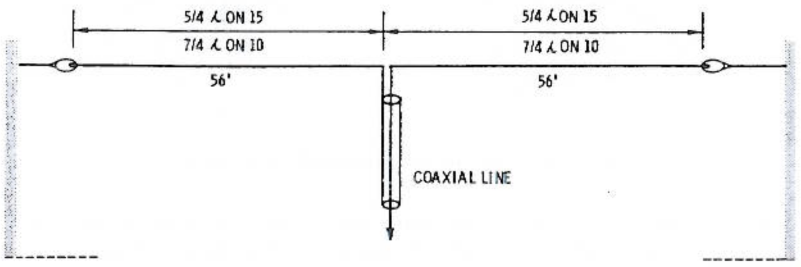


Fig. 43. Long-wire center-fed antenna for 10 and 15 meters.

Dimensions are given for the 10- and 15-meter two-band antenna of topic 52. Note that the ends of the two vee wires can be kept at a desired height above ground by using an appropriate length of plastic clothesline (nonmetallic core) between the insulator and the fence posts. Slope angles of 5° to 10° are employed. Refer to topics 1, 2, 17, 44, 51, and 52.

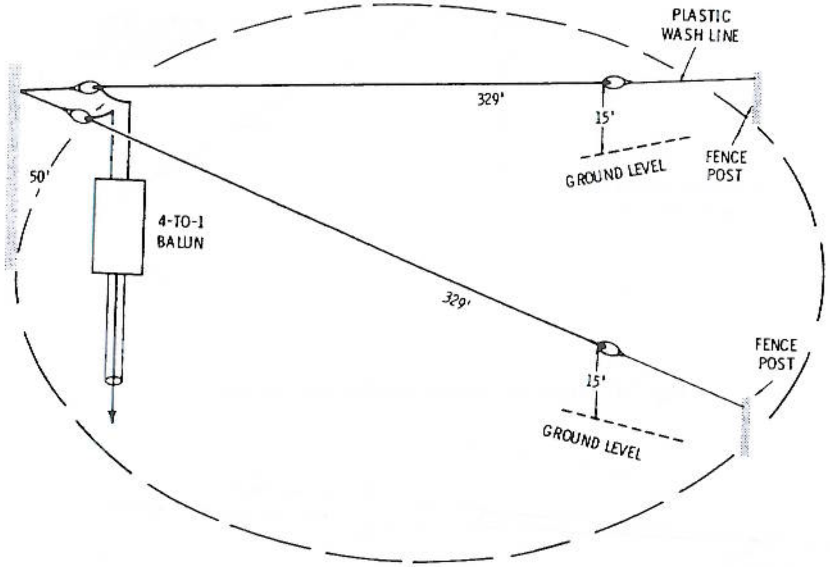


Fig. 73. Sloping vee-beam antenna.

56 — 10-15-20 Sloping Vee Beam

Space permitting, the long vee beam is a fine DX antenna. A single antenna can provide optimum operation on the three popular DX bands. Furthermore, this operation can be accomplished without the use of a tuner, which is a definite inconvenience in changing frequency of operation and bands. You can use one of two approaches in obtaining three-band facility.

If only a single pair of antenna wires is to be employed, these can be end-tuned as shown in Fig. 74. Dimensions for 10- and 15-meter operation are the same as those given in Fig. 70. Formula length for 20-meter operation as a 19/4-wavelength antenna is:

$$(20)\ \text{Leg length} = \frac{4674}{14.25} = 328\ \text{feet}$$

Practical length was found to be 322 feet. Optimum angle for

$$d = 2A = 2(\sin 23^\circ \times 322) = 252 \text{ feet}$$

Four separate fence posts can be driven into the ground at appropriate distances. The inner two are used for 10- and 15-meter operation with the insulator jumpers closed. For 20-meter operation, the two antenna wire's ends are connected to the outer posts, and the jumpers are operated in the open position. Don't forget that additional posts in other positions permit you to orient the vee beam in other directions.

An alternative plan using two pairs of wire is shown in Fig. 75. This arrangement provides sideband operation on three bands without any antenna changes and without the use of a tuner.

Three band c-w operation is possible by making appropriate adjustments in the leg length using the equations of this topic and topics 51 and 52. Refer to topics 1, 2, 17, 44, 45, 51, 52, and 55.

on one segment of that band, and multiband operation of an antenna is feasible without making any antenna changes when switching bands. Tuner adjustments must be made but this is done right at the operating position. The use of a line tuner is not a cure-all, but it does offer transmitter protection and contributes some convenience and versatility. Refer to Appendix VI.

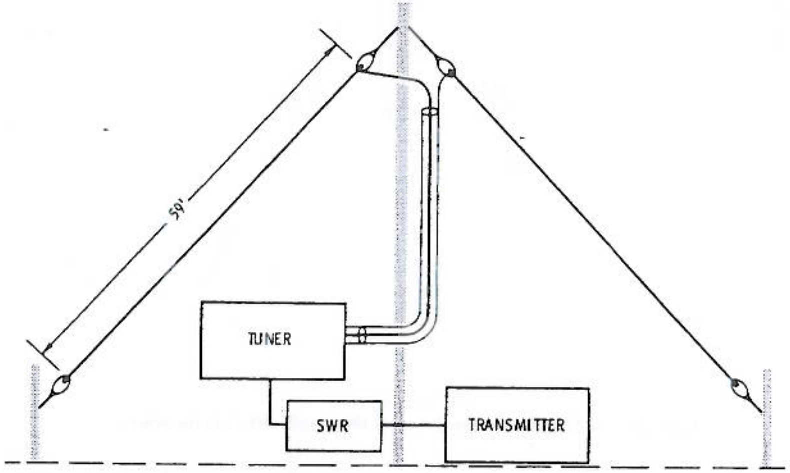


Fig. 40. 10-15-20 long-wire inverted vee, line-tuned.

The inverted-vee antenna of Fig. 40 is adaptable to the use of a simple line tuner. This is a version of the inverted-vee antenna discussed in detail in topic 25. The antenna has been cut to its longest dimension of 59 feet. The tuner discussed in Appendix VI when used with this antenna permits low-SWR operation on 10, 15, and 20 meters without making any antenna changes. Standing-wave ratios of less than 1.3 to 1 are attainable over the entire three bands. The antenna also loads well on both 40 and 80 meters with standing-wave ratios of less than 1.5 to 1.

If space is available, leg lengths can be increased. For example a leg length of 77.5 feet will load well on 10, 15, and 20 meters (leg lengths approximate 9/4, 7/4, and 5/4 wavelengths respectively). The antenna will also load on 40 and 80 meters using the line tuner of Appendix VI. Commercial match boxes can be employed with this style of antenna. Refer to topics 1, 2, 9, 17, 22, and 25.

SECTION 6

Rhombic Antennas

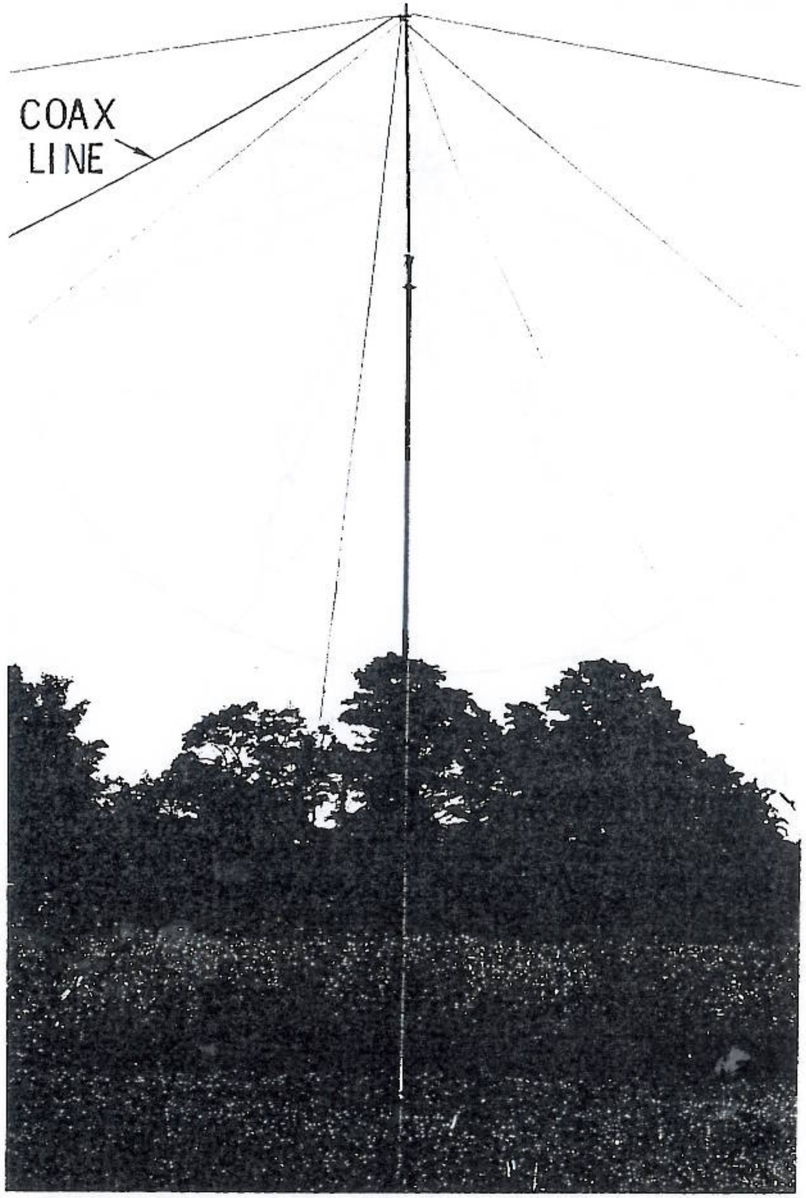


Fig. 38. W3FQJ inverted-vee sidebander.

57 — 10-15 Rhombic Antenna

A rhombic is a diamond-shaped long-wire antenna (Fig. 76). For a given length of antenna wire it has a gain approximately 3 dB higher than a long vee-beam antenna. The space requirements are longer and narrower than are needed for the vee antenna. An additional support mast is required by the rhombic.

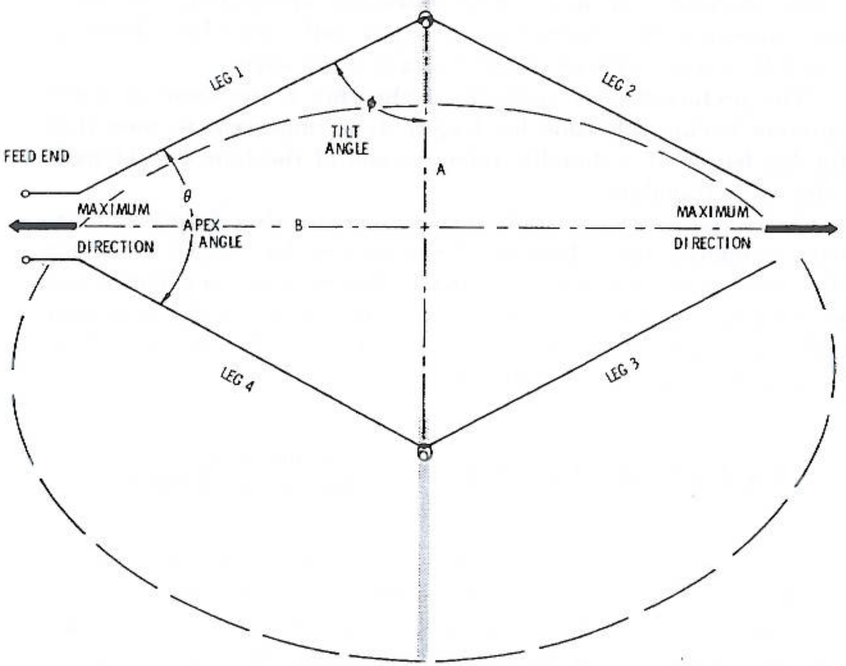


Fig. 76. Resonant rhombic.

Chart 9 relates the antenna leg length to the apex angle and gain. In discussing rhombic antennas the term tilt angle is often used rather than apex angle. These two angles are shown clearly

29 — 10-15-20 and 20-40-80 Inverted-Vee Trios

This is a three-section antenna that permits three-band operation without requiring any antenna changes. Operation can be selected on the basis of the triples 10-15-20 or 20-40-80. Two other triples can be selected if desired. These are 10-20-40 or 15-20-80. The antenna is a combination of the 20-40-80 inverted dipoles of topic 14 and long-wire inverted vees. Any of the three-band trios listed can be set up using appropriate jumpers. No changes need be made when switching among the three selected bands.

The antenna operates as inverted dipoles on 40 and 80, three-halves wavelength antennas on 15 and 20, and a nine-halves wavelength antenna on 10 meters. Preferred lengths of transmission line are multiples of 45 feet for phone operation and 46 feet for cw.

Calculations for phone-band operation are as follows:

$$\text{(80) Dipole length} = \frac{234}{3.9} = 60'$$

$$\text{(40) Dipole length} = \frac{234}{7.25} = 32'\,3\tfrac{1}{2}''$$

$$\text{(20) 3/4-wave leg length} = \frac{738}{14.25} = 51'\,9''$$

$$\text{(15) 3/4-wave leg length} = \frac{738}{21.3} = 34'\,6''$$

$$\text{(10) 9/4-wave leg length} = \frac{1722}{28.6} = 60'\,4''$$

Actual dimensions for a practical version are shown in Fig. 37. Of course, frequencies can be selected and legs cut to meet your needs. Refer to topics 1, 2, 9, 13, 14, 17, and 22.

30 — W3FQJ Inverted-Vee 6-Through-80 Sidebander

In maintaining multiband schedules, net activities, participating in multiband sideband contests, and for general all-band operation, it is convenient to have a good single antenna that requires no changes when changing bands. Such an antenna can be constructed using the principles of the inverted dipoles and the long-wire

Chart 9. Rhombic Data Chart

Leg Length in λ	Side Lengths in λ	$L_1 + L_2$ and $L_3 + L_4$	Apex Angle θ	Gain dB
1.125	9/4	2214/f	104°	5.2
1.375	11/4	2706/f	94°	6.5
1.625	13/4	3198/f	86°	7.2
1.875	15/4	3690/f	80°	7.8
2.125	17/4	4182/f	74°	8.3
2.375	19/4	4674/f	70°	8.8
2.625	21/4	5166/f	67°	9.2
2.875	23/4	5658/f	64°	9.6
3.125	25/4	6150/f	61°	10.0
3.375	27/4	6642/f	58°	10.3
3.625	29/4	7134/f	56°	10.6
3.875	31/4	7626/f	54°	10.9
4.125	33/4	8118/f	52°	11.2
4.375	35/4	8610/f	50°	11.4
4.625	37/4	9102/f	49°	11.6
4.875	39/4	9594/f	48°	11.8
5.125	41/4	10086/f	47°	12.0
5.375	43/4	10578/f	46.5°	12.1
5.625	45/4	11070/f	46°	12.2
5.875	47/4	11562/f	45.5°	12.3
6.125	49/4	12054/f	45°	12.35
6.375	51/4	12546/f	44.5°	12.4
6.625	53/4	13038/f	44°	12.45
6.875	55/4	13530/f	43.5°	12.5

The resonant rhombic has a bidirectional pattern (Fig. 76) with maximum lobes in a line bisecting the apex angle. A rhombic can be made unidirectional with a proper termination.

A practical 10- and 15-meter rhombic is shown in Fig. 77. Total side lengths corresponding to 39/4 wavelengths on 10 and 29/4 wavelengths on 15 are approximately the same:

$$\text{(10) Side length} = \frac{9594}{28.6} \cong 335 \text{ feet}$$

$$\text{(15) Side length} = \frac{7134}{21.3} \cong 335 \text{ feet}$$

Each rhombic leg is one-half of this value or 167.5 feet. Approximate leg lengths on 10 and 15 are 5 and 3.5 wavelengths respectively. Preferred apex angles for 0° wave angle would be 48° and 56° respectively. A compromise angle of 50° is satisfactory.

The practical resonant lengths for the rhombic erected by the author are given in Fig. 77. Rhombic antenna height was 48 feet.

The inverted-vee construction, because the leg ends are near ground potential, can be adjusted to ensure top performance on each band. The inverted-vee dipole of Fig. 35 is cut precisely to the center of the 40-meter novice band. Calculated dimensions from topic 4 are 32′ 8″. The length of a three-quarter wavelength leg for 15-meter operation is slightly longer if ideal operation is desired:

$$(15)\ \text{Leg length} = \frac{738}{21.175} = 34'\,10''$$

It is very easy to add this additional leg length of approximately 2′ 2″ when changing over from 40- to 15-meter operation. Practical lengths (Fig. 35), are somewhat shorter as a function of height above ground.

Chart 2 can be used to calculate coaxial line lengths that are favorable for two-band operation. Half wavelengths of regular 72-ohm coaxial line are:

$$(40)\ \text{Half-wave line length} = \frac{325}{7.175} = 45'\,4''$$

$$(15)\ \text{Half-wave line length} = \frac{325}{21.175} = 15'\,4''$$

For a span of somewhat less than 100 feet, an optimum line length would be about 91′ 6″ (45′ 4″ × 2 and 15′ 4″ × 6). Refer to topics 1, 2, 4, 9, 10, 17, 22, and 25.

28 — 15-40-80 Novice Inverted Vee

The three novice bands are so situated frequency-wise that they do not lend themselves to the use of a single antenna for three-band operation when optimum performance is to be obtained on each channel. The exception is the inverted-vee which can be band-changed conveniently because its leg ends can be made readily accessible from the ground.

The inverted-vee antenna of Fig. 36 consists of segmented 40- and 80-meter inverted dipoles and a 15-meter long-wire inverted vee with three-quarter-wavelength legs. Only a single mast is needed (25 to 50 feet) and a single transmission line feeds from the transmitter to the center connection point at the top of the apex. Two metal fence posts can be the tie points for the leg ends. It should be possible to release these leg ends for convenient band changes.

47°; a compromise apex angle of 45° is appropriate. Space requirements increase as follow:

$$d_1 = 2(\sin 22.5^\circ \times 236.5) \cong 182'$$

$$d_2 = 2(\cos 22.5^\circ \times 236.5) \cong 440'$$

A 4-to-1 balun is used and the length of the coaxial transmission line to the transmitter is made an odd multiple of an electrical half wavelength. Refer to topics 1, 2, and 52.

58 — 10-15-20 Rhombic With Line Tuner

A line tuner (as per Appendix VI) in conjunction with a rhombic can bring the SWR down to a very low value over an entire band (c-w and phone portions). Furthermore, the antenna can be operated on lower-frequency bands as well.

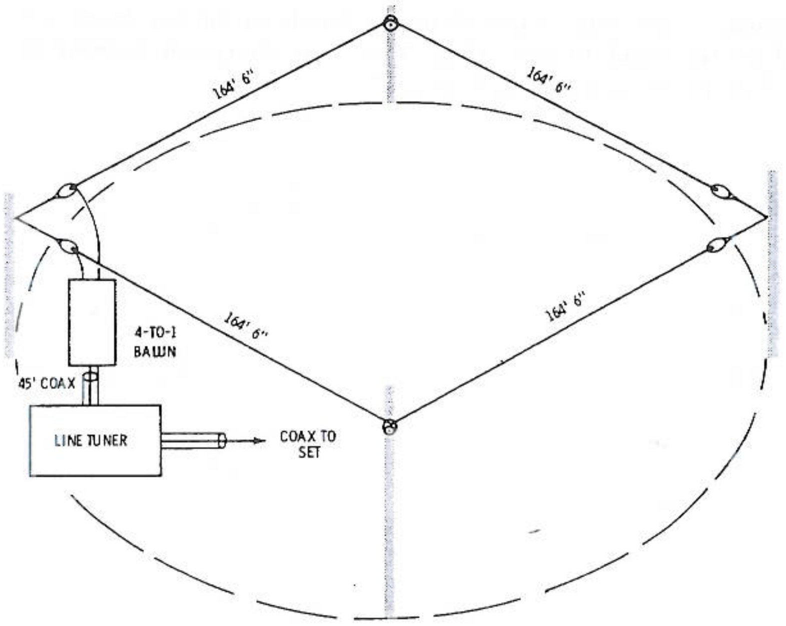


Fig. 78. Rhombic antenna with line tuner.

For example, the antenna of Fig. 77 operates well without a tuner over the sideband segments of the 10- and 15-meter bands. The use of a line tuner permits optimum matching to a trans-

160-meter operation is feasible without requiring any additional space by folding the legs back toward the mast (Fig. 34). This return span to the mast can be made at a height above ground of about 6.5 feet. This keeps all band-changing positions within easy reach.

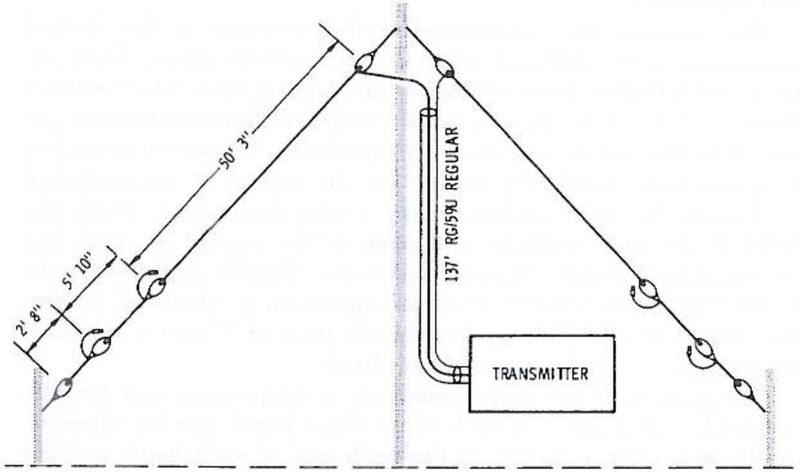


Fig. 33. 10-15-20 sideband long-wire inverted vee.

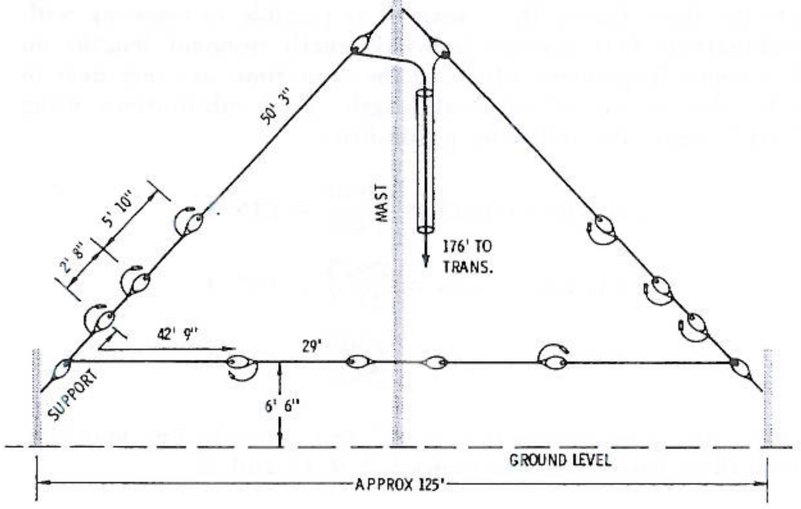


Fig. 34. 6-160 meter inverted dipole and long-wire inverted-vee system.

Adding a length of some 40 feet provides an overall leg length several inches more than 101 feet—the dimension for obtaining

59 — 10-15-20-40 End-Tuned Rhombic

The rhombic antenna, like the other long-wire types, can be end-tuned using insulators and associated jumpers (Fig. 79). Such multiband operation can be accomplished without the use of a tuner. The basis for the antenna is the 10-15 rhombic of topic 57. Operation on 20 meters is accomplished by using somewhat shorter sides. Formula length for 20-meter operation as a 19/4-wavelength antenna is:

$$(20)\ \text{Side length} = \frac{4674}{14.25} = 328\ \text{feet}$$

Practical length was found to be 322 feet. The compromise apex angle used is also satisfactory for 20-meter operation. The band-change point is made accessible by bringing the end points down close to ground level as shown in Fig. 79 .

For 40-meter operation an attractive formula value for total side length corresponds to 11/4 wavelengths:

$$(40)\ \text{Side length} = \frac{2706}{7.25} = 373\ \text{feet}$$

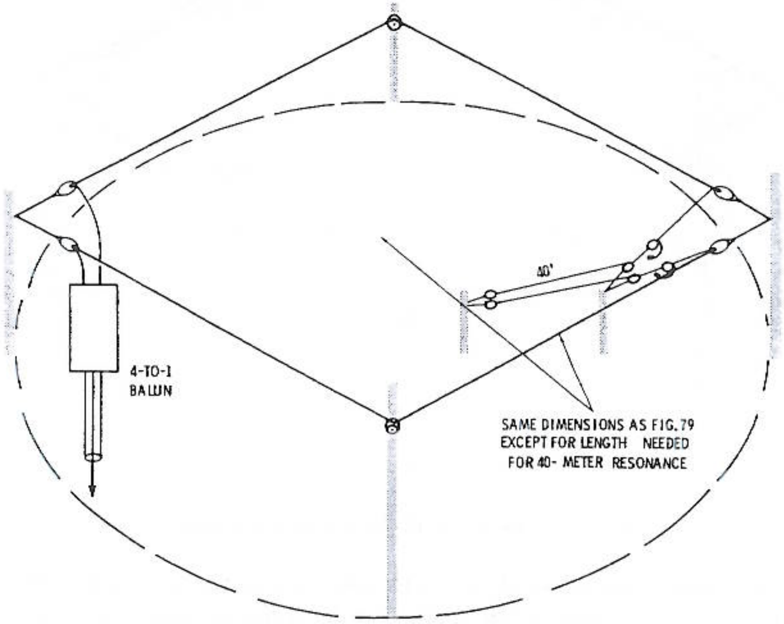


Fig. 80. 10-15-20-40 end-tuned rhombic.

that a short segment of line must be connected or disconnected when changing over from one band to the other. This really is a very simple operation, because it can be done conveniently (Fig. 32). Refer to topics 1, 2, 9, 17, 22, and 23.

Fig. 32. Alligator clips can be used to add length to an inverted vee.

25 — Long-Wire Inverted Vee—Sideband 10-15-2

Two attractive features of the inverted-vee construction are that the ends of the legs are near to ground where changes can be made conveniently and operation as a resonant antenna can be accomplished on more than one band with limited adjustments in leg length. The 10-15-20 single-sideband antenna demonstrates this versatility.

Preferred center frequency points were selected at 14.3, 21.3, and 28.6 megacycles. Reference to Chart 5 and suitable substitutions indicate that a practical inverted-vee can be operated as a 3/2-wavelength antenna on 20, a 5/2 wavelength on 15, and a 7/2 wavelength on 10. The required leg lengths are:

$$(20)\ \text{Leg length} = \frac{738}{14.3} = 51.6'$$

$$(15)\ \text{Leg length} = \frac{1230}{21.3} = 57.7'$$

61 — Resonant Rhombic With Tuner and Open-Wire Line

When the length of the transmission line between the rhombic feed point and the transmitter/receiver is more than 135 to 150 feet, it is advisable to employ open-wire transmission line to minimize line loss. More power is delivered to the rhombic, and more signal is delivered to the receiver from a distant station. The 300-ohm and 450-ohm types are readily available. When the line can be brought into the shack, the antenna tuner of Appendix VII is ideal (Fig. 82).

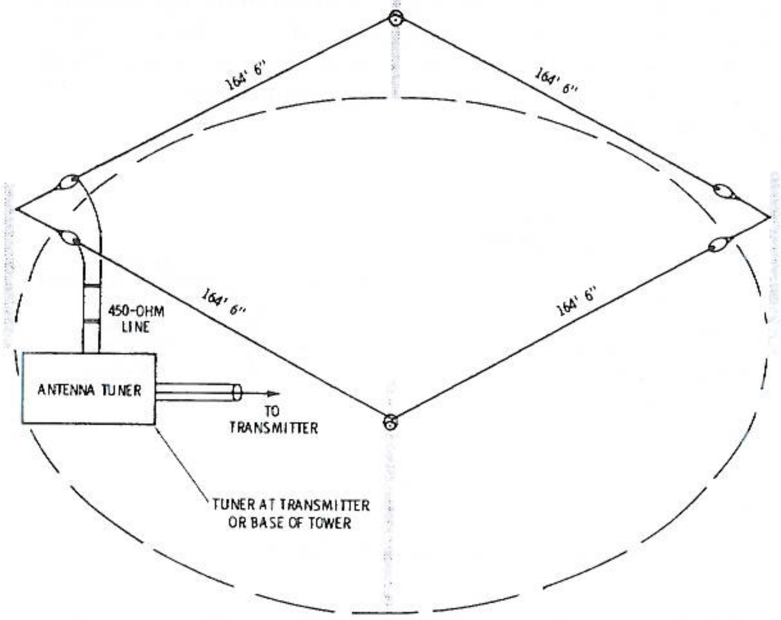


Fig. 82. Rhombic with open-wire line and antenna tuner.

The rhombic antenna when loaded properly also functions well on lower frequencies because of the long length of its legs. Of course, it does not have the sharp directional characteristics present on the higher-frequency bands unless it is made exceptionally long. An antenna tuner is essential.

Open-wire line can also be used to advantage with any of the vee and rhombic antennas when long lengths of transmission line are a necessity. Center-fed long wires can be fed in the same manner.

ensions given in Fig. 30 provide a good combination for 10- and 75-meter single-sideband operation.

The 15- and 40-meter combination is a less favorable pair because the cut must be such that it will provide 40-meter c-w and 15-meter phone operation. Chart values are:

$$\text{(40) Dipole leg length} = \frac{234}{7.1} = 33'$$

$$\text{(15) Long-wire leg length} = \frac{738}{21.4} = 33'\,6''$$

Note that on 15 meters the antenna operates as a 3/2-wavelength inverted vee (three quarter-wavelengths on a leg). A practical dimension which takes shortening effects into consideration is given in Fig. 30.

A third possible combination is a 6- and 20-meter inverted-vee antenna. This long-wire operates with legs three-quarters of a wavelength long on 20 meters and eleven quarter wavelengths on 6 meters. Formula calculations are:

$$\text{(20) Leg length} = \frac{738}{14.2} = 52'$$

$$\text{(6) Leg length} = \frac{2706}{52} = 52'$$

Dimensions for the practical cut are given in Fig. 30.

Various other combinations for two-band operation can be found by using Chart 5, in topic 17. Length selected depends on desired bands and the available physical space for the erection of the long-wire inverted-vee antenna. Sometimes a compromise choice must be made with regard to the resonance spectrum within each band, and it is not always possible to resonate at the exact frequency desired in each band. Refer to topics 1, 2, 9, 17, and 22.

24 — Two-Band Inverted Vee—End-Tuned

It is possible to resonate a two-band long-wire inverted-vee antenna at some specific frequency in each of the two bands to be covered simply by end-tuning each of the legs. A pair of alligator clips and two short segments of antenna wire permit optimum resonance on each of the two bands using the plan shown in Fig. 31.

network. The net resistance of the network is 750 ohms. Such a network displays a wattage rating capable of handling 200 watts PEP with no difficulty. In fact, the pulse nature of sideband transmission is such that considerably more power can be handled safely by the network.

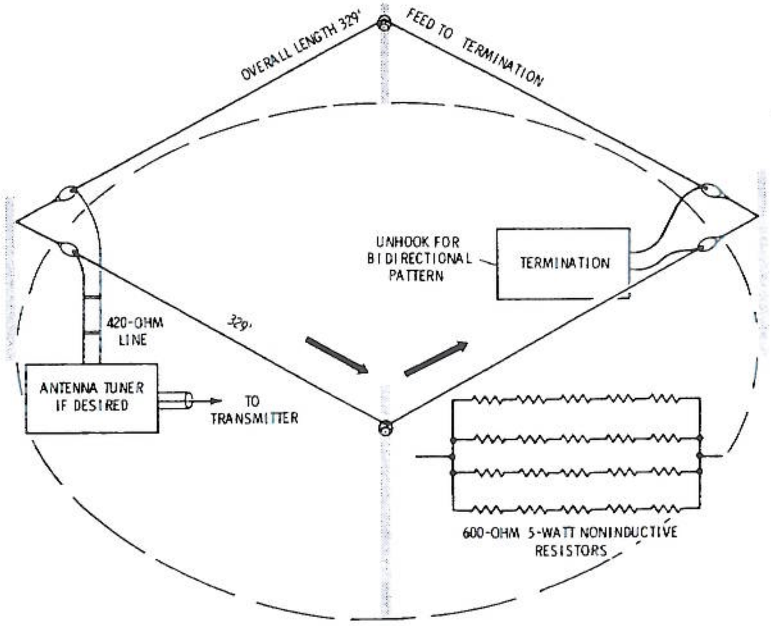


Fig. 84. Practical terminated rhombic.

The terminated rhombic can be fed suitably in a number of ways. A reasonable match is made to the 450-ohm open-wire line. A 50-foot section of this line can connect the rhombic feed point to an antenna tuner mounted at the base of the mast. The alternative plan is to continue the open-wire line from the rhombic feed point to the radio room and some point where the antenna tuner can be mounted conveniently.

Any leg length is permissible provided the appropriate apex angle is employed. An antenna tuner is advisable if you wish to avoid some trimming and you are fussy about SWR. Refer to topics 1, 2, 17, 54, 57, and 61.

The matching problems related to the long-wire inverted vee can also be minimized by choosing leg lengths that correspond to multiples of a quarter wavelength at the operating frequencies, and by using transmission line lengths that correspond to multiples of a half wavelength at operating frequencies (Fig. 28).

Lengths are selected according to available space and apex height by using Chart 5 in topic 17. Next the separation between the feed point and the transmitter is estimated. Chart 2 is then used to determine a preferred length of transmission line. Refer to topics 1, 2, 9, and 17.

A practical 20-meter design is shown in Fig. 29. A 25- to 45-foot vertical mast was assumed. Formula leg length for three-quarter wave operation is:

$$\text{Leg length} = \frac{738}{14.2} = 52 \text{ feet}$$

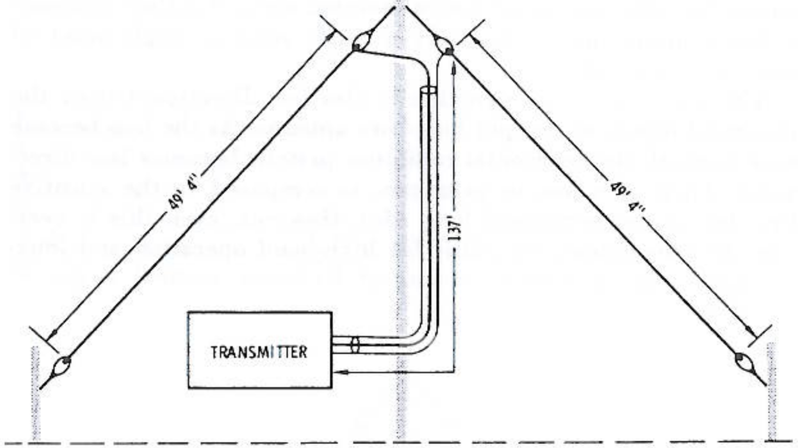


Fig. 29. Twenty-meter long-wire inverted vee—3/4 wavelength on each leg.

An estimate indicates that separation between feed point and second-floor location of transmitter is approximately 50 feet. The constants of Chart 2 indicate that a favorable transmission line length would then be:

$$\text{Line length} = \frac{650}{14.2} = 45'\,9''$$

It is significant that an inverted-vee antenna is a sturdy construction. The mast itself does not support the antenna; rather the antenna wires contribute additional guying for the mast.

SECTION 7

Very Long Long-Wire Antennas

63 — Two-Band Very Long Long-Wire Antennas

The single long-wire antenna properly fed and very long in length is an effective gain antenna and can often be erected in positions where other types of long-wire antennas are not feasible. Length for two-band operation can be attained by calculating samples from dimension Chart 10. Such an antenna also has all-band capabilities if end-tuned. It has a high directivity in the direction of the far end of the wire for the high-frequency bands. Radiation patterns are less directional for the low-frequency bands.

Chart 10. Long Long-Wire Lengths

Length in Wavelengths	Length in Feet
39/4	9594/*f*
41/4	10086/*f*
43/4	10578/*f*
45/4	11070/*f*
47/4	11562/*f*
49/4	12054/*f*
51/4	12546/*f*
53/4	13038/*f*
55/4	13530/*f*
57/4	14022/*f*
59/4	14514/*f*
61/4	15006/*f*
63/4	15498/*f*
65/4	15990/*f*
67/4	16482/*f*
69/4	16974/*f*
71/4	17466/*f*
73/4	17958/*f*
75/4	18450/*f*
77/4	18942/*f*
79/4	19434/*f*
81/4	19926/*f*
83/4	20418/*f*
85/4	20910/*f*
87/4	21402/*f*

four-to-one balun is used for matching, and the coaxial transmission line to the transmitter is made a whole multiple of an electrical half wavelength.

A long long-wire antenna can be erected to obtain good directivity in some desired direction for 40- and 80-meter operation. Formula dimensions for 14/4 wavelengths and 7/4 wavelengths for 40 and 80 meters respectively are attractive:

$$(40)\ \textbf{Long-leg length} = \frac{3198}{7.25} = 441 \text{ feet}$$

$$(80)\ \textbf{Long-leg length} = \frac{1722}{3.9} = 441 \text{ feet}$$

The shorter leg lengths are:

$$(40)\ \textbf{Short-leg length} = \frac{234}{7.25} = 32.3 \text{ feet}$$

$$(80)\ \textbf{Short-leg length} = \frac{234}{3.9} = 60 \text{ feet}$$

Again practical dimensions are given in Fig. 85.

An attractive 20- and 40-meter length is a 21/4- and 41/4-wavelength combination:

$$(20)\ \textbf{Long-leg length} = \frac{10086}{14.2} = 710 \text{ feet}$$

$$(40)\ \textbf{Long-leg length} = \frac{5166}{7.25} = 712 \text{ feet}$$

Other two-band combinations can be found by sampling the length equations. Refer to topics 1, 2, 17, 33, and 34.

64 — End-Tuned Very Long 5 DXCC Long Wire

The very long long-wire antenna can also be segmented to permit operation on other bands. The addition of a pair of insulators and associated jumpers can add 20-meter operation to the basic 10- and 15-meter antenna of topic 63.

Formula value for 27/4 wavelengths on 20 is:

$$(20)\ \textbf{Long-leg length} = \frac{6642}{14.2} = 468 \text{ feet}$$

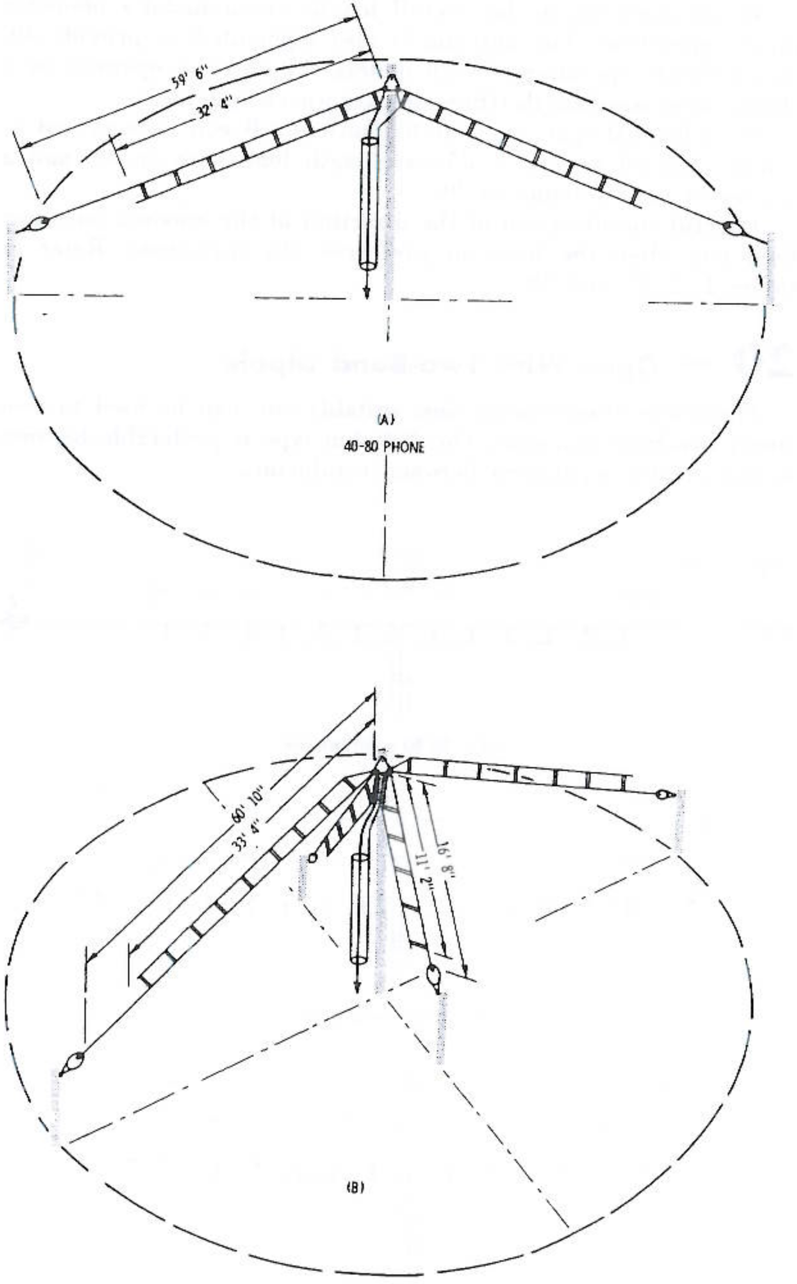


Fig. 27. Inverted dipoles (A) and four-band 15-20-40-80 dipole pairs (B).

This length provides both 10- and 80-meter resonance. Refer to topics 1, 2, 17, 33, 34, 36, and 63.

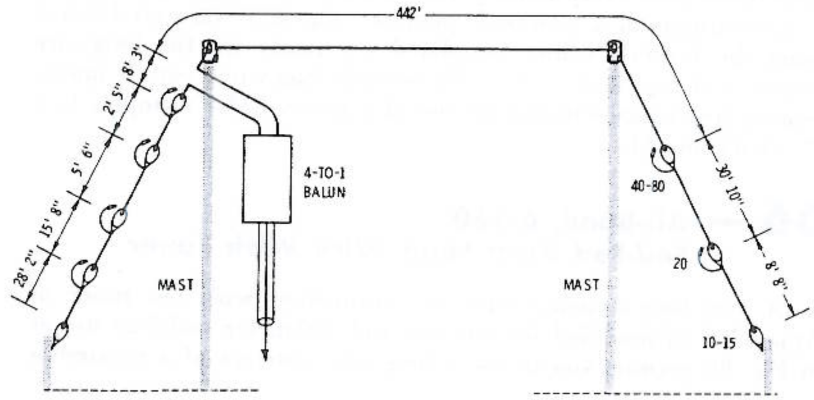


Fig. 86. End-tuned very-long wire.

65 — 5 DXCC Long-Wire Special

The 5 DXCC long-wire special consists of three individual long wires that permit five-band operation (10 through 80) without making any changes in the long wires once they are trimmed to resonance. The three long legs (Fig. 87) can be mounted high and clear in a permanent position because far-end switching is not necessary. The short quarter-wave legs can be mounted low and accessible for convenient band change.

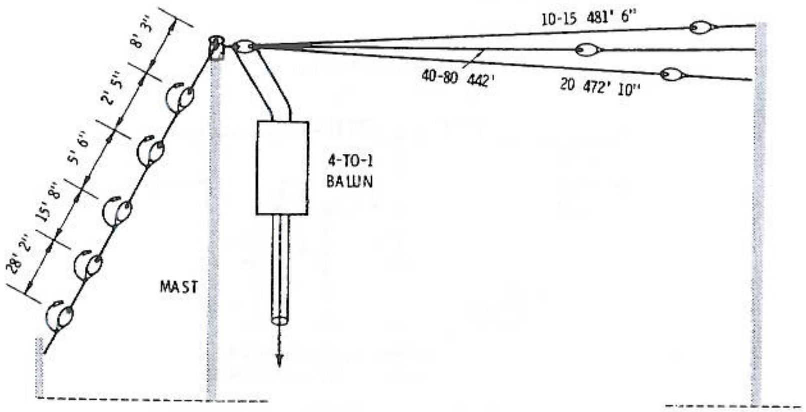


Fig. 87. Long-wire 5DXCC special.

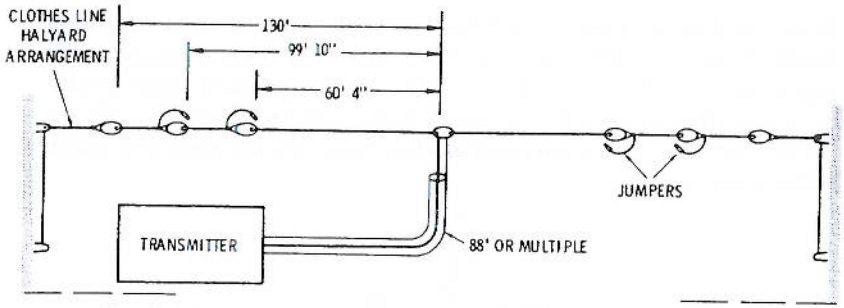
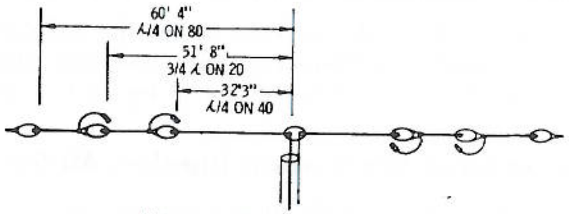


Fig. 24. Low-bands segmented dipoles—40, 80, and 160 phone.

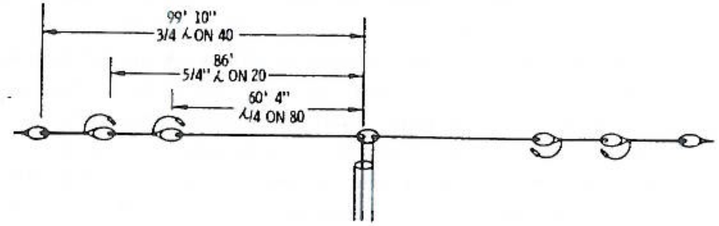
would be 176 feet or an integral multiple. Although a 160-meter dipole is used, transmission-line lengths of 88 feet (or a multiple) can be used if the 160-meter dipole is cut and resonated rather carefully for the portion of the 160-meter band in which operation is desired. Refer to topics 1, 2, and 17.

19 — Middle-Band Segmented Dipoles, 20-40-80

A single antenna and transmission line can provide optimum dipole operation on these three bands using the segmented construction of Fig. 25. The one selected depends on available space. Again insulators, jumpers, and a halyard arrangement provide easy band changeover.



(A) Overall length is used for 80.



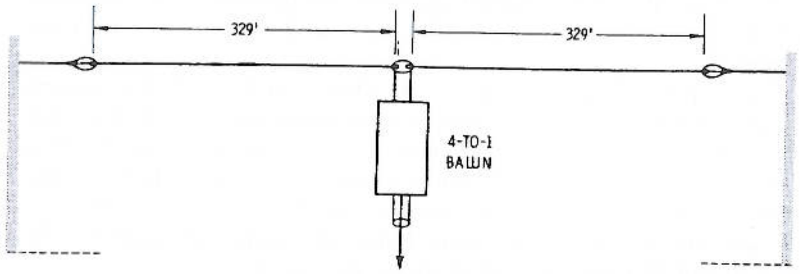
(B) Arrangement if more space is available.

Fig. 25. Segmented dipoles for 20, 40, and 80.

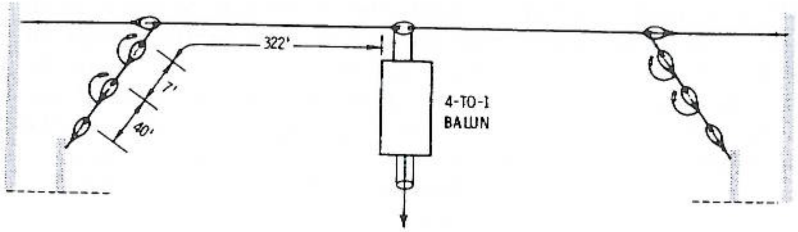
length that can be accommodated on your property. The longer the wire is, the more directive the antenna becomes, and the higher is the antenna gain off the far end of the antenna wires. The directivity and gain is at a maximum on the highest-frequency band.

In DX communications the higher the antenna is, the greater is the radiation at low wave angles. Thus one should attempt to keep most of the antenna as high as possible.

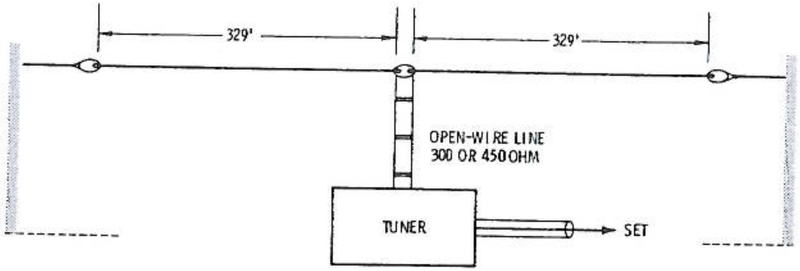
The transmitter end of the long-wire antenna can be brought directly into the shack. Of course, this part of the antenna should be insulated to prevent shorting to metallic surfaces. As mentioned early in the book, the antenna wire itself can be covered



(A) 10-15 meters.



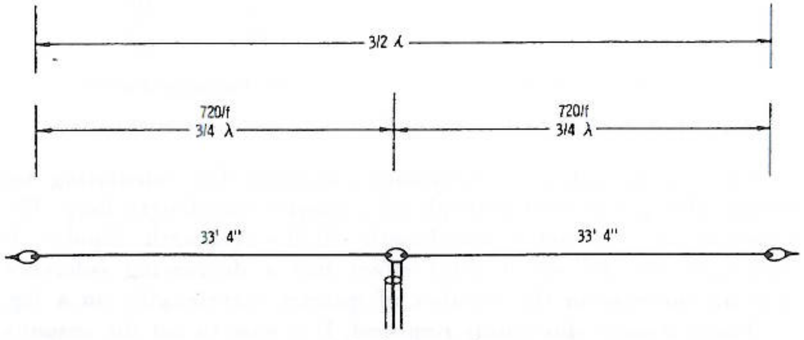
(B) 10-15-20 or 10-15-20-40, end-tuned.



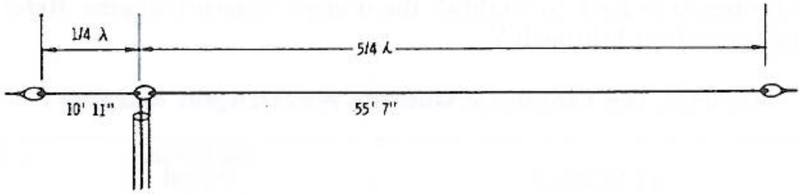
(C) Open-wire line with tuner.

Fig. 89. Bidirectional center-fed long wires.

Two practical 3/2-wavelength antennas are shown in Fig. 22. They have been cut for the 15-meter phone band. When an antenna is made an odd multiple of a half wavelength long, it can be fed either at the center or near one end. End-feed does influence the directivity pattern as compared to the center feed. The change is such that the lobes are of greater magnitude (more gain) on the five-quarter-wave side of the feed point as compared to the one-quarter-wave side.



(A) Center fed.



(B) Off-center fed.

Fig. 22. 3/2-wavelength antenna.

Antenna resistance rises to near 100 ohms. Again this is a theoretical free-space value. The practical value depends on height above ground and other surrounding conducting surfaces. It is this indefinite value for most antennas that makes the use of transmission line which is a whole multiple of an electrical half-wavelength a useful practice.

The horizontal lobes of a long-wire antenna can be oriented in favored directions by choosing a favored angle for running the antenna wire. Approximate angles for the 3/2 wavelength antenna are 45°, 90°, 135°, 225°, 270°, 315°. The 90-degree and 270-degree lobes are weaker and narrower than the four cloverleaf lobes. If the antenna wire were run 20-200 degrees in the eastern U.S., there would be favorable lobes at 65°, 155°, 245°, and 335°. As

SECTION 8

Special Vees and Rhombics

A practical one-wavelength antenna is shown in Fig. 20. Dimensions are for 15-meter operation. Note that the feed point has been moved away from the center by a quarter wavelength. In so doing, a lower-impedance feed point is found (one quarter wavelength on one side and three quarter wavelengths on the other). There is a suitable match to either 50- or 72-ohm coaxial cable. Antenna feed-point impedance is only slightly higher (80 to 90 ohms) than a conventional dipole.

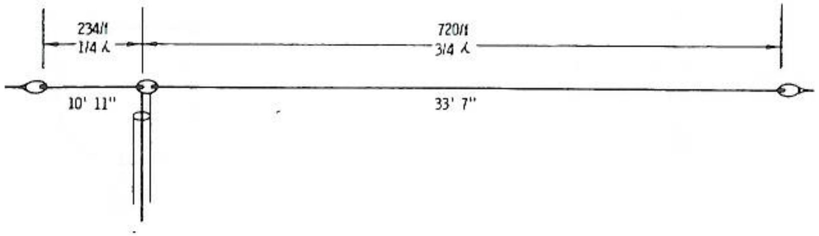


Fig. 20. One-wavelength antenna.

In the erection of the one-wavelength antenna, the direction of the antenna wire should be such that one or more horizontal lobes of the pattern are oriented in preferred directions. For any type of long-wire antenna, it is wise to choose a length of transmission line that corresponds to a whole multiple of an electrical half wavelength. Refer to topics 1 and 2.

17 — 3/2-Wavelength Antenna

Antennas can be resonated to a specific frequency by making their overall electrical length a whole multiple of a half wavelength. There is a rise in gain with each half-wavelength addition. In the case of a horizontal antenna, the antenna becomes more directive with antenna length.

The addition of leg lengths in odd multiples of a half wavelength ensures a low-impedance center feed point because each leg of such an antenna is an odd number of quarter wave-lengths long.

For example, the antenna of Fig. 21 is 3/2 wavelength long, and each leg is ¾ wavelength long, establishing a low-impedance feed point at the center. The directive pattern of a horizontal 3/2-wavelength antenna is shown in B. Note that two additional lobes have been added as compared to the one-wave-length antenna of Fig. 19.

68 — 160-Meter Two-Mast Inverted Vee

Three factors of concern in the erection of a 160-meter antenna are space requirement, noise pickup, and local-DX capability. Generally the half-wavelength horizontal antenna is quieter and less subject to noise pickup as compared to the vertical. Furthermore a good ground system is very important to the operation of a vertical antenna. Long-haul DX contacts usually favor the verticals. At times the reception of DX stations is better on a horizontal. Better reliability is usually obtained with the long horizontal antenna for medium distances, while strictly local contacts are often more favorable with a good vertical.

The two-mast inverted-vee antenna is a compromise arrangement capable of accommodating an antenna with a full half-wavelength dimension in a shorter space. Furthermore the use

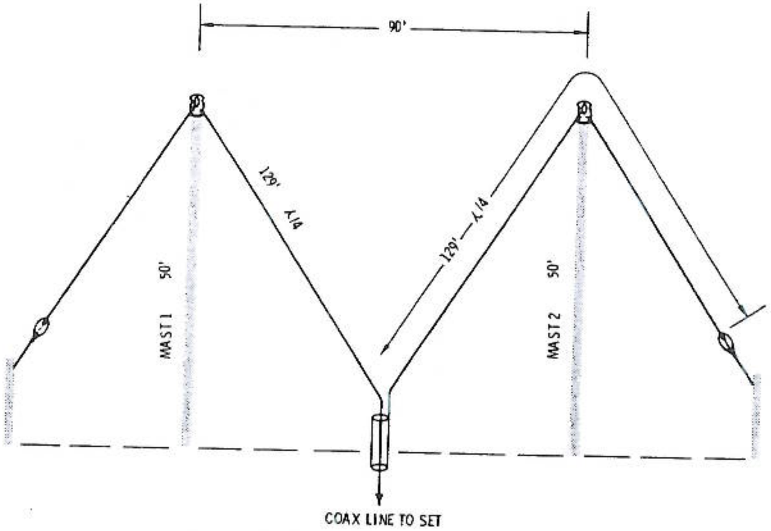


Fig. 90. Two-mast inverted vee for 160.

shifted at will toward the low end of any band by clipping on additional short sections of antenna wire to the dipole ends (Fig. 18). Refer to topics 1, 2, 9, and 13.

15 — 20-40-80 C-W Special Inverted Dipoles

The inverted dipole construction of the previous topic (Fig. 17) is ideal for the c-w ham who concentrates his operations on 20, 40, and 80. The antenna occupies a relatively small space, is low cost, and no changes are needed when switching bands. The quarter-wave dipole segments when cut to resonate in the special and advanced c-w bands are 63′ 4″, 33′ 1″, and 16′ 8″ for the 80-, 40-, and 20-meter bands respectively.

If you operate both phone and c-w, an ideal arrangement is to use the dimensions for phone operation given in the previous topic. Cut clip-on extensions for attachment when operating cw (Fig. 18). These lengths are 5′, 1′, and 3″ for the 80-, 40- and 20-meter bands respectively. Refer to topics 1, 2, 9, 13, and 14.

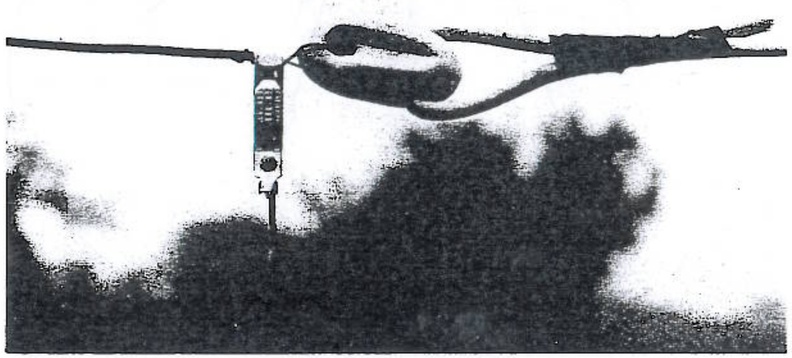


Fig. 18. Clip-on extension to lower resonant frequency of antennas.

16 — One-Wavelength Antenna

A half-wavelength dipole antenna is resonant on a specific frequency. Resonance on the same frequency can also be obtained by doubling the dipole length to form a "long-wire" one-wavelength antenna (Fig. 19). Such an antenna can be fed at the center. However, the center is a maximum-voltage/minimum-cur-

$$(40)\ \text{Leg length} = \frac{1230}{7.2} = 170\ \text{feet}$$

$$(20)\ \text{Leg length} = \frac{2214}{14.2} = 156\ \text{feet}$$

$$(15)\ \text{Leg length} = \frac{3690}{21.3} = 173\ \text{feet}$$

$$(10)\ \text{Leg length} = \frac{5166}{28.6} = 180\ \text{feet}$$

These lengths have to be trimmed to find the desired resonance point. Practical dimensions for the model erected by the author are given in Fig. 91. A coaxial transmission line that is a compromise whole multiple of an electrical wavelength was used (approximately 135 feet). Refer to topics 1, 2, 17, 18, 19, 24, and 68.

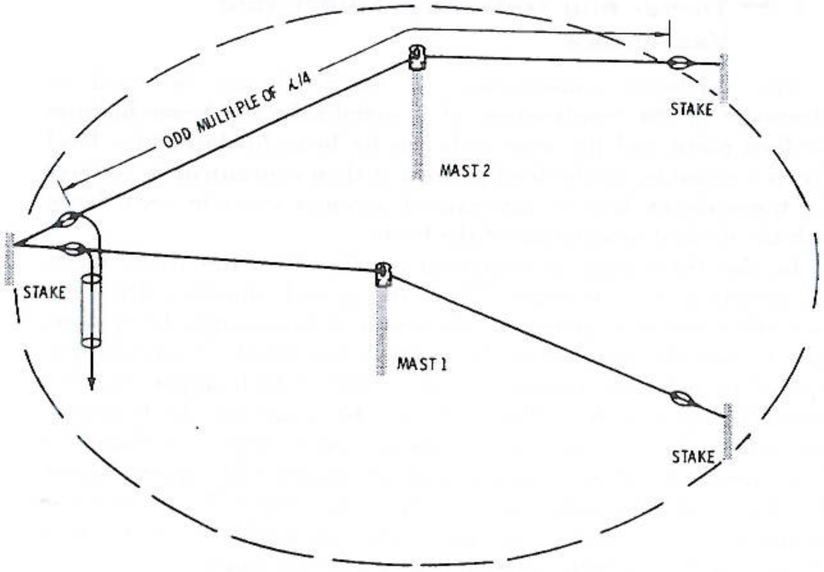
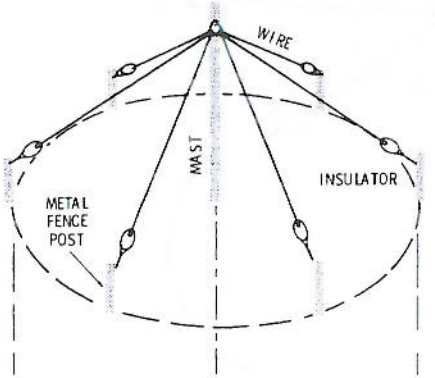


Fig. 92. General plan of two-mast vee beam.

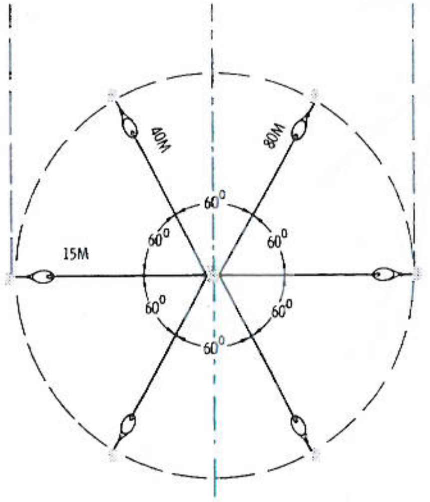
70 — Two-Mast Vee-Beam

The legs of a two-mast inverted vee can be tilted forward to form a vee-beam antenna as in Fig. 92. The mast is located at the approximate center of each leg and the leg wires slant down toward the feed point and toward the antenna wire ends in inverted-vee fashion. Ordinarily the vee-beam antenna requires three masts.

ment using a single mast is the maypole arrangement of three inverted dipoles as shown in Figs. 15B and 16. The individual dipoles are 60 degrees related to each other in terms of their horizontal positioning around the mast. Refer to topics 1, 2, 4, 9, and 10.



(A) Side view.



(B) Top view.

Fig. 16. Inverted-vee multi-antenna construction.

14 — 20-40-80 Maypole

Many radio amateurs confine their operations to 20, 40, and 80 meters. Some transmitters and transceivers function only on

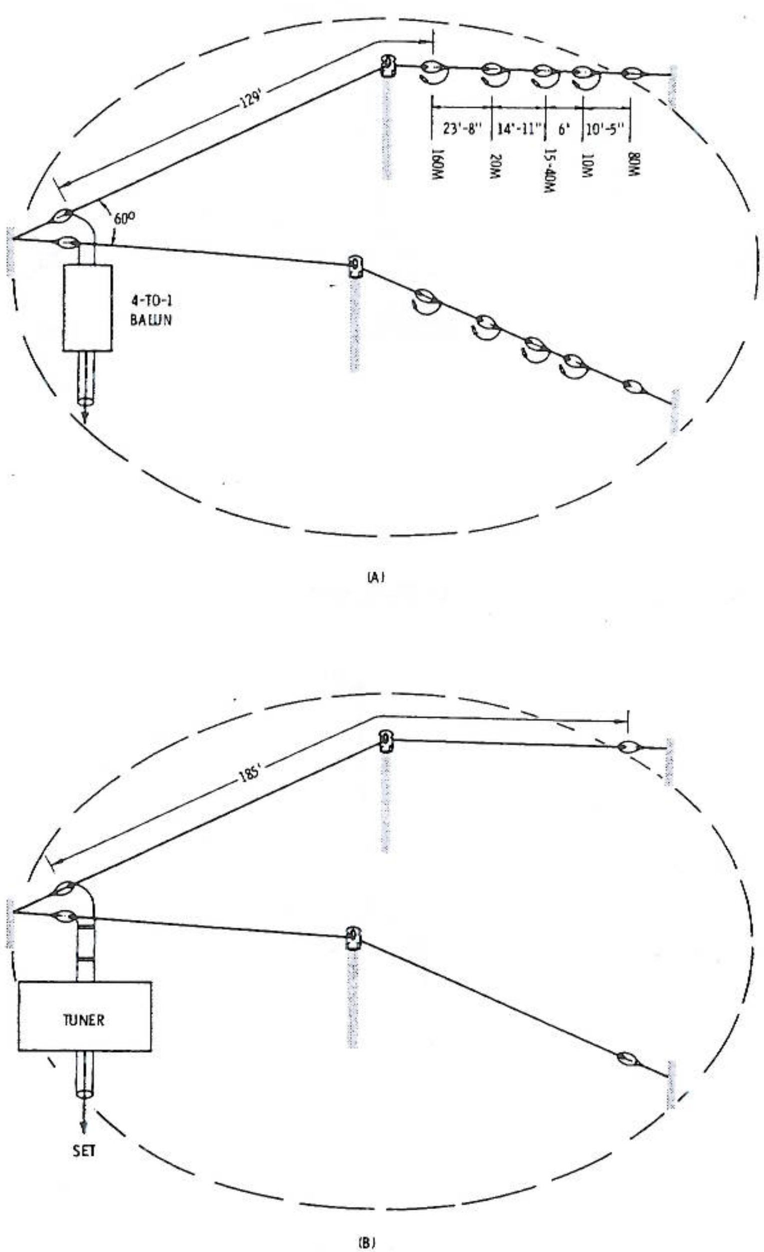
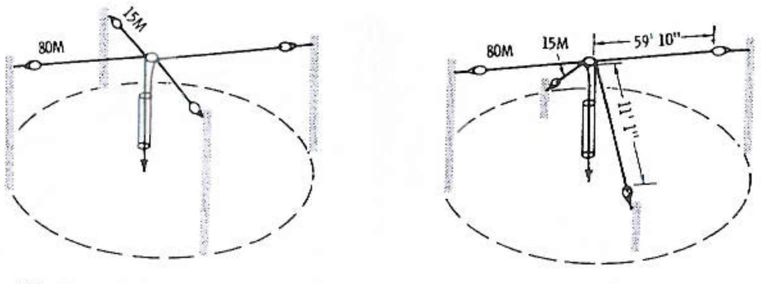


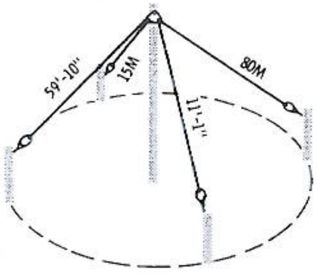
Fig. 93. Two-mast end-tuned vee beam.

point. There are three arrangements that perform well (Fig. 14). The 40- and 80-meter dipole elements can both be mounted horizontally but at right angles to each other; both can be connected as inverted-vee dipoles; or, if the 80-meter dipole can be mounted high enough, it is possible to run the 40-meter antenna wires off the center point as an inverted dipole. Forty- and 80-meter inverted dipole leg lengths are 32′ 3″ and 59′ 10″ respectively. Straight dipole dimensions are given in Chart 4. Refer to topics 1, 2, 4, 9, and 10.



(A) 15 and 80 on same plane.

(B) 80 horizontal, 15 inverted.



(C) 80 and 15 inverted.

Fig. 14. 15-80 meter dipole combinations.

13 — Novice 15-40-80 Dipoles

Three-band operation for the novice can be obtained by using three separate dipoles connected to the same center feed point. The secret of multi-dipole operation is to keep the various antennas isolated from each other as much as possible. Stay away from parallel runs of the antenna wires.

Two favorable arrangements are shown in Fig. 15. In example A the dipoles are mounted horizontally and are 60 degrees related in their physical positions. A simple and good performing arrange-

Four masts mounted in a square is a more versatile construction. The four antenna wires of such a combination are spaced 90°, which is a more favorable angle for vee-beam operation on the DX bands. As shown in Fig. 94B you now have four maximum directions available to you by selecting the appropriate pair of adjacent antenna wires. These pairs are 1 and 2, 2 and 3, 3 and 4, plus 4 and 1. Two center-fed long-wire combinations are also possible using antenna wires 1 and 3 or 2 and 4. Feed arrangement is the same as that of the three-mast plan except that four coaxial connectors or insulators are employed. Two additional insulators or connectors (from 1 to 3 and 2 to 4) are needed if you wish to take advantage of the center-fed long-wire pairs. Refer to topics 1, 2, 17, 44, 51, 54, 67, 68, 69, and 70.

72 — Two-Mast Rhombic

By tilting down the feed end and far end of a rhombic antenna in inverted-vee fashion only two center masts are needed for erection (Fig. 95). The feed point can then be made accessible for transmission-line changes and, if desired, for the direct attachment of an antenna tuner. The far end is also readily accessible and

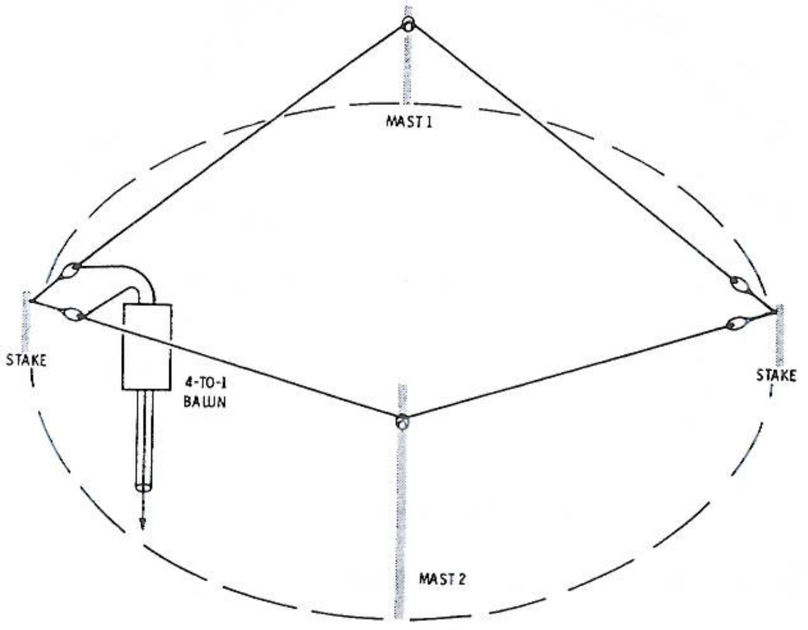
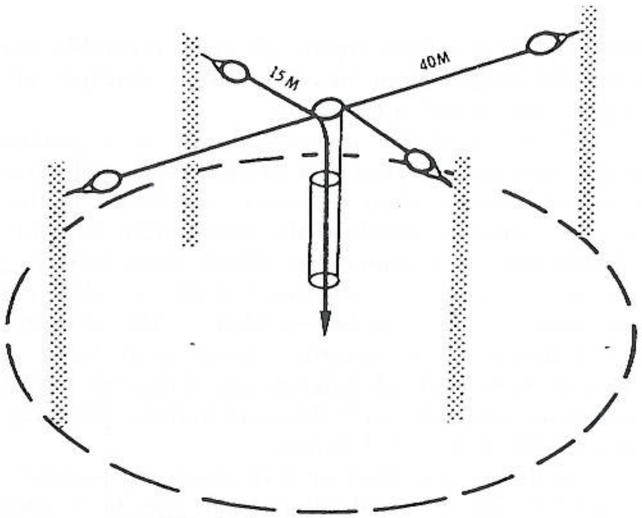
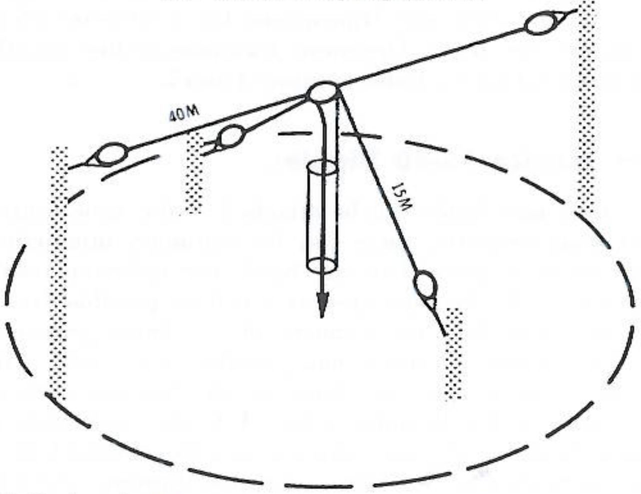


Fig. 95. General plan of a two-mast rhombic.



(A) Horizontal-dipole placement.



(B) Horizontal 40-meter dipole and inverted 15-meter dipole at center.

Fig. 12. 15- and 40-meter dipoles connected to same feed point.

of the 40-meter band is still too short for three-quarter wavelength operation at the high end of the 15-meter band. This is because end effect is a consideration in choosing the length of the 40-meter dipole, while it is less influential in determining the overall length of a three-halves wavelength antenna on 15 meters.

The inverted-dipole combination of Fig. 13 is a good combination. Only a single mast is required and the advantages of low-

corner of this square (Fig. 97) permits you to erect a versatile and good-performing rhombic antenna that can be used on all bands. It provides a choice of omnidirectional, two bidirectional, and four unidirectional patterns. The use of open-wire line and an antenna tuner gives you all-band capability.

At each corner the rhombic antenna can be fed, terminated, or left open for bidirectional operation. The open-wire transmission line is brought to the center of the square near ground level where it is fastened securely. A section of open-wire transmission line is now cut to run from the center to any one of the four possible antenna feed points. A halyard arrangement at each mast lowers each rhombic corner for changes.

Let us assume that a bidirectional pattern is to be established along the diagonal between poles 2 and 4. In this case the antenna wires are jumped at poles 1 and 3. The antenna can be fed at corner 2 and left open at 4 or it is possible to feed at pole 4 and leave 2 open. For unidirectional operation in the direction of pole 2, it is necessary to feed at pole 4, and attach a noninductive termination at pole 2. Oppositely, for a unidirectional pattern in the direction of pole 4, the antenna must be fed at pole 2 and terminated at pole 4. It is apparent that it is possible to obtain

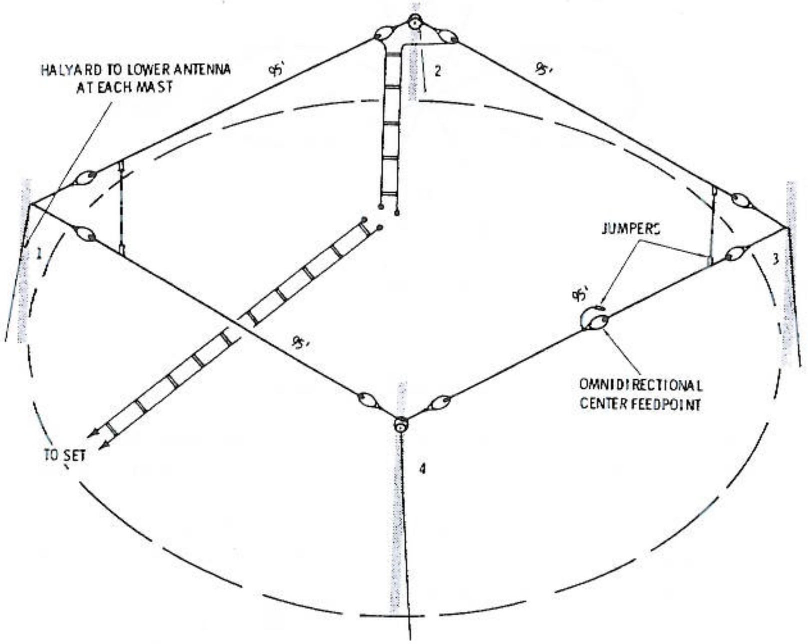
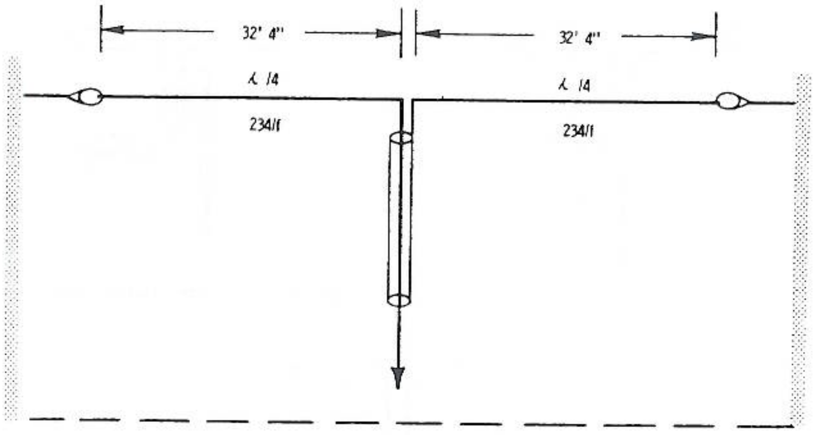
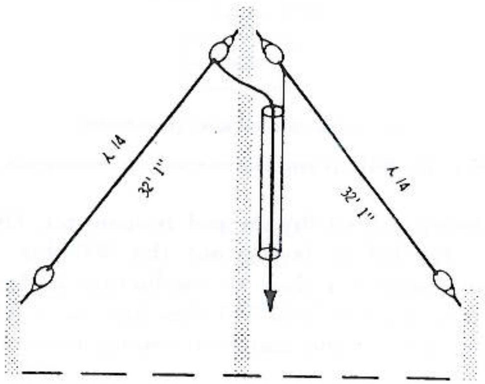


Fig. 97. Short squared rhombic.



(A) Horizontal dipole.



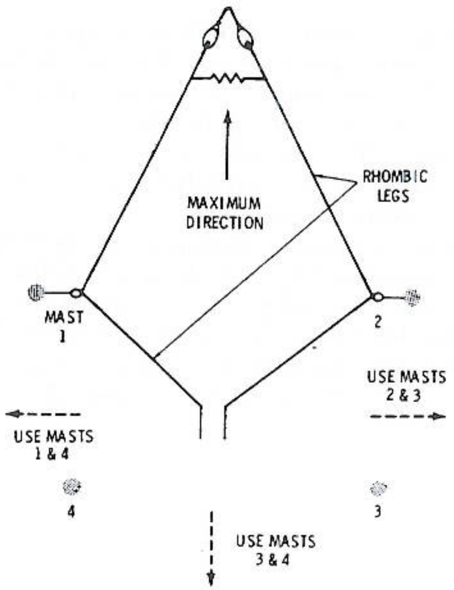
(B) Inverted dipole.

Fig. 11. Dimensions for 40-meter phone operation.

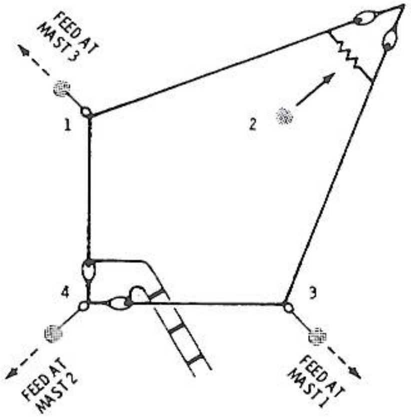
The leg length for a given resonant frequency is somewhat shorter than that of a straight horizontal dipole. As a function of apex angle and nearness of the leg ends to ground, the shortening falls between 2 and 6 percent. The nearer the antenna ends are brought to ground, the shorter is the leg length for a given resonant frequency. An antenna bridge or SWR meter is helpful in trimming the antenna to frequency. The work can be done conveniently with the antenna erected, because the leg ends are accessible from ground. Refer to Appendices I through IV.

Antenna feed-point impedance drops away from the impedance value of a horizontal dipole, becoming lower as the angle between the two wires is decreased. Usually a better match is made to

---



(A) Two-mast rhombic.



(B) Other directions available by changing feed point.

Fig. 99. Other antennas possible with four masts in a square.

When a reasonably omnidirectional pattern is desired, the antenna can be fed at one of the leg centers (Fig. 97). In this mode the wires at each of the four corners are jumped. For rhombic operation a jumper must always be placed across the insulator that is used for omnidirectional feeding.

7 — Twin-Lead Folded Dipole

An inexpensive and popular form of quick antenna construction has been the twin-lead folded dipole (Fig. 9). A folded dipole has a feed-point impedance of approximately 300 ohms rather than 70 ohms. Consequently it matches the characteristic impedance of the twin line from which it is made.

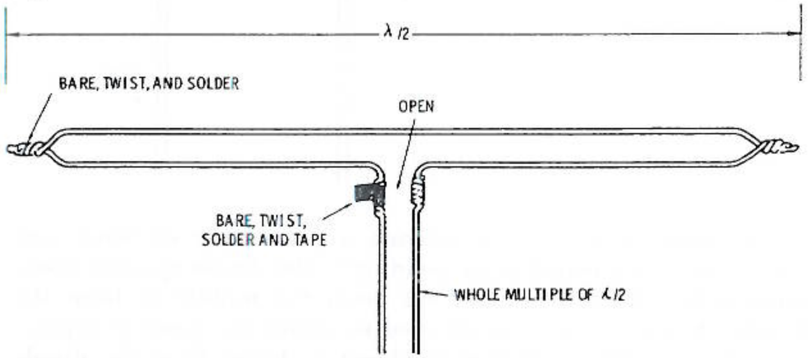


Fig. 9. Twin-lead folded dipole.

Some transmitters have enough output tuning range to provide a suitable match to a 300-ohm system. Again, matching help can be obtained by making the length of 300-ohm transmission line a multiple of a half wavelength.

The velocity factor of most 300-ohm lines approximates 0.82 and is substituted in determining the physical length needed to obtain a total line length that is a multiple of an electrical half wavelength. Values approximate those given in Chart 2 for foam-dielectric coaxial line which has a velocity factor of 0.81. Refer to topics 1 and 2.

8 — Folded Dipole and Balun

A folded-dipole antenna with its resistance of 300 ohms can be matched to a 50-ohm unbalanced system using a balun. The balun is attached to the feed point of the folded dipole (Fig. 10). The balun ratio should be 4 to 1.

One of the commercially available wideband types can be used or one can be constructed from a section of 72-ohm coaxial transmission line as shown in Fig. 10B. Don't forget to consider the velocity factor in cutting the line that is employed in the balun.

An alternate plan is to position the balun near the transmitter. This is a more economical arrangement when there is a great

APPENDIX I

Antenna Noise Bridge

The antenna noise bridge* is an especially useful device in cutting antennas to resonance and transmission lines to specific electrical lengths. It can also be used to measure antenna resistance. The unit consists of a signal source, the bridge circuit, and a detector (Fig. A-I-1). A diode noise generator and amplifier is built into the compact device along with the bridge. Your ham receiver serves as the detector. In fact, the noise generator is a broadband type and your ham receiver serves as a calibrated frequency-selective detector.

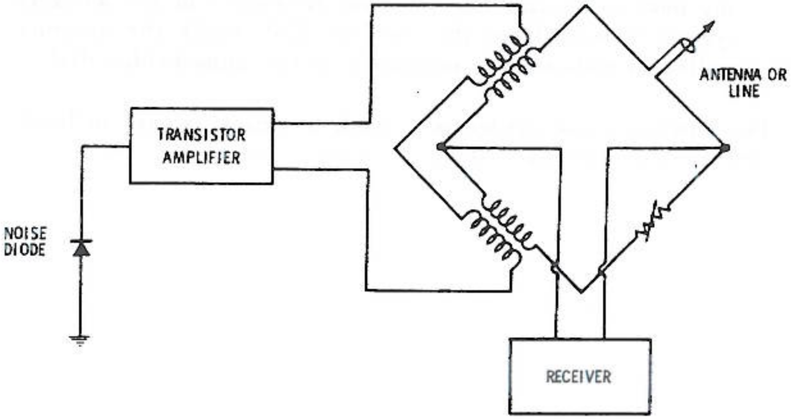


Fig. A-I-1. Omega-T antenna noise bridge.

Two balanced legs of the bridge are the secondary of a bifilar transformer which is wound on a toroid core. The broadband noise signal is applied across the primary. A third leg of the bridge is a calibrated variable resistor which is the only control of the unit. The dial is calibrated in ohms of antenna resistance between 0 and 100 ohms.

---

*Omega-T Inc., Richardson, Texas 75080

integral multiples of these stated values may also be used. Refer to topics 1 and 2.

5 — Advanced- and Extra-Class Band Dipoles

Some amateurs concentrate their operations within the advanced- or extra-class bands. Dipoles can be cut with optimum performance on these portions of the spectrum. Dimensions as centered on the advanced and extra portions of the frequency spectra are given in Chart 4. Line lengths for optimum performance are also suggested. Line lengths which are multiples of the values given also provide optimum results. Refer to topics 1 and 2.

Chart 4. Advanced and Extra-Band Dipole and Line Dimensions

ADVANCED			
MHz Band	**Center**	**λ/2 Dipole**	**λ/2 Line 0.66 VF**
3.825—3.9	3.8625	121′2″	84′2″
7.2 —7.25	7.225	64′8″	45′
14.2 —14.275	14.2375	32′10″	22′10″
21.275—21.350	21.3125	21′11″	15′3″
EXTRA			
MHz Band	**Center**	**λ/2 Dipole**	**λ/2 Line 0.66 VF**
3.5 — 3.55	3.525	132′9″	92′2″
3.8 — 3.825	3.8125	122′9″	85′3″
7.0 — 7.05	7.025	66′7″	46′3″
14.00—14.05	14.025	33′4″	23′2″
21.00—21.05	21.025	22′3″	15′6″
21.25—21.275	21.2625	22′	15′3″

6 — Lamp-Cord Dipoles

Common electrical lamp cord can be used to construct indoor, portable, or emergency dipoles. The lamp cord can be divided down the middle, setting off two dipoles of appropriate length (Fig. 7). The remainder of the lamp cord then serves as the transmission line between antenna and transmitter. Antenna resistance of the dipole is 72 ohms and the characteristic impedance of the lamp cord is usually not too much different from this value. To aid in matching, the line segment is made a multiple of a half-wavelength long.

APPENDIX II

How to Measure the Velocity Factor of Transmission Line With a Noise Bridge

The noise bridge described in Appendix I can also be used to make transmission-line checks and measurements. Velocity factor is an important line characteristic in cutting lines to specific electrical wavelengths. Sometimes the information is not available from the manufacturer or it is necessary to know the velocity factor very exactly. If such is the case, the hookup of Fig. A-II-1 can do the job.

The near end of the transmission line is connected to the antenna terminal of the noise bridge. The far end of the line is shorted. At some frequency the total length of the line will be an electrical half wavelength or a multiple of a half wavelength. At this frequency a short is reflected to the near end of the line, and there is no reactive component. The electrical length of the line is determined as follows:

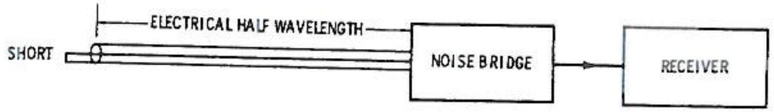


Fig. A-II-1. Determination of velocity factor of transmission line.

1. Set the noise bridge dial just a hair away from zero corresponding to the few ohms of resistance of the transmission line. Tune the receiver for a noise null. It is customary to check a section of line that is approximately one-half wavelength long although multiples can be used for making the measurement.
2. Now measure the physical length of the transmission line. The velocity factor is obtained by dividing the physical length of the line by the calculated free-space half wavelength of the frequency indicated by the receiver dial.

$$\text{Velocity factor} = \frac{\text{physical length of line}}{492/\text{receiver freq. reading in MHz}}$$

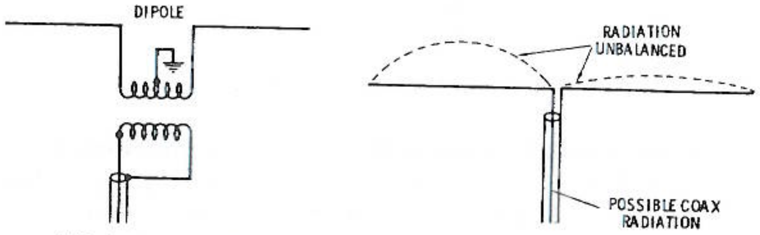
Chart 2. Dimensions of Half-Wavelength Line Segments for Velocity Factors of 0.66 and 0.81

Line Segments in Wavelengths	(VF=0.66) Line Lengths in Feet Reg. RG/58U-RG/59U	(VF=0.81) Line Lengths in Feet of Foam RG/58U-RG/59U
1/2	325/f	400/f
2/2	650/f	800/f
3/2	975/f	1200/f
4/2	1300/f	1600/f
5/2	1625/f	2000/f
6/2	1950/f	2400/f
7/2	2275/f	2800/f
8/2	2600/f	3200/f
9/2	2925/f	3600/f
10/2	3250/f	4000/f
11/2	3575/f	4400/f
12/2	3900/f	4800/f
13/2	4225/f	5200/f
14/2	4550/f	5600/f
15/2	4875/f	6000/f
16/2	5200/f	6400/f

3 — Dipole and Balun

A dipole antenna presents a resistive 72-ohm load only at its resonant frequency. The idealized value of 72 ohms can be affected by surroundings. At points off the resonant frequency, there are also reactive components present. Nevertheless, the performance of the antenna system can be optimized using the procedure covered in topic 2.

The dipole antenna is a *balanced* antenna system with identical and equal-length elements on each side of the feed point. Conversely, the commonly used coaxial transmission line constitutes an *unbalanced* feed system. Thus there are unequal r-f currents in the quarter-wavelength dipole sections which can disturb the radiation pattern and produce unfavorable line conditions which result in line radiation (Fig. 5).



(A) Balun equivalent.

(B) Unbalanced condition.

Fig. 5. Plan of a balun and condition which it reduces.

APPENDIX III

Cutting Half-Wave Sections of Transmission Line Using the Antenna Noise Bridge

When the velocity factor of a transmission line is known, it is possible to cut that line to some whole multiple of a half-wavelength using the following relationships:

$$\text{Line length in feet} = VF \times \frac{492}{f\text{MHz}} \times \text{whole multiple of } \lambda/2$$

If the velocity factor of a specific line is unknown it can be determined using the procedure of Appendix II.

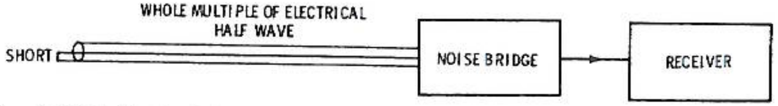


Fig. A-III-1. Method for cutting a transmission line to whole multiple of a half wavelength.

Once a section of line is cut, its exact electrical wavelength can be determined with the arrangement of Fig. A-III-1. Again the far end of the line is shorted while the near end is connected to the antenna terminal of the antenna bridge. This procedure is as follows:

1. Set the bridge control slightly above zero. Set the receiver to the desired frequency band.
2. Tune the receiver over the band to obtain a good null. For some receivers a more pronounced null can be obtained by deactivating the avc circuit and/or reducing the receiver r-f gain.
3. If the frequency indication is too low, the length of the transmission line can be trimmed slightly to make the electrical length of the line correspond to a specific operating frequency within the band.

if at all possible. This can be accomplished by cutting the length of the transmission line to an electrical half wavelength or a multiple of one-half wavelength (Fig. 3). In cutting an electrical

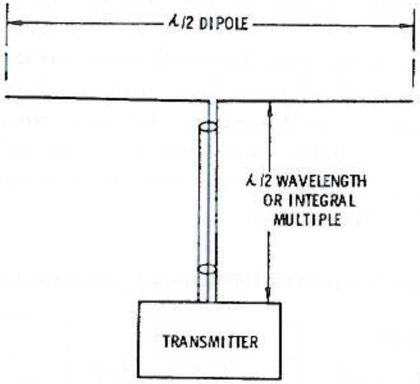


Fig. 3. Line-tuned half-wavelength antenna.

half wavelength of line, it is necessary to consider the velocity factor of the line:

$$\textbf{Line length } (\lambda/2) \textbf{ in feet} = \frac{492 \times VF}{f\,\text{MHz}}$$

Of course, the length of the transmission line can be any integral multiple of the above length.

Chart 2 is based on the velocity factors of 0.66 and 0.81 typical of 50-ohm and 72-ohm regular and foam-dielectric type coaxial lines respectively. This information can be used to determine the dimensions of a length of line that will best accommodate the separation between the transmitter and the antenna feed point. For example, if you plan to operate a dipole on 7.1 MHz, and the approximate distance between antenna and transmitter is 100 feet, it is wise to use a length of transmission line of approximately 91 or 137 feet corresponding to either 2 or 3 half wavelengths of regular RG/58U or RG/59U line:

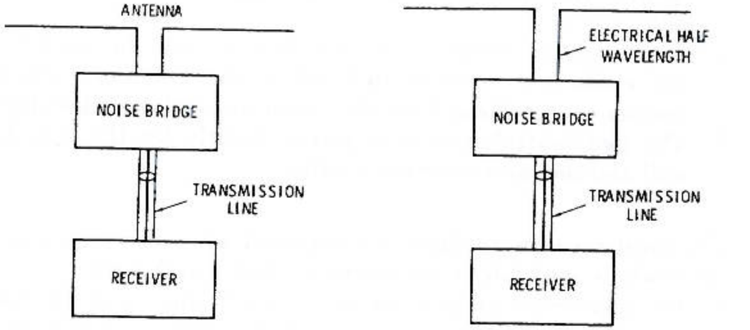
$$\text{Line length} = \frac{650}{7.1} = 91.55 \text{ ft.}$$

$$\text{Line length} = \frac{975}{7.1} = 137.3 \text{ ft.}$$

APPENDIX IV

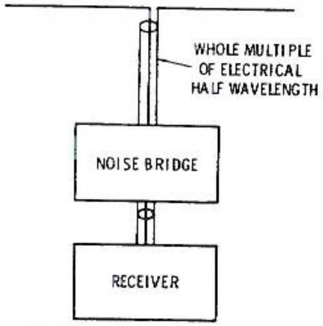
Measuring the Resonant Frequency and Resistance of an Antenna With the Antenna Noise Bridge

The antenna noise bridge is battery operated and can often be placed at the antenna feed point, Fig. A-IV-1. It is of small size and no external signal source is needed. A noise generator source is a part of the device.



(A) Bridge at feed point of antenna.

(B) Bridge at half wave from antenna terminals.



(C) Bridge at the receiver.

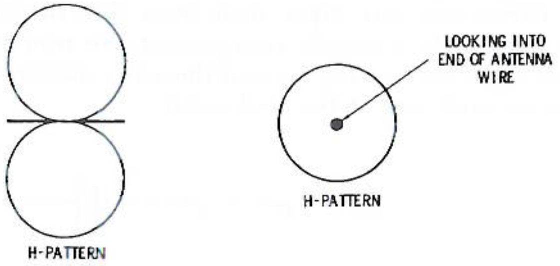
Fig. A-IV-1. Arrangements for measuring antenna resonance and antenna resistance.

by approximately 5 per cent. A practical equation for calculating the length of a half-wavelength dipole is:

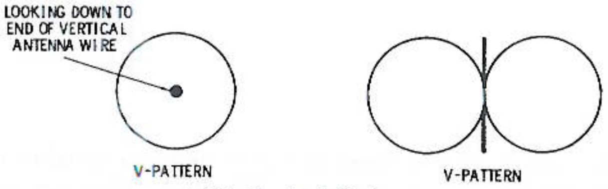
$$\lambda/2 = \frac{468}{f\,\text{MHz}}$$

This length is influenced some by conductor dimensions, height above ground, and nearby conducting objects.

The directional pattern of a dipole antenna is a figure 8 with maximum radiation and sensitivity broadside to the antenna wire (Fig. 2). The vertical radiation pattern for a horizontal antenna is circular. For a vertical dipole, the horizontal pattern is circular, while the vertical pattern in free space is a figure 8. In a practical situation the vertical pattern is modified by the influence of ground.



(A) Horizontal dipole.



(B) Vertical dipole.

Fig. 2. Free-space dipole radiation patterns.

When a dipole antenna is fed with a 72-ohm line and the transmitter output loading circuit can be tuned to an output impedance of 72 ohms, the entire system is matched, and there is efficient transfer of power to the antenna. The standing wave on the transmission line is minimum and there is minimum attenuation of the signal by the line. In this case the matching is unaffected by the overall length of the line. Of course, losses increase with line length as a function of line attenuation figures. Under

This can be checked throughout the text by comparing the formula dimensions with those practical situation dimensions shown on the various antenna illustrations. If you have no means for checking and trimming antennas and lines use dimensions given in the illustrations and duplicate exactly the antenna arrangement shown.

equation for determining the physical length of an electrical half-wavelength line for a given frequency is as follows:

$$\textbf{Line length} = VF \times \frac{492}{f\text{MHz}} \times \textbf{whole multiple of } \lambda/2$$

The SWR measurement technique requires the use of a signal source (transmitter operated at low power level or a signal generator with an output capable of supplying adequate signal level to the SWR device). Because of transmitter designs, it is sometimes necessary to operate the transmitter at normal output power level, so that its operating conditions are favorable for matching into 50 ohms.

The usual procedure for operating your SWR meter is employed. In most cases when using the formula dimensions given in Charts 1 through 6 the antenna will be cut long and to a resonant frequency lower than that which is desired. Therefore if you tune your transmitter to the desired frequency and make an SWR measurement it will be higher than that which can be ultimately obtained. As you tune the transmitter lower in frequency the SWR reading drops. The actual minimum may be found considerably lower than desired.

The antenna may now be trimmed as you watch the SWR minimum move up toward the desired operating frequency. The resonant frequency indication and the SWR readings using this technique are reasonably accurate, and are more indicative of operating conditions than is indicated by random insertion of an SWR meter into a transmission line. In fact, with this method readings were quite comparable to those obtained using the antenna noise bridge for the many dipole and resonant long-wire antennas covered in this book.

The purpose of a line tuner is to provide the most favorable loading of a transmitter, although the impedance looking into the transmitter end of the transmission line is not optimum. Such a line tuner permits a given antenna to be used at a frequency removed from the limited frequency range for which it presents optimum loading conditions for the transmitter. It also permits the loading of a random length of antenna wire or permits a given antenna type to be operated on more than one amateur band. Such facility adds convenience and versatility to a station.

It must be emphasized that a line tuner does not improve the operation of an antenna and does not improve standing-wave conditions on the transmission line. It cannot duplicate the performance of an antenna made resonant at a specific frequency and matched precisely to the transmission-line system at that frequency. Even when using a tuner the very best antenna-system performance is obtained by establishing favorable resonant conditions at the antenna and using optimum lengths of transmission line that correspond reasonably close to whole multiples of a half-wavelength.

A line tuner does permit you to design an antenna system for peak performance over a certain desirable band of frequencies, and, with a tuner, you can at least operate your transmitter off of these frequencies and obtain results that are superior to those obtained without using a tuner. At the same time your transmitter operates under no burden because it sees a proper load impedance.

The tuner of Fig. A-VI-1 has been designed for optimum operation on the 10-, 15-, and 20-meter bands. It will also function on the 40-and 80-meter bands by connecting fixed capacitors of appropriate value across the variable capacitor (C_1).

The matching network is basically a T-section low-pass filter. Although there is some interaction between the two sections of the filter, inductor L_2 at the transmission-line (antenna) end of the tuner matches the antenna system impedance to the tuner, while the taps on inductor L_1 provide matching adjustment between the tuner and the transmitter and tune out reactive components reflected from the antenna system. Theoretically the ohmic value of the reactance of capacitor C_1 must be:

$$X_{C1} = \sqrt{Z_{in} R_T}$$

where,

Z_{in} equals input impedance of line,

R_T equals the output impedance of transmitter.

SECTION 3. LONG-WIRE ANTENNAS

SECTION 4. VEE-BEAM ANTENNAS

SECTION 5. LONG VEE-BEAM ANTENNAS

SECTION 6. RHOMBIC ANTENNAS

that the best performance is obtained with the transmitter preset. Some manufacturers provide tables for a match to specific impedances. If such is the case, preset the dials for 50-ohm operation.

Before turning on the power, preset the two tuner switches in accordance with the tuner information of Fig. A-VI-1. Operate the transmitter at low power and switch off the power whenever you change tuner switch positions.

Capacitor C_1 acts in a resonant way. If you are using the correct tap of inductor L_1 there is a dip in the SWR reading as you tune through the minimum position. The switch positions of inductor L_2 determine just how low an SWR reading can be obtained as the capacitor is tuned through its minimum. Thus various L_2 positions should be tried to determine the best minimum. If your minimum on any one band cannot be made to fall below 1.5, experiment with the appropriate tap positions of L_2. Likewise if your minimum seems to be indicated at the minimum or maximum capacitor settings, a change in the L_1 inductor tap is indicated.

Using this technique the tuner of Fig. A-VI-1, when used with the antenna of Fig. 40, provided standing-wave ratios of less than 1.3 to 1 on any frequency in the 10-, 15-, and 20-meter bands.

One unusual condition arises when employing a line tuner of this type with a dipole, inverted-vee, or horizontal vee beam. A false matching position can show up for which the inner conductor of the transmission line and one side of the antenna acts as the

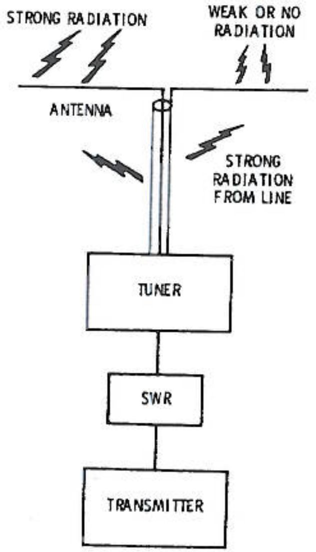


Fig. A-VI-3. Result of a tuner tuning the line and one antenna leg as random length of wire.

Two limited-height telescoping masts (up to 36 feet) are available from Radio Shack. PVC piping can also be used with excellent results. Usually the longest length available is 20'. Two larger diameter sections can be bolted together and guyed to form a very rigid mast. Clothline guying is no longer advisable --- quality has declined over the years. Stout Dacron line or wire guys are appopriate. A sturdy self-supporting mast is attractive except for the trouble of raising and lowering --- a hazard and costly, too. The latter is not too attractive to the persistent antenna experimenter. A lower guyed mast that can be easily lowered and raised is more to his liking.

A *quality tuner* is also appropriate in obtaining a good match to the critical output characteristics of modern transmitters.

Amateur band frequency changes have been made over the years. Please check the latest band allocations. Novice bands in particular have been shifted. There is a sideband allocation on 10 meters for novice use.

APPENDIX VII

Antenna Tuner for Long-Wire Vees and Rhombics

The purpose of an antenna tuner is to match and obtain the maximum transfer of r-f energy between the antenna end of a

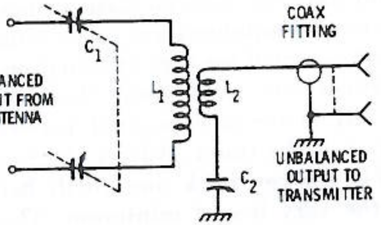


Fig. A-VII-1. Antenna tuner for vee, center-fed, long-wire, and rhombic antennas.

C_1 *2 140-pF variables, ganged with insulated shaft connector*
C_2 *200-pF variable*
L_1-L_2 *Plug-in coils (L_2 centered within L_1). L_1 AIR DUX 2006T except AIR DUX 2010T for 80 meters. L_2 AIR DUX 1610T.*

Regular Coil Sizes.

Band	L_1 Turns	L_2 Turns
10-15	6	2
20	10	3
40	18	6
80	44	10

Intermediate Coil Sizes

Band	L_1 Turns	L_2 Turns
10-15	4	1
20-40	14	4
80	32 (2010T)	8

First Printing - 1969
Limited Reprinted Edition - 1992

MFJ ENTERPRISES, INC.
P. O. Box 494, Mississippi State, Mississippi 39762