quite near to each other because of the 0.1 wavelength spacing which amounts to only 25 feet for 80-meter sideband operation.

The inverted-vee parasitic construction is ideal for any combination director and reflector operation because the parasitic ends are near ground level. A 40-meter inverted-vee with a combination director-reflector parasitic is shown in Fig. 78. A variety of feed arrangements can be employed including direct connection to coaxial line, stub, 1-to-1 balun, line tuner, and last, open-wire along with a balanced tuner. Refer to topics 1, 2, 3, 8, 35, 38, 39, 40, and 42.

44 —Multiband Inverted-Vee and Parasitic-Element Combinations

The inverted dipole is an attractive antenna because band changes can be made conveniently from ground level. Likewise, an inverted parasitic element can be changed over conveniently at ground level for multiband operation. The technique is covered in topics 34 and 36. Such a bandswitching parasitic-element antenna can be constructed conveniently for 40 and 80 meters or for 40-, 80-, and 160-meter operations.

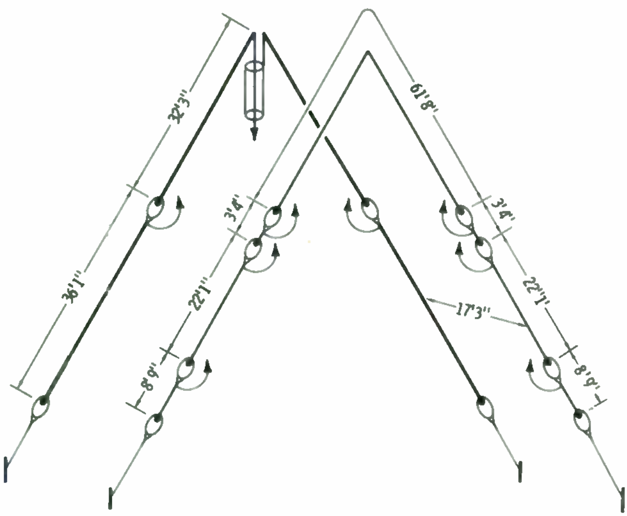


Fig. 79. Inverted-vee parasitic reflector-director combination for 40 and 80 meters.

Practical dimensions for 40- and 80-meter operation are given in Fig. 79. Keep the apex angle 120° or greater. The driven element uses a single pair of jumpers. These are opened for 40-meter operation and closed on 80. Note that the parasitic element contains four pairs of insulators. They permit bidirectional operation of the antenna. On 40 and 80 meters the parasitic operates either as a director or reflector. With the innermost pair of jumpers open, the parasitic functions as a director on 40 meters. When all jumpers are closed, it operates as an 80-meter reflector.

The spacing is $\lambda/4$ on 40 meters. This amounts to approximately 0.125 wavelength on 80 meters.

If space is available, the three-band version can be constructed to include 160 meters. Considerably more erection space is needed because of the long length of the 160-meter legs. Ideal spacing is not so readily obtainable as for the two-band version. However, a spacing of 0.1λ on 160 meters is used. This corresponds to a spacing of approximately 0.2λ on 80 meters and 0.4λ on 40. A sacrifice in 40-meter gain is made. Refer to topics 1, 2, 3, 8, 12, 34, 36, 38, 39, 40, 42, and 43.

45—Single-Mast Inverted Vee With Parasitic Element

A director or reflector can be added to an inverted dipole antenna in the manner shown in Fig. 80. The legs of the inverted dipole extend out in opposite directions or can be tilted forward slightly (no more than 120°). The parasitic-element reflector or director is continuous and also spans outward from the center mounting position. However, the parasitic elements have a greater tilt so that the separation of the dipole and parasitic ends falls somewhere between 0.1 and 0.25 wavelength.

Dimensions for 40-meter operation are given in Fig. 80. The parasitic element serves either as a director or reflector depending upon whether the jumpers of the innermost insulators are opened or closed. The length of the reflector must be made somewhat longer when it tilts back away from the driven element. Its ends should extend beyond the ends of the driven element as shown in the small insert of Fig. 80. A value of $540/f$ is usually long enough. Final trimming to a specific frequency can be accomplished at ground level.

In addition to the bidirectional switching of the parasitic element this arrangement can be oriented readily from ground level. The

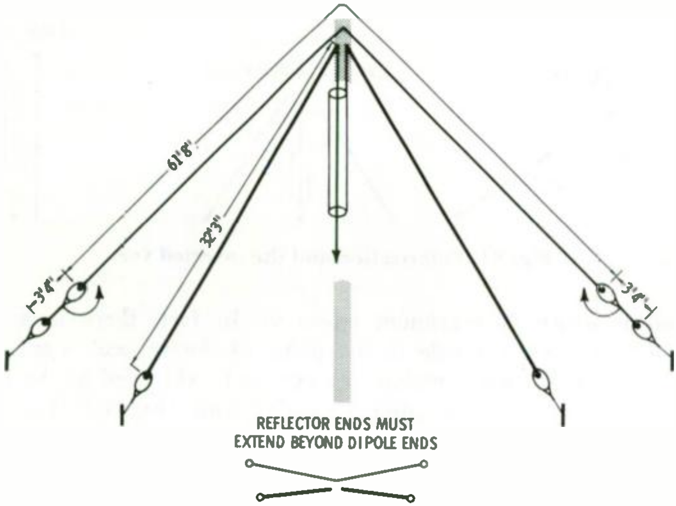


Fig. 80. Single-mast inverted vee with parasitic element.

elements can be moved about to favor a given direction. The sharpness of the directivity of this type of antenna is not as good as when the antenna elements are horizontal. However, there is an improvement in a given single direction, and, at the same time, the omnidirection characteristic is good. It is possible to construct two- and three-band versions of the same antenna using appropriate jumpers for the driven and parasitic elements. Refer to topics 1, 2, 3, 8, 12, 34, 35, 36, 38, 39, 40, 42, 43, and 44.

46—Acute-Angle Vee With Parasitic Element

The angle between the two legs of an inverted dipole has much to do with the dominant polarization of the emitted wave. When the angle approaches the horizontal (Fig. 81), the dominant polarization is horizontal and maximum radiation is broadside to the antenna legs. There is some vertically polarized radiation off the ends. However, as the apex angle is made more and more acute, the magnitude of the vertically polarized component coming off the ends increases while the horizontally polarized broadside radiation decreases. The extreme case as shown in Fig. 81 occurs when the apex angle has been decreased to the extent that the two legs are parallel to each other. In this case the bulk of the energy is radiated as a vertically polarized

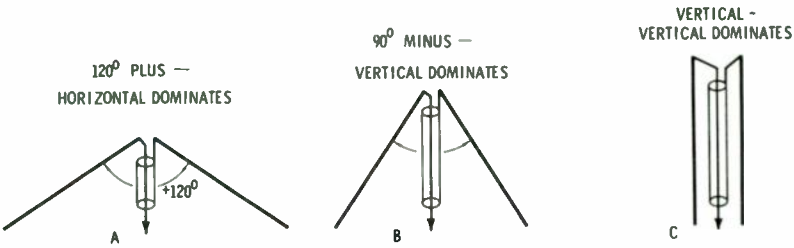


Fig. 81. Polarization and the inverted vee.

component which is maximum edgewise. In fact, there is a rather deep null exactly broadside to the plane of the vertical legs.

The very simple construction of example C when fed at the bottom and attached to a rotator using a wooden mast (Fig. 82) has a good directional characteristic. Although this cannot be considered a big transmitting beam antenna it can be loaded simply with a stub. The very sharp receiving null broadside to the frame is a definite aid in minimizing received QRM.

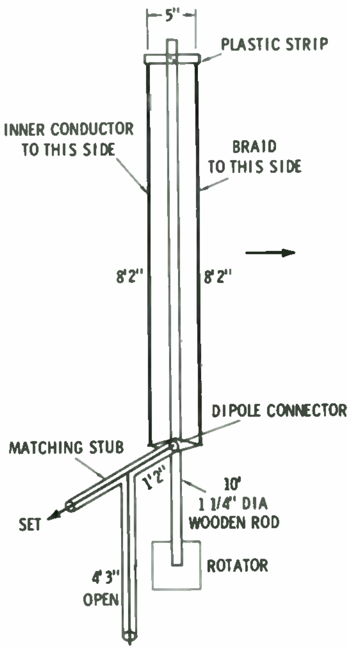


Fig. 82. Simple directional vertical for 10 meters.

When a coaxial feedline is used the unbalance can be used to advantage to obtain a unidirectional pattern. Maximum radiation and sensitivity are in a line between the side of the frame fed by the center conductor of the coaxial line toward the side attached to the coaxial braid (Fig. 82). It is a simple vertically polarized beam construction.

More transmit gain and higher receive sensitivity can be obtained by opening up the angle as shown in Fig. 83. Of course, the angle may not be increased too much because of the resultant increase in horizontally polarized components that are radiated broadside to the plane of the inverted dipole legs. In practice an angle of 90° or less ensures strong vertically polarized radiation and only a relatively low level broadside horizontal radiation. A unidirectional pattern is obtained by adding a parasitic director or reflector (Fig. 83B).

It is easy to suspend this type of beam between two masts which make it readily adaptable to both high- and low-band operation. The

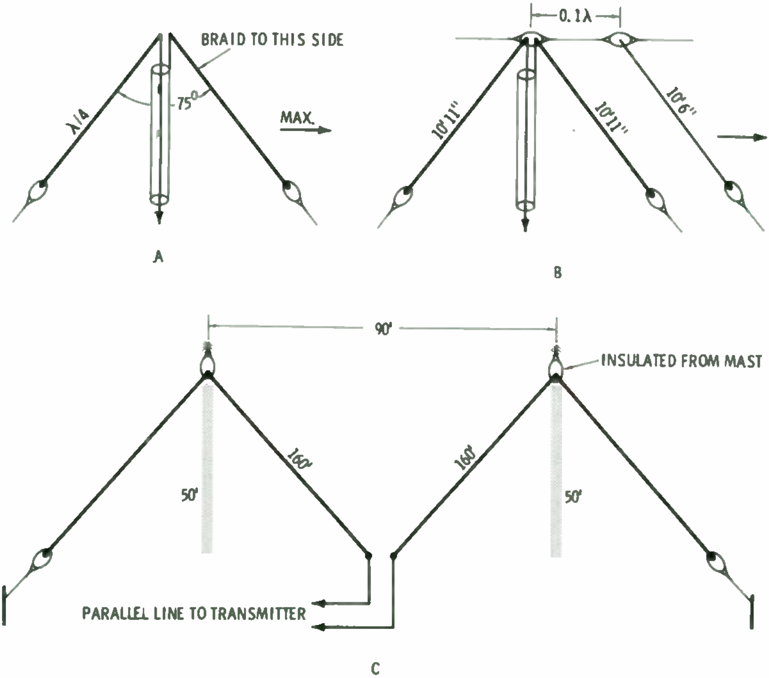


Fig. 83. Acute-angle inverted vee's.

suspension span can be made of wire, hanging the vee and parasitic elements from insulators, or from plastic clothesline (nonmetallic core). This antenna does a fine job with the antenna ends near ground level. With the antenna ends about 4 or 5 feet above ground level they are accessible for tuning, bandswitching, and pattern changing.

The practical antenna shown in Fig. 83B was cut for 15-meter operation. A single jumper permits the parasitic element to be used either as a director or reflector. Tuners and open-wire transmission line can also be used with the antenna type. This antenna plan can be applied to long wires also. The antenna of Fig. 83C, with open-wire line and balanced tuner, performed very well on all bands 10 through 160. High gain and sharp bidirectivity off the ends were obtained 10 through 40 meters. Gain on 10 meters surpassed a three-element beam. Patterns were more omnidirectional on 80 and 160 meters. Refer to topics 1, 2, 3, 8, 12, 34, 35, 36, 38, 39, 40, 42, 43, 44, and 45.

SECTION 6

Horizontal Phased Arrays

47—Horizontal End-Fire, 90° and 180°

In a 180-degree end-fire configuration two horizontal dipoles are fed out of phase (Fig. 84A). Maximum radiation is broadside to the

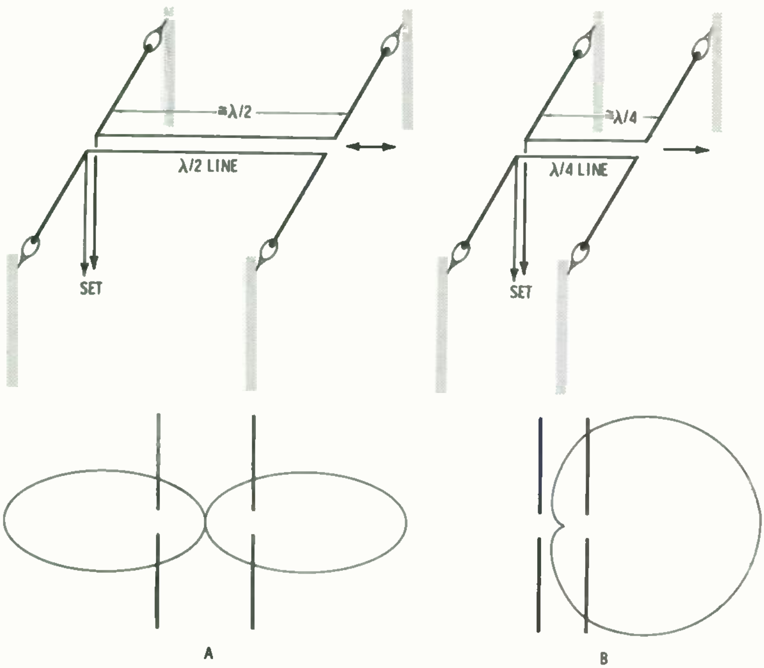


Fig. 84. Basic end-fire configurations.

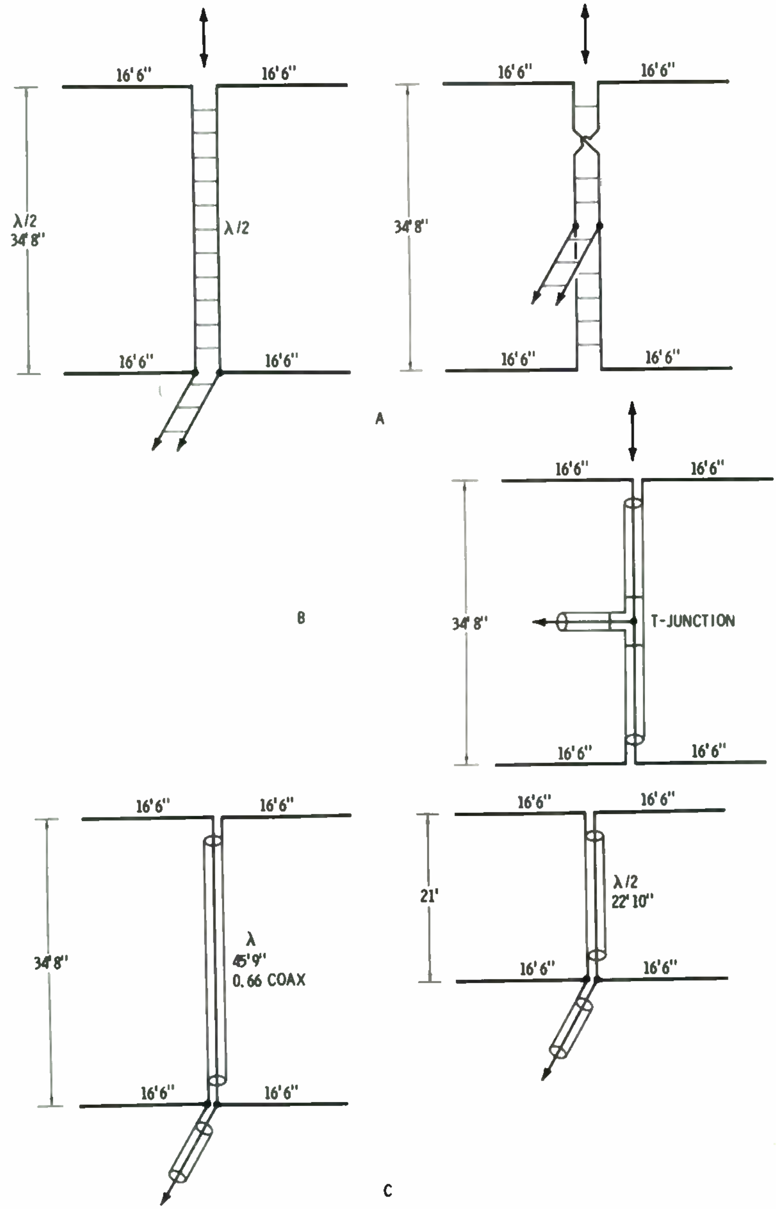


Fig. 85. Feed methods for end-fire (180°) two elements.

antenna wire just as in the case of a horizontal dipole. However, the figure eight is a narrower one and the gain in the maximum directions is approximately 4 dB.

Practical dimensions for 20-meter operation are given with the antenna of Fig. 85. Various feed methods are permissible. Open-wire line is ideal for this type of configuration because its velocity factor is near unity. Therefore, the two half-wavelength antennas can be separated by exactly a half wavelength. The interconnecting half-wave section of open-wire line produces the phase reversal needed to feed the two antennas out of phase. The alternative arrangement of A is to feed at the center through quarter-wavelength segments of open-wire line. However, the line on one side is transposed so as to obtain out-of-phase feed of the two dipoles. A balanced tuner, either at the antenna or at the transmitter, is required. When a tuner is used, the antenna can also be loaded on other bands.

When coaxial transmission line feeds the two dipoles, use a T-junction at the center. One coaxial feed line is transposed. This involves connecting the inner conductor of one feed line to the left leg of No. 1 dipole and the outer braid of the other section of coaxial feed line to the same side of the second dipole. This is shown in Fig. 85B.

When the interconnecting line is to be run from one dipole to the other, the velocity factor of the coaxial line must be considered. To obtain out-of-phase feed with one-half wavelength spacing, it is necessary that the coaxial line between the two be an electrical full wavelength and transposed in its feed, as shown in C.

An alternative method that provides somewhat less gain is shown in C. In this case the two dipoles are spaced less than a half wavelength so that a coaxial transmission line of an electrical half wavelength can be strung between them. If the coaxial line has a velocity factor of 0.66, the spacing between the two dipoles should be somewhat less than ($0.66 \times 0.5\lambda$). If the velocity factor is 0.81, the spacing should be less than ($0.81 \times 0.5\lambda$).

When using coaxial feed systems a line tuner can be employed at the transmitter to lower the SWR. An alternative approach is to use the stub-matching scheme detailed in topic 41.

An end-fire pair of verticals can be spaced and fed in such a manner that a unidirectional pattern results. To do so the antennas must be separated by $\lambda/4$ and one vertical must be fed 90° behind the other (Fig. 84B). The direction of maximum radiation is in line with the two verticals in the direction of the vertical receiving the lagging excitation. The 90° lag is obtained by feeding the one vertical through

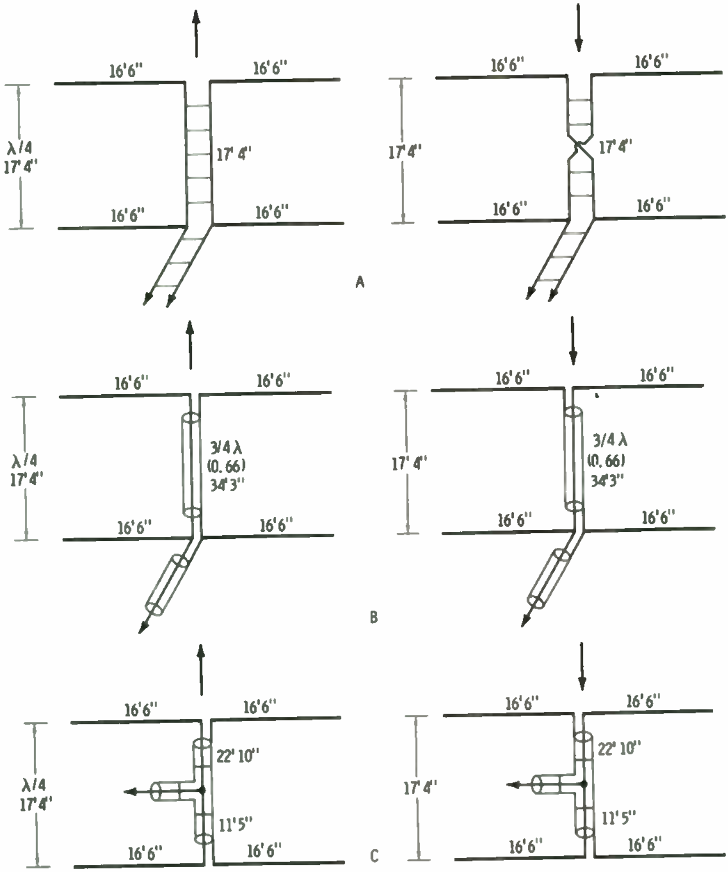


Fig. 86. Ninety-degree end-fire feed methods.

an additional $\lambda/4$-section of line or an appropriate odd multiple of an electrical quarter wavelength. The 90° feed method produces a broad unidirectional forward load. At the same time, the back response dips down to a minimum. This is an ideal situation in locations troubled by severe QRM pickup from the rear.

Again, open-wire line affords a good feed method. With the two dipoles spaced $\lambda/4$, the quarter-wave section of line between the two dipoles provides the 90° feed (Fig. 86A). Furthermore, by transposing the feedline it is possible to obtain 270° feed which will reverse the pattern direction.

Coaxial feed methods are shown in Fig. 86B. In the first arrangement the two dipoles are separated by a quarter wavelength with the second dipole being fed from the first dipole through a section of coaxial line which is an electrical ¾-wavelength long. The maximum is in the direction from the second dipole toward the transmission-line-fed dipole. Pattern reversal can be obtained by transferring the feed line over to the second dipole or by transposing the ¾-wavelength line between the two dipoles.

An alternative feed method involves a center junction and a length of transmission line on one side that is an electrical quarter wavelength longer than on the other. Pattern reversal can be obtained simply by transposing either one of the feed lines at the point where they connect to the dipole. Refer to topics 1, 2, 3, 8, 12, 16, and 17.

48—Broadside and Collinear Two-Element Horizontals

Two dipole antennas, one stacked a half wavelength above the other and fed in phase, result in a figure-eight horizontal pattern and a figure-eight vertical pattern (Fig. 87). The horizontal pattern is the same as that obtained with a single horizontal dipole. The vertical pattern sharpens and produces low-angle radiation, a favorable condition for DX operation. Open-wire line feed is again attractive because its velocity factor is near unity and the transmission line can be attached to the bottom dipole, transposed and then continued on to the top dipole. Center feed is also feasible but the transmission line must be routed up to a midpoint between the top and bottom dipoles.

If there are space limitations the two dipoles need only be separated a quarter wavelength with some sacrifice in gain. Center feed provides in-phase operation of the two dipoles (Fig. 87B). Maximum gain is obtained when the two dipoles are separated by ⅝ wavelength. Center feed is used.

Coaxial feed methods are shown in Fig. 88. The center-tap feed method is most often used for coaxial line using a T-junction. Spacing can be anywhere between ¼ and ⅝ wavelength, according to mounting requirements.

The coaxial feed method (Fig. 88B) uses a full-wavelength section of coaxial line between the bottom and top dipoles. If the velocity factor is 0.66 wavelength, this corresponds to a section of coaxial line of 45′9″ (0.66 × 984/14.2) on 20 meters. A spacing of ⅝ wavelength in free space corresponds to approximately 43′3″ (⅝ × 984/14.2) on

20 meters. Therefore, with a separation corresponding to the length of the full-wave section of transmission line there can be in-phase feed, and, at the same time, the separation between the two broadside

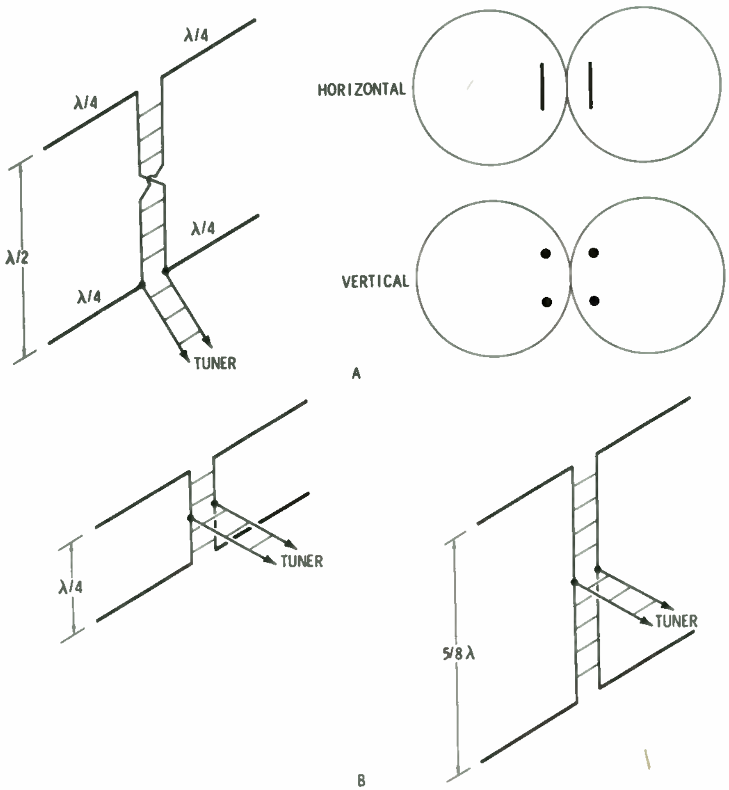


Fig. 87. Two-element horizontal broadside antenna.

dipoles provides maximum gain. Dimensions for this antenna for 20-meter operation are given in Fig. 88B. However, a similar relationship exists for other bands.

The collinear antenna (Fig. 89) is not used too frequently on the low-frequency bands because of space requirements. In a collinear configuration the two antennas must be placed end to end. However, for good performance it is necessary that the two ends be well separated. The collinear pattern is a sharpened figure eight broadside to the collinear elements.

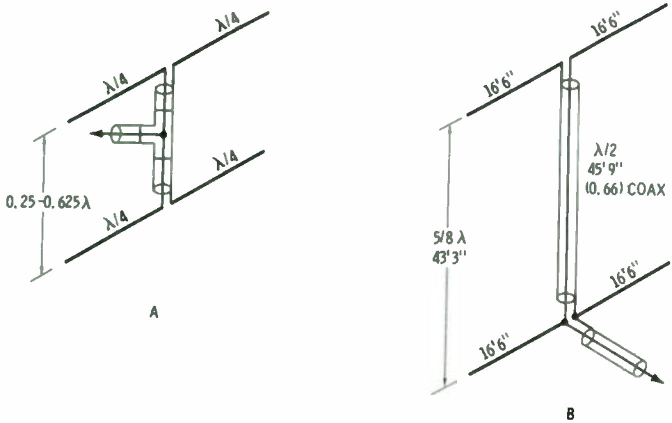


Fig. 88. Coaxial feed methods for 2-element broadside.

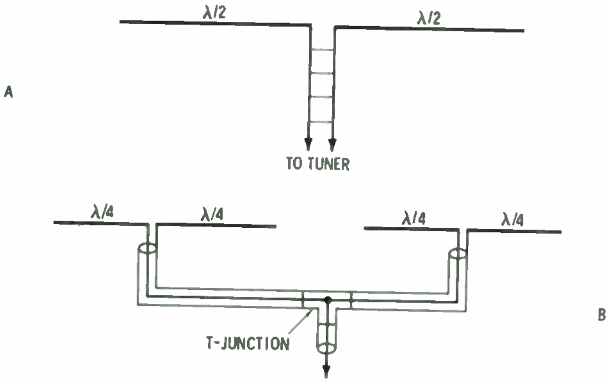


Fig. 89. Collinear feed methods.

The two most common feed methods are shown in Fig. 89. In A, each antenna leg is a half wavelength long. These two antenna legs are end-fed, which is a maximum voltage and minimum current point. Therefore, it presents a high impedance to the transmission line, and open-wire line with balanced tuner represents the preferred feed method.

The low-impedance feed method is shown in B. This method of feed can employ coaxial transmission line. A T-junction is located at the center between the two collinears. An equal length of line goes out to each of the dipoles and provides in-phase excitation. Preferred separation between the ends of the dipoles is at least λ/4. More gain is obtained with λ/2 separation between ends.

All of the common methods of feeding can be employed with the phased horizontal antennas—direct coaxial connection with a line tuner, open-wire line with a balanced tuner, stub matching, etc. Refer to topics 1, 2, 3, 8, 12, 16, 18 19, 41, and 47.

49—Collinear, End-Fire (180°)

The simple full-wavelength collinear antenna can be combined with more than one collinear element in an end-fire or broadside combination. The antenna of Fig. 90 is an end-fire collinear combination with

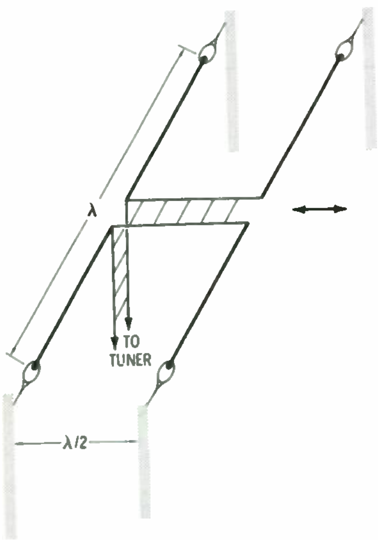


Fig. 90. Collinear, end-fire, 180° phased horizontals.

the end-fire pair being fed 180° related. The horizontal radiation pattern is an elongated figure eight. The end-fire connection also provides a favorable low-angle vertical radiation.

This antenna is a high-impedance one because of the collinear connection, and open-wire transmission line is preferred. An alternative is to use stub matching. Refer to topics 1, 2, 3, 8, 12, 16, 18, 19, 41, 47, and 48.

50—End-Fire (90°), Broadside

The 90° end-fire connection provides a unidirectional pattern that can be combined with the low vertical-angle characteristics of a broadside connection. This antenna has good gain and a single-direction pattern. Such an antenna also has a minimum of back pickup and a consequent reduction in the QRM pickup from the rear.

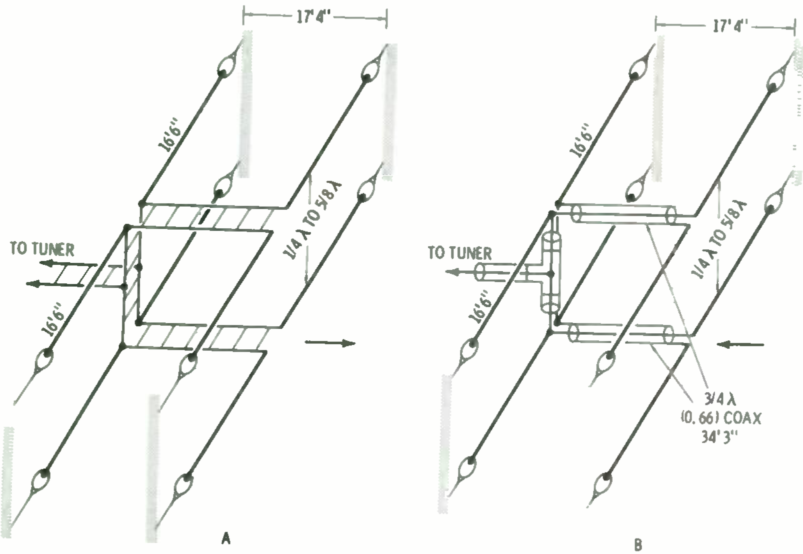


Fig. 91. End-fire (90°) broadside antenna.

The antenna of Fig. 91 is dimensioned for 20-meter sideband operation. Quarter-wave open-wire line or ¾-wavelength coaxial line links the end-fire pairs. Note that the ¾-wavelength line must be transposed if the same pattern direction is to be obtained for open-wire and coaxial feed. The pattern can be reversed simply by reversing connections at the outside end-fire dipoles. The broadside grouping is fed correctly by attaching the transmission line at the center between the upper and lower dipoles.

A variety of feed methods can be employed as with most of the phased antennas. Feed methods can be direct connection of coaxial transmission line and a line tuner, open-wire line with a balanced tuner or a stub-matching arrangement. Refer to topics 1, 2, 3, 8, 12, 16, 18, 19, 20, 41, 48, and 49.

51—End-Fire Beam

The end-fire configuration, because of the close spacing of its elements, also lends itself to the construction of small beams for 10 and 15 meters. It can be noted from Fig. 41 that with $\lambda/8$ spacing and phasing angle between 90° and 135° that a reasonably good unidirectional pattern can be obtained. A 15-meter antenna using this principle is shown in Fig. 92. The $\lambda/8$ spacing is:

$$\text{Spacing} = \frac{123}{21.3} = 5'9''$$

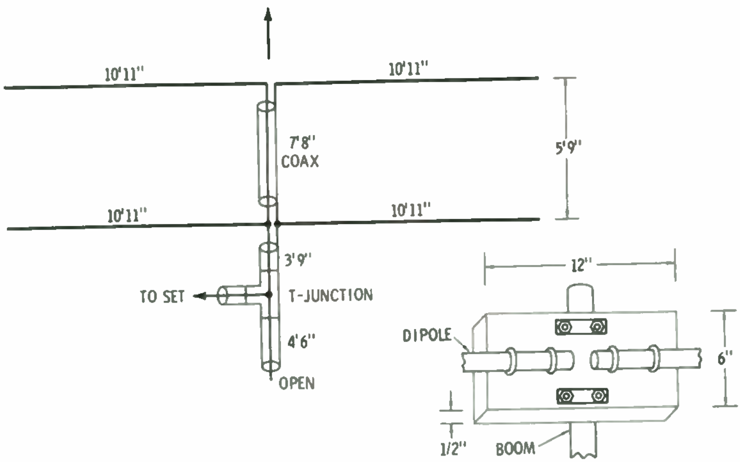


Fig. 92. Close-spaced end-fire beam.

A $\lambda/4$ section of coaxial line with a velocity factor of 0.66 is:

$$\text{Phasing line} = \frac{246 \times 0.66}{21.3} = 7'8''$$

Stub matching reduces the SWR to a very low value. This antenna has a broad forward lobe and when attached to a rotator it is possible to maneuver the antenna for a minimum rear pickup of QRM at the same time the desired signal is not changed too much in magnitude as the antenna is rotated over a reasonable range. Stub matching is a trial and error process. Measure SWR and start out with stub values about one foot longer than Chart 6 calculations. Lengths given in Fig. 92 should be satisfactory in most situations.

A very short boom is required and the antenna assembly can be made quite simple. Insulators are cut from plastic sheet according to the dimensions of Fig. 92. U-bolts hold the insulators to the boom. Smaller U-bolts hold the antenna elements to the insulators. Refer to topics 1, 2, 3, 8, 16, 21, 41, 47, 50, and 51.

52—10-15 End-Fire Beam, Open-Wire Line

The use of open-wire line and the balanced tuner of Appendix VII lend themselves well to the construction of a phased two-band beam. Good results are obtained on both bands although the antenna itself is dimensioned for 15 meters (Fig. 93). Two 15-meter dipoles are spaced $\lambda/4$ on a 12-foot boom. The spacing between the end-fire dipoles is:

$$\lambda/4 \text{ spacing} = \frac{236}{21.3} = 11'6''$$

The $\lambda/4$ phasing line is of the same physical length. Adjust line length and spacing appropriately. The spacing of the dipoles is made slightly less than $\lambda/4$, just enough to permit the open-wire line to be interconnected and insulated away from the boom with standoffs. If the antenna is used with a rotator it is of course necessary to provide enough slack in the 450-ohm open-wire line to permit a complete rotation.

Good performance is obtained on 10 meters although the element lengths are somewhat greater than that needed for dipole resonance. Likewise the spacing and phasing is somewhat greater than 90°. A good unidirectional pattern is obtainable. The balanced tuner permits ideal loading on both 10 and 15 meters using the single 10- and 15-meter coil assembly of Appendix VII. Refer to topics 1, 2, 3, 12, 16, 21, 47, 50, and 51.

53—Stacked 10-15 End-Fire Beam

A phased beam antenna can be stacked (fed broadside) to obtain higher gain and improved low-angle vertical radiation. In fact, the antenna of Fig. 93 lends itself well to two-band operation. The two

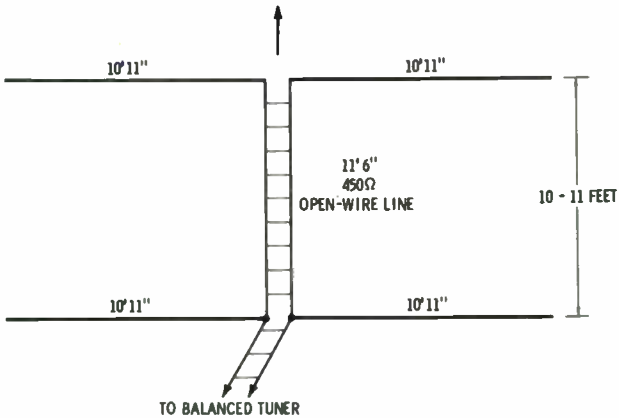


Fig. 93. Ten- and fifteen-meter open-wire end-fire beam.

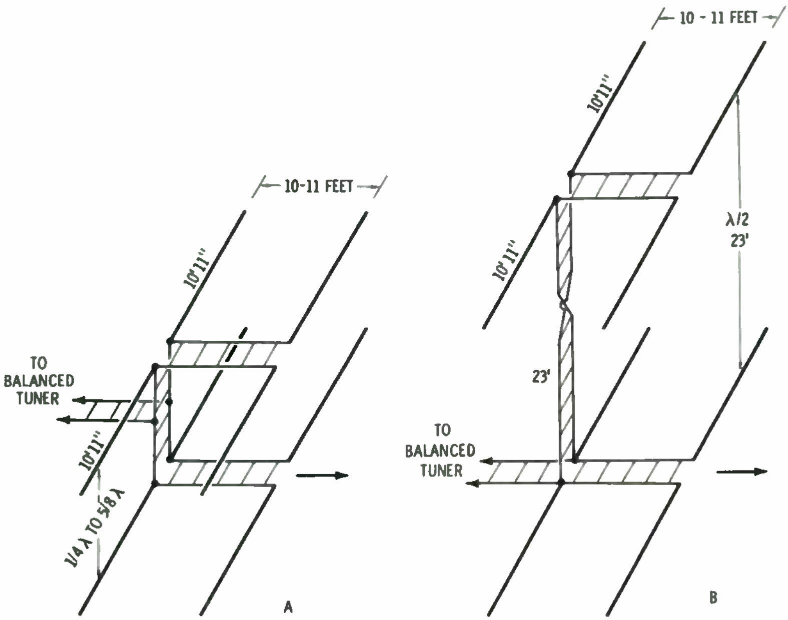


Fig. 94. Stacking end-fire antennas.

sections (Fig. 94A) can be stacked anywhere from a ¼ to ⅝ wavelength apart, depending on mounting facilities. The greater the separation up to the ⅝ maximum is, the higher is the possible gain. However, this gain can only be obtained if the bottom end-fire pair can be kept at least $\lambda/2$ above ground. Regardless of the spacing this expedient helps to improve the low-angle radiation.

For $\lambda/4$ stacking the separation must be 11′6″. This can also be the length of the broadside phasing line. The transmission line that runs back to the transmitter is connected to the midpoint of the broadside phasing line.

If 23-foot half-wavelength broadside spacing is possible, the antenna can be fed at the bottom and the broadside phasing line transposed to obtain in-phase feeding of the two end-fire pairs (Fig. 94B). With this latter arrangement the antenna provides proper broadside phasing only on 15 meters.

If one desires an optimum end-fire pattern on each band it is possible to use telescoping elements that can be pushed in for 10-meter operation and extended full length for 15-meter operation. With the telescoping sections extended for 15-meter operation, the use of the balanced tuner detailed in Appendix VII ensures proper loading of the transmitter when 10-meter operation is desired. Separation between the end-fire pairs should again fall between $\lambda/4$ and $5/8\lambda$, keeping the bottom pair at least $\lambda/2$ above ground. Refer to topics 1, 2, 3, 8, 12, 16, 17, 18, 19, 20, 21, 47, 48, 50, and 52.

SECTION 7

Yagis, Quads, and Triangles

54—Three-Element Yagi, Stub-Matched

The most popular yagi antenna in "hamdom" is the three-element type (Fig. 95). The reflector is cut longer than the driven element and resonates lower in frequency; the director is cut shorter

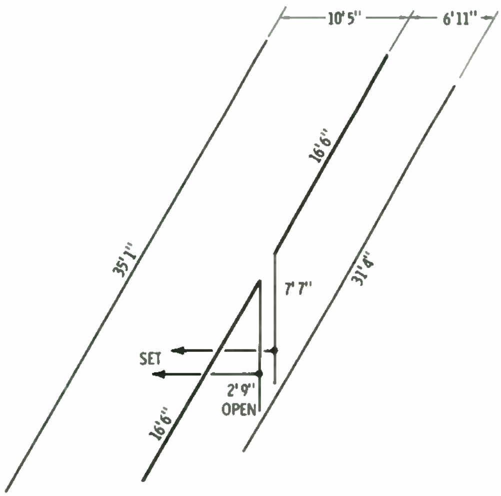


Fig. 95. Three-element 20-meter beam, stub-matched.

and resonates higher in frequency than the driven element. Rule-of-thumb figures indicate that the reflector must be cut at least 5 percent longer than the driven element and the director 4 percent shorter. However, bandwidth is a factor in selecting the most appropriate length. A good practice is to cut the reflector for the lowest frequency and the director for the highest frequency of the desired bandwidth. Dimensions for all-band operation on the various amateur bands are as follows:

BAND	$\lambda/4$ Driven Element $234/f$	Reflector $492/f_L$	Director $450/f_H$	Spacings λ			
				0.1	0.15	0.2	0.25
10	8′2″	17′6″	15′3″	3′5″	5′2″	6′10″	8′6″
15	11′	23′5″	20′11″	4′8″	6′11″	9′3″	11′6″
20	16′6″	35′1″	31′4″	6′11″	10′5″	13′9″	17′4″
40	32′9″	70′	61′8″	13′8″	20′6″	27′4″	34′2″

The most popular matching methods are the closed types of connection such as gamma, T, and delta. There are mechanical advantages because the driven element is continuous and not broken. Some hams favor the more open type of matching using a split dipole driven element. There is evidence that more beam-like characteristics result, especially with regard to receiving. However, this apparent improvement in receive performance may be more directly related to receiver input characteristics rather than the beam characteristics of the yagi.

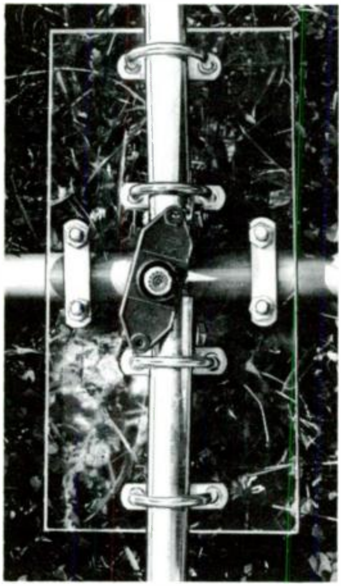


Fig. 96. Plastic insulator for split dipole.

Yagi-style antennas covered in this book emphasize the split dipole with stub matching and the use of open-wire transmission line. The dimensions of Fig. 95 are for a 20-meter sideband beam with driven element cut for 14.25, reflector for 14.2 and director for 14.35 MHz. The stub-matching plan of topic 41 is employed. The stub was adjusted at step-ladder height with the total length of transmission line in the circuit made a whole multiple of an electrical half wavelength at 14.25 MHz. The SWR meter was connected between the yagi coaxial connector and the end of the transmission line. The reading obtained was then used with the chart of topic 41 to determine approximate L and T lengths. Cut each section one foot longer and trim back for lowest SWR. Driven elements can be shortened and the techniques of topic 41 (Fig. 75) used for matching.

The mechanical construction of the driven element is shown in Fig. 96. The insulator is made of 12″ × 6″ × ⅝″ plastic sheet.

A wire-type yagi for 40 meters is shown in Fig. 97. Four poles are needed for this antenna. The wire-driven element can be suspended across the center. Using a λ/4 spacing between driven element and reflector and driven element and director, the four poles can be mounted in a square of approximately 70 feet. If a pair of jumpers

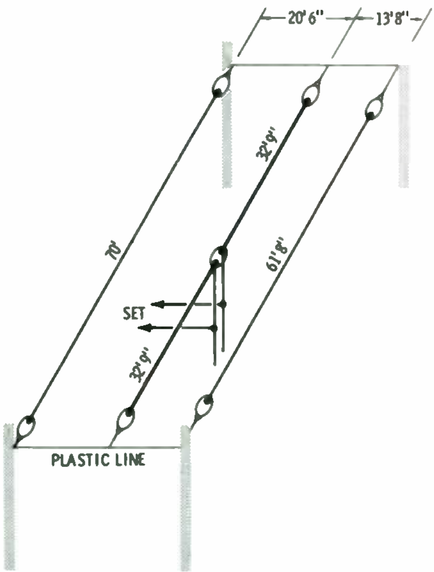


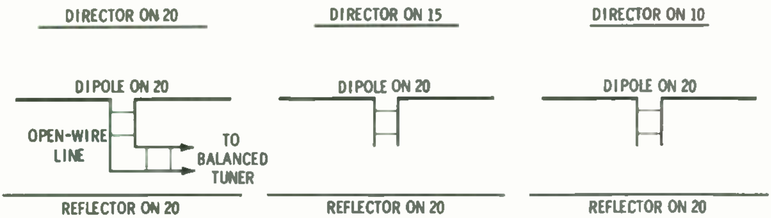
Fig. 97. Forty-meter fixed wire yagi.

are included with each parasitic element and a halyard for letting them down easy, the pattern can be reversed conveniently. Refer to topics 1, 2, 3, 8, 12, 38, 39, 40, 41, and 42.

55 —Three-Element Yagi, Open-Wire Line

Open-wire line represents a low-loss method of feeding a beam. When a long length of line must be employed the comparison between a beam that is coax fed and another one that is open-wire fed is quite surprising, and especially so from the standpoint of reception. The disadvantage is that a balanced tuner (Appendix VII) or a commercial balanced matchbox is needed.

In addition to the low standing-wave ratio seen by the transmitter, the use of a tuner has other advantages. The antenna system is



(A) 20 meters. *(B) 15 and 20 meters.* *(C) 10, 15, and 20 meters.*

Fig. 98. Three-element yagi, open-wire feed line.

peaked for reception on a given frequency. Spurious and harmonic radiations are reduced. Furthermore, it permits a monoband beam to be loaded on other bands as well, particularly those on its high-frequency side. For example, the 20-meter beam of Fig. 98A does load on both 10 and 15 meters and has an acceptable pattern on these bands. On 10 and 15 meters (and particularly on 10 meters) the driven element acts as two collinear half waves. The reflector is effective on both 10 and 15 meters.

If good two-band operation (15 and 20) is desired with some decrease in 20-meter gain, cut the director for 15 (21 feet). A director cut for 10 (15 feet 6 inches) provides three-band operation with a decrease in 20-meter gain. Refer to topics 1, 2, 3, 12, 38, 39, 40, 41, 42, and 54.

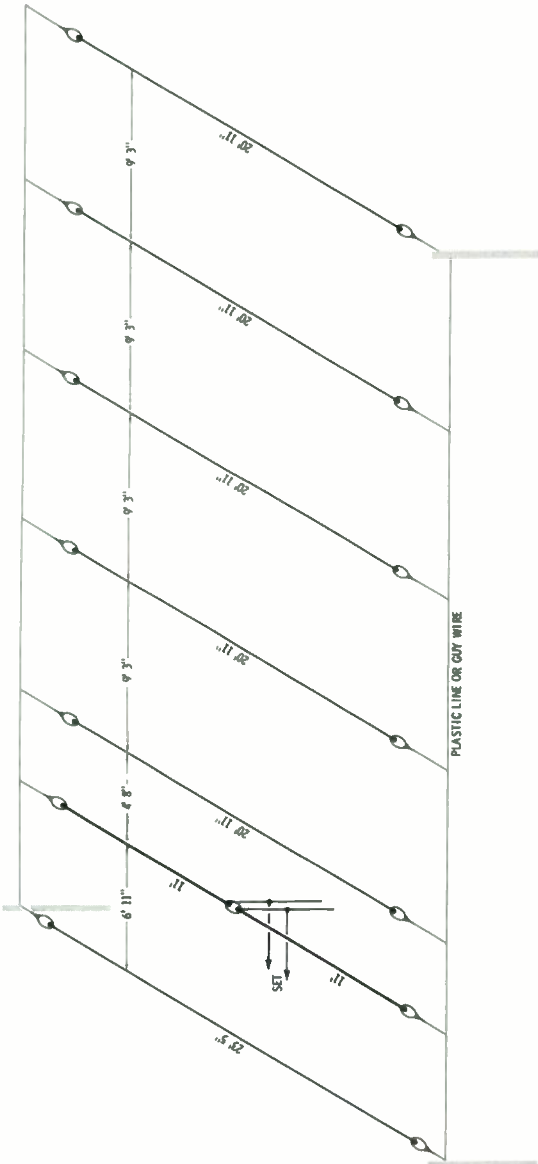


Fig. 99. Suspended 15-meter yagi.

56—Multielement Yagis

More than two parasitic elements can be added to the basic three-element yagi configuration. Four and five element monoband yagis are quite common. They use three and four parasitic directors, respectively. Wide spacing (0.2λ) between directors is typical. Performance measurements and experimentation over the years have indicated that wide spacing of multielement yagis provides more gain, better pattern, and fewer impedance-matching problems as compared to close-spaced types when more than two parasitic elements are used. In some models the first director is close spaced (0.1λ) to the driven element while all succeeding directors are spaced 0.2λ.

A suspended wire yagi for 15-meter operation is illustrated in Fig. 99. Four poles are erected at the corners of a 30′ by 60′ rectangle. This area can accommodate a seven-element yagi with wide-spaced directors.

Dimensions are as shown. Stub matching can be used with coaxial line. For a very long length of transmission line between antenna and transmitter, the open-wire line and balanced tuner provide optimum results. Refer to topics 1, 2, 3, 8, 12, 38, 39, 40, 41, 54, and 55.

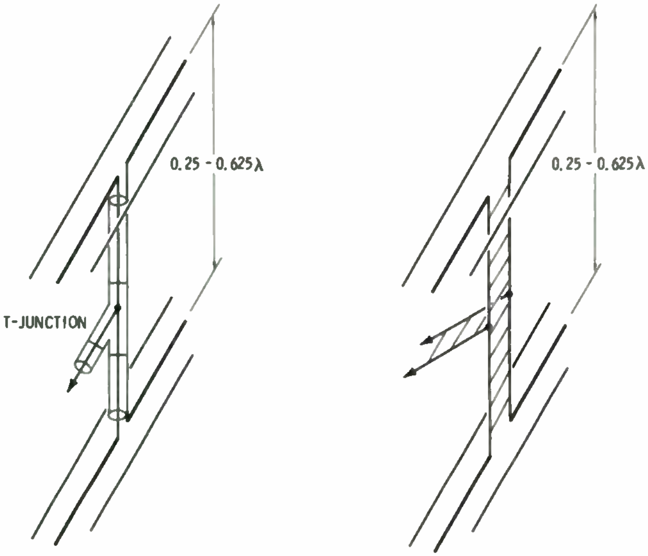
57—Stacked Yagis

The broadside stacking of yagi antennas has produced rewarding performance. The theoretical gain increase, particularly with spacing of only $\lambda/4$, is not encouraging. However, for long-distance work there appears to be an ample improvement in low-angle vertical radiation.

Recommended spacings fall between a $\lambda/4$ and 0.625λ. Higher gains are obtained with wider spacing. However, the good characteristics of stacking are best obtained when the low member (bay) of the stack is at least a half wavelength above ground.

Stacked yagis must be fed in phase. Of course, the easiest way to do this is to feed at the center between bays. A coaxial T-junction can be used for this purpose (Fig. 100A). A stub can be used for matching on the transmission line side of the T junction or a line tuner (Appendix VI).

Open-wire transmission line can be used in a similar fashion as shown in B. With a center-point feed arrangement the bay separation can be set in accordance with the physical needs of the mounted positions.



(A) Coaxial feed system. *(B) Open-wire feed system.*

Fig. 100. Stacking of yagis, midpoint feed.

When the transmission line is to be attached to the bottom bay, the interconnecting feed line must be made an *even multiple of an electrical half wavelength* when not transposed. The two cases are shown in Fig. 101. In example A there is no transposition. Consequently, the length of the line must be a full wavelength. If the velocity factor of the coaxial line is 0.66λ, the physical length of the line must be:

$$\text{Electrical } \lambda = \frac{0.66 \times 984}{f}$$

This indicates that the spacing between bays must be approximately 0.66 wavelength, which is nearly maximum-gain optimum.

If the coaxial line is transposed, a half wavelength segment will suffice. Again, with a velocity factor of 0.66 the length of the transmission line must be:

$$\text{Electrical } \lambda/2 = \frac{0.66 \times 492}{f}$$

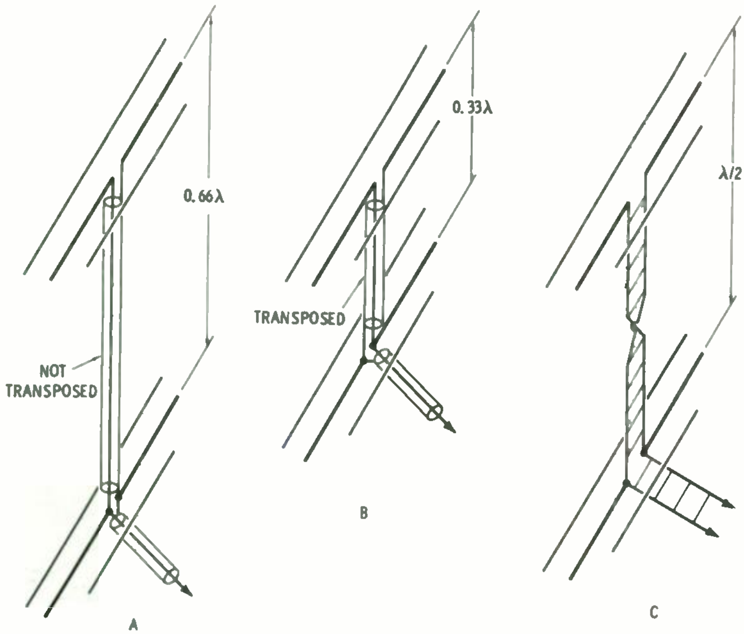


Fig. 101. Stacking of yagis, bottom feed.

To accommodate this requirement it is necessary that the bays be separated by approximately 0.33 (0.66/2) wavelength. Thus with some loss in gain it is now possible to mount the two bays near to each other.

If open-wire transmission line with its velocity factor near unity is used, the separation between bays must be λ/2, provided the interbay coaxial feed line is transposed as shown in Fig. 101C.

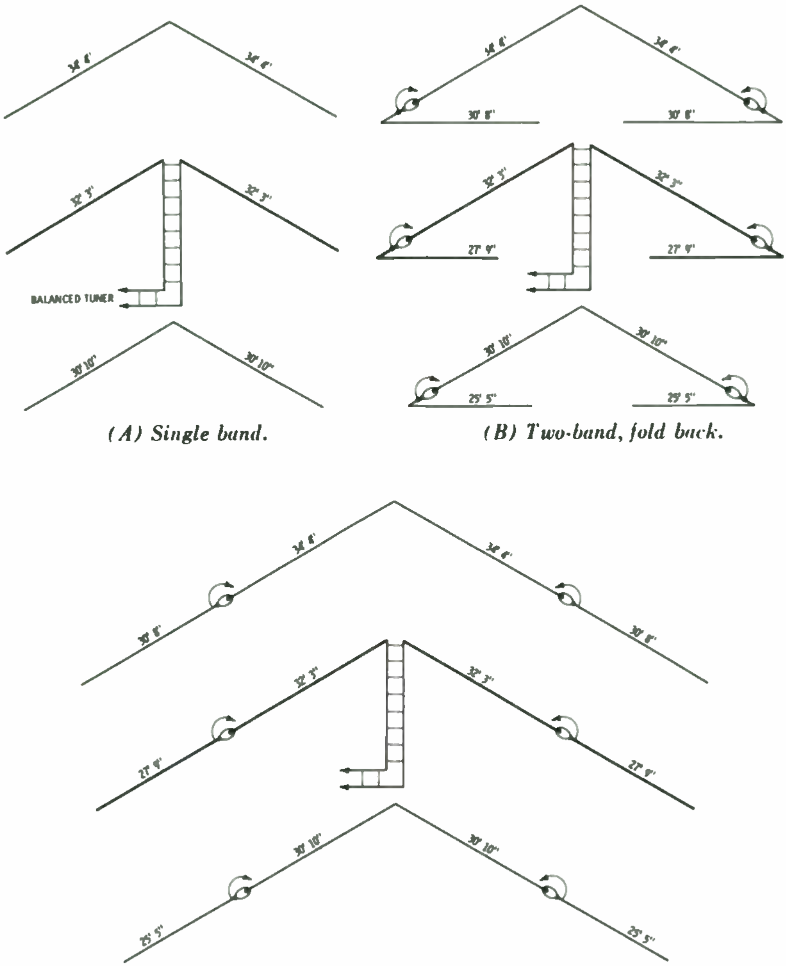
Where coaxial line with a velocity factor of 0.81 is used, an electrical half wavelength transposed feed for 10 meters would have a physical length of:

$$\text{Electrical } \lambda/2 = \frac{0.81 \times 492}{28.6} = 13'11''$$

The separation between bays for 10 meters would be approximately the same, corresponding to about 0.4λ. Refer to topics 1, 2, 3, 8, 12, 28, 39, 40, 41, 54, 55, and 56.

58 —Two-Band Inverted-Vee Yagi for Low Bands

The inverted-vee construction lends itself well to the construction of low-band antennas with yagi-like characteristics. With a 30-to-40-



(A) Single band.

(B) Two-band, fold back.

(C) Two-band, stretched out.

Fig. 102. Single and 2-band inverted-vee yagis, 40 and 80 meters.

foot apex height a combination 40- and 80-meter yagi takes up only limited space (Fig. 102A). For 40-meter operation, it can be confined to an area somewhat less than 60 feet square. Parasitic elements are close spaced. The use of wide spacing ($\lambda/4$) requires about a 70- by 50-foot area. Keep the apex angle greater than 120°.

The addition of jumpers permits two-band 40- and 80-meter operation in approximately the same area. In this arrangement the driven elements and parasitics are folded around toward the center (Fig. 102B). Using wide spacing on 40 meters this becomes a close-spaced beam arrangement on 80. In an area of approximately twice the dimensions (140 feet square), one can erect an 80- and 160-meter combination using three 35- to 50-foot masts.

If space is available, the low-band elements can be stretched out to full horizontal length for both the 40-80 or 80-160 combinations (Fig. 102C). This arrangement is attractive for use with open-wire transmission line. In this case no jumpers are needed and the driven element on the higher-frequency band acts as two half wavelengths fed in a collinear manner. Refer to topics 1. 2. 3, 8, 12, 38, 39, 40, 41, 42, 43, 48. 54, and 55.

59 —10-15 Three-Element Yagi

The 10- and 15-meter bands are unique in that they are spaced rather closely in frequency. A parasitic reflector cut for 15 meters performs well as a reflector on 10 meters. Conversely, a parasitic director cut for the 10-meter band also has directive effects on 15 meters.

When this approach is used to establish dimensions for a reflector and director, and the driven element is suitably matched with a

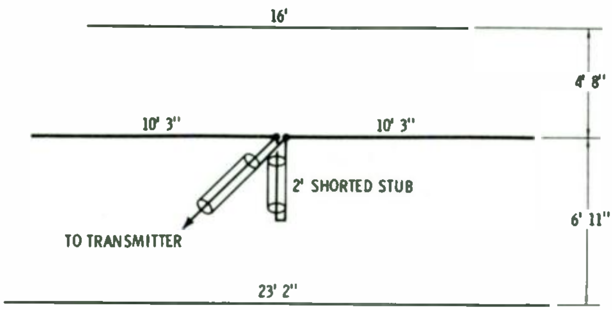


Fig. 103. Ten- and fifteen-meter 3-element yagi.

stub or line tuner, a satisfactory two-band three-element beam of simple construction is possible. Such an antenna is shown in Fig. 103.

The driven element is cut short on 15 and matched directly with a shorted stub. Note that the length of each $\lambda/4$ side is 10′3″ (about 5 percent shorter than the formula value for a $\lambda/4$ dipole segment on 15 meters). A shorted two-foot stub provides a low SWR. Trim carefully for minimum SWR. It should drop below 1.5 to 1.

The reflector was made 23′2″ (a favorable length for 15-meter sideband operation) while the director was made 16′ long (suitable length for 10-meter sideband operation). Transmission-line length is made a whole multiple of an electrical half wavelength. Dipole insulator is a plastic sheet. Refer to topic 54.

When the antenna is stub-matched on 15 meters, no line tuner is necessary at the transmitter. However, the line tuner (Appendix VI) is needed for 10-meter operation. This antenna provides excellent performance on 15 and good results on 10. Refer to topics 1, 2, 3, 8, 41, and 54.

60—Two-Element Quad

The two-element quad has been a popular DX antenna. It consists of a full-wavelength driven element in a perfect square and a longer but similarly shaped reflector (Fig. 104). Optimum gain spacing between driven element and reflector is approximately $\lambda/8$ (0.125

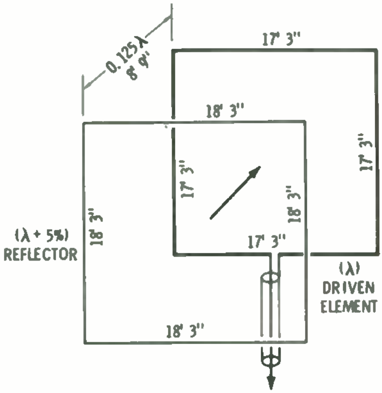


Fig. 104. Twenty-meter 2-element quad.

wavelength). On 20 meters this would be 8 to 10 feet. Quad frames are constructed variously with bamboo, aluminum cross pieces with end insulators, and *fiberglas*.

The overall wire length for the driven element can be determined as follows:

$$\textbf{Wire length} = 1\lambda = \frac{984}{f(\text{MHz})} \textbf{ feet}$$

In the construction of multielement and/or multiband quads, it is wise to lengthen the quad driven element and the equation is modified to:

$$\textbf{Driven element wire length} = \frac{1000}{f(\text{MHz})}$$

The driven wire can then be cut back to the desired resonant frequency, if necessary.

Wire length for the quad reflector is made 5 percent longer than the driven element. Dimensions for the 20-meter, two-element quad are given in Fig. 104. The added reflector is handled by using a larger frame. Dimensions for other bands are as follows:

BAND (METERS)	DRIVEN 984/f	REFLECTOR 1030/f_L	SPACING 123/f
10	34′5″	36′5″	4′4″
15	46′3″	48′10″	5′9″
20	69′3″	73′1″	8′9″
40	136′8″	147′	17′6″

Various procedures can be used to resonate the driven element of a quad to a specific frequency. A dip meter along with a calibrated receiver affords a convenient and accurate combination for checking resonance. A single-turn loop connected from one side of the quad insulator to the other and around the dip-meter coil is all the coupling that is required (Fig. 105). The dip point is located on the meter. Next the dip-oscillator signal is picked up on the receiver to obtain an accurate frequency measurement.

Two other methods of checking resonance are also given. An SWR meter can be located right at the feed point of the driven element (Fig. 105B). Resonance is that frequency at which the SWR reading is minimum. The SWR meter can also be located at the transmitter to make this arrangement, provided the overall length of the transmission line is a multiple of an electrical half wavelength.

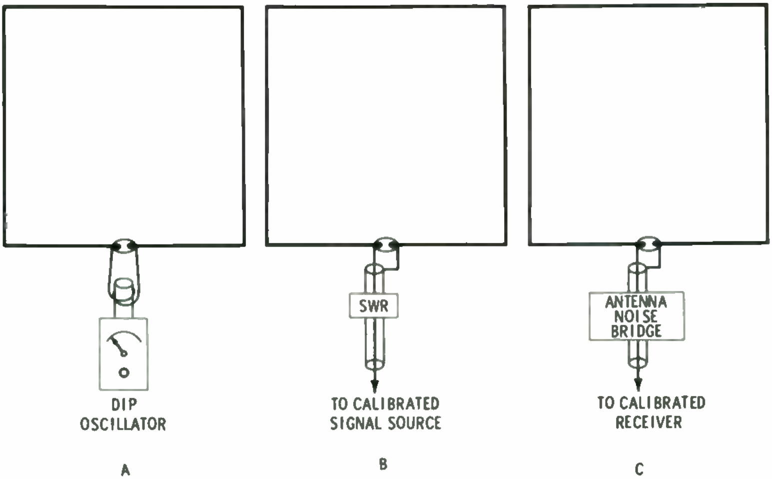


Fig. 105. Resonating a quad antenna.

The third method is to position an antenna noise bridge right at the feed point. This signal is delivered to the receiver at the other end of the line. There is a minimum reading when the receiver is tuned through the resonant frequency of the driven quad.

Either the dip method or the antenna noise bridge can also be used to tune the reflector. To do so, provide some means of opening the reflector loop at a position comparable to the feed point of the driven element. Customarily the reflector wire length is 5 percent longer than that of the driven element. Consequently, reflector resonant frequency will be on a frequency 5 percent lower than the resonant frequency of the driven element:

$$f_{refl} = f_{res} - 0.05 f_{res}$$

When this approach is used, it is possible to counteract the influence that one frame has on the other in terms of the resonant frequency. This approach is particularly useful for multiband quads for tuning out the interaction between frames and among the multiband wires on each frame.

The dip oscillator and noise-bridge approach can be used to find the resonant frequency. However, the SWR technique is not feasible because the resonant points usually fall outside the radio amateur bands. Refer to topics 1, 2, and 3 plus Appendices I, IV, and V.

61—Two-Element Quad, Tuned Reflector

The two-element quad of topic 60 incorporates a reflector with a larger-area frame than the driven element. It is possible and popular to use the same length of reflector wire as driven wire. Frames are the same dimensions. In this case the reflector is resonated to a proper frequency by using a shorted stub or an inductor as shown in Fig. 106.

In example A the shorted stub provides the additional electrical length that resonates the reflector wire to a lower frequency than the driven wire. Again, reflector resonance can be measured using a dip oscillator or a noise bridge.

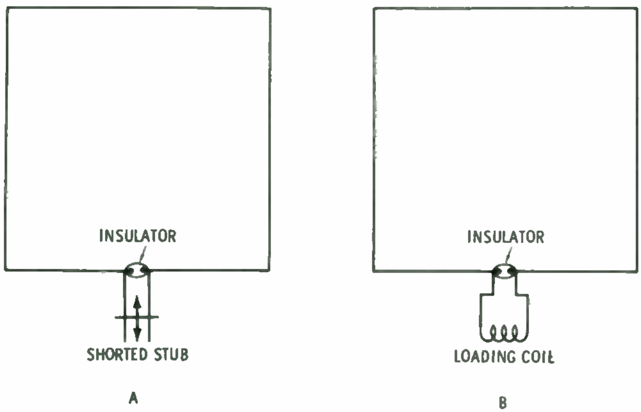


Fig. 106. Tuned reflector.

Small coils can be fashioned and used to join the two ends of the reflector wire. A dip oscillator held near the coil can be used to adjust coil turns and spacing for the desired reflector resonant frequency.

It must be stressed that there is interaction between frames, between other-band wires for the multipurpose type, and between other metallic surfaces such as spreaders and spiders. Therefore, the cut-and-try method is recommended for obtaining reflector resonance on a desired frequency.

The advantage of the tuned-reflector method is that identical frames and wire lengths can be used for reflector and driven element. Refer to topics 1, 2, 3, and 60.

62—Two-Element Quad, Straight Reflector

A common on-the-air complaint about quad antennas is their substantial side and back pickup. In fact, to obtain optimum performance from a two-element quad it is necessary to adjust reflector length and frame spacing quite carefully. Furthermore, one must compromise between forward gain and front-to-back ratio.

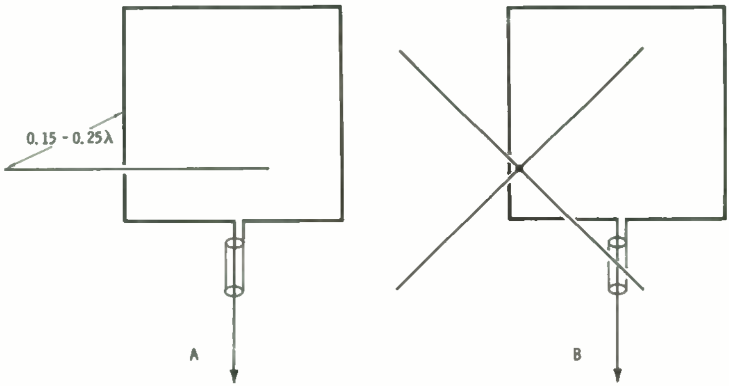


Fig. 107. Quad driven element with straight or X reflector.

The good characteristics of a quad seem to be pretty much vested in the quad driven element. In fact, the use of a straight reflector or the X-type reflector of Fig. 107 makes very little difference in the forward gain and may even increase it if dimensioned carefully. There is some pattern improvement with the X-type in particular in the form of less rear pickup and radiation. Most of all, the use of a conventional reflector circumvents the tedious process of adjusting the reflector frame.

$$\textbf{Reflector length} = \frac{\mathbf{492}}{f\mathbf{(MHz)}}\ \textbf{feet}$$

Refer to topics 1, 2, 3, 60, and 61.

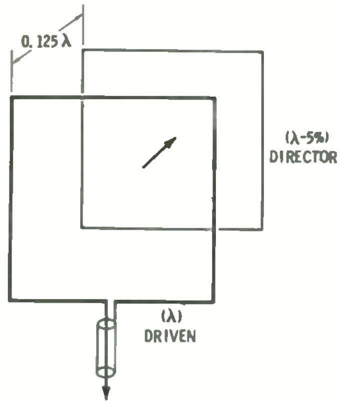


Fig. 108. Quad driven element and director.

63—Two-Element Quad, Director

It has been the author's experience that a parasitic quad director tunes easier and results in a higher gain and a better pattern than a quad driven element and reflector combination. Of course, stub tuning or the use of a series coil are not appropriate for a director. The director effect is obtained by making the length 5 percent less than that of the driven element (Fig. 108). Dimensions for various amateur bands are:

BAND	DRIVEN 984/f	DIRECTOR 935/f_H	SPACING 123/f
10	34'5"	32'4"	4'4"
15	46'3"	43'7"	5'9"
20	69'3"	65'2"	8'9"
40	136'8"	128'	17'6"

Spacing between director and driven element is λ/8 (0.125λ). The match to a 70-ohm coaxial line is almost ideal. Refer to topics 1, 2, 3, 60, 61, and 62.

64—Three-Element Quad

Additional gain can be obtained with a reflector and a director. A typical 20-meter three-element arrangement is shown in Fig. 109. Reflector and director frames are spaced λ/8 from the driven-element frame. The director wire length is made approximately 5 percent

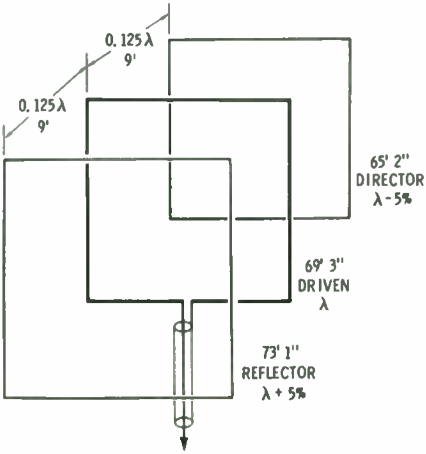


Fig. 109. Three-element quad.

shorter than that of the driven wire. However, dip oscillator or noise bridge can be used to trim to an exact frequency 5 percent higher than that of the driven element. The reflector can be either a tuned type, a longer frame wire, or a straight X. Refer to topics 1, 2, 3, 60, and 61.

65—Two- or Three-Element Quad, TV-Line Feed

The quad is a balanced antenna. Therefore, it is adaptable to any sort of balanced feed system. When there is a long length of transmission line (over 100′) between antenna and transmitter, the use of a good quality 300-ohm TV line instead of coaxial line results in a significant improvement in output and sensitivity. The improvement can be comparable to that obtained with the addition of another director to the antenna.

The disadvantage of the plan is that a balanced tuner such as that covered in Appendix VII is required. However, the use of such a tuner ensures that an optimum load is placed on the transmitter, so it can deliver the maximum power of which it is capable.

The balanced feed permits the driven element to operate in a more balanced manner and a definite drop in the side radiation can be noted. Also, a general improvement in the overall pattern results. Refer to topics 1, 2, 3, 12, 60, 61, 62, 63, and 64.

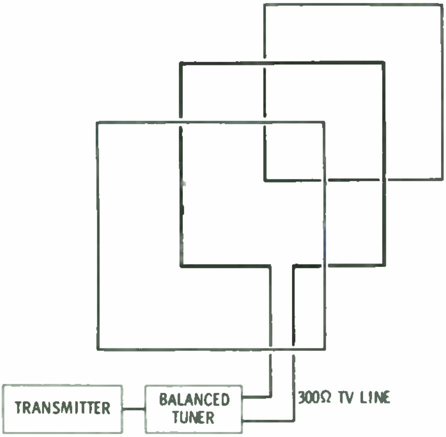


Fig. 110. Two- or three-element quads fed with TV line.

66 —Multiband Quad

A multiband 10-15-20 meter quad consists of a group of three quad wires mounted on a single frame. The frame is made large enough to accommodate the 20-meter wire and then the 15- and 10-meter wires are placed within the frame according to their required full-wavelength wire lengths (Fig. 111). Driven element, reflector, and director frames are constructed in the same manner. Spacing between frames corresponds to 0.125λ on 20 meters. Wavelength spacings are greater and are not optimum values for the 15- and 10-meter bands. Also the antenna resistance rises and matching arrangements are mandatory when using coaxial transmission line.

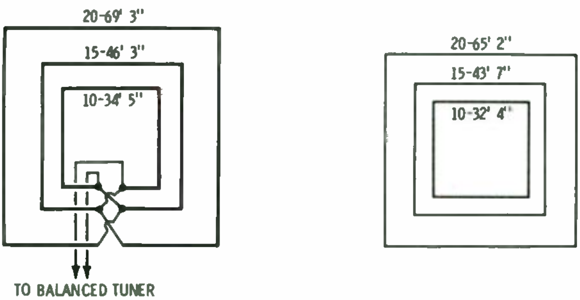


Fig. 111. Three-band quad, TV line fed.

Optimum results are obtained when the quad is fed with three separate transmission lines. However, it is common to use single-line feed with some sacrifice in performance. Wire-length dimensions are the same as those given in topics 60, 61, and 63. The antenna must be adjusted on each band using a dip oscillator, noise bridge, or SWR meter.

The quad arrangement of Fig. 111 uses a single good-quality 300-ohm TV line to feed all three driven elements. The TV line transposes between driven elements, the feedpoint being at the 10-meter terminals. The parasitic element is a director and is dimensioned as shown. It is positioned 8 feet in front of the driven element.

The balanced tuner of Appendix VII is used at the transmitter. It brings the SWR down to less than 1.05 to 1. Excellent results are obtained on all three bands. Refer to topics 1, 2, 3, 12, 60, 61, 62, 63, 64, and 65.

67—Low-Band Triangle

On low frequencies the quad becomes large, clumsy, and almost impossible to construct. However, most of the favorable characteristics of a quad can be obtained from a triangular driven element. The triangular construction is simple, strong, and easy to erect (Fig. 112). The quad equation can be used to calculate the overall length of the triangle wire:

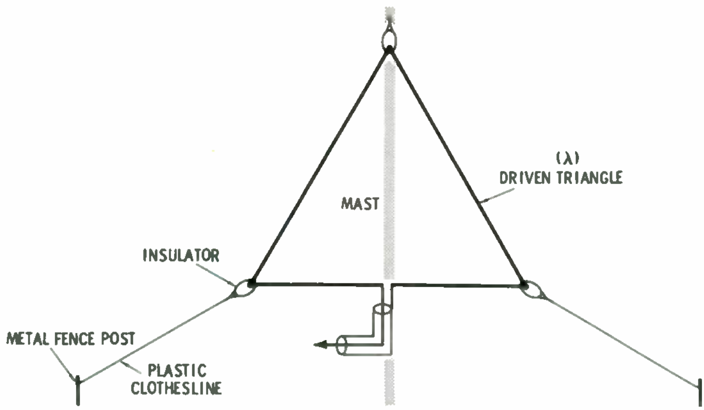


Fig. 112. Low-band triangle.

$$\text{Total wire length} = \frac{984}{f(\text{MHz})} \text{ feet}$$

The proximity of ground and the support mast may require that the triangle be shortened somewhat below this value after it is erected. This can be accomplished quite readily from step-ladder height.

The very center of the full-wavelength wire is attached at the top of the support mast with an insulator. The two legs then fan out and fold back on themselves. The ends are returned to the mast to a dipole connector or other form of insulator. The triangle can then be stretched out on each side using plastic clothesline (nonmetallic core) and two metal fence posts. You will find it is a very rigid assembly, acting also as partial guying for the mast. Furthermore, its directivity can be changed from ground level by shifting the side supports to other fence posts. A single triangle, driven element functions as a very good low-frequency antenna. Omnidirectional performance is quite good.

Antenna impedance is quite low because the base of the triangle is so near ground. A rather good direct match to coaxial line is possible. The triangle is also adaptable to stub matching, line tuner, or balanced transmission line and tuner. A balun is a fine matching aid. In fact, if a ground radial system is employed for low-band DXing, the ground point of the balun secondary can be connected electrically to the radial system via the mast or a piece of large-diameter wire.

An important advantage is the almost perfect direct match that can be obtained when using a triangle driven element with a triangle reflector and/or director frames. Refer to topics 1, 2, 3, 8, 12, 41, 60, 61, 62, 63, 64, 65, and 66.

68—Triangle and Parasitic

Reflector and director triangles can be added to increase the gain and sensitivity in a preferred direction (Fig 113A). Wire lengths for low-band triangle directors and reflectors are given in the chart:

BAND	DRIVEN $984/f$	REFLECTOR $1030/f_L$	DIRECTOR $935/f_H$	SPACING $123/f$
40	136′8″	147′	128′	17′6″
80	252′3″	278′3″	234′	31′6″
160	540′	572′3″	505′5″	67′4″

The parasitic element can be made to act either as a director or reflector if it is dimensioned first for director operation. When reflector

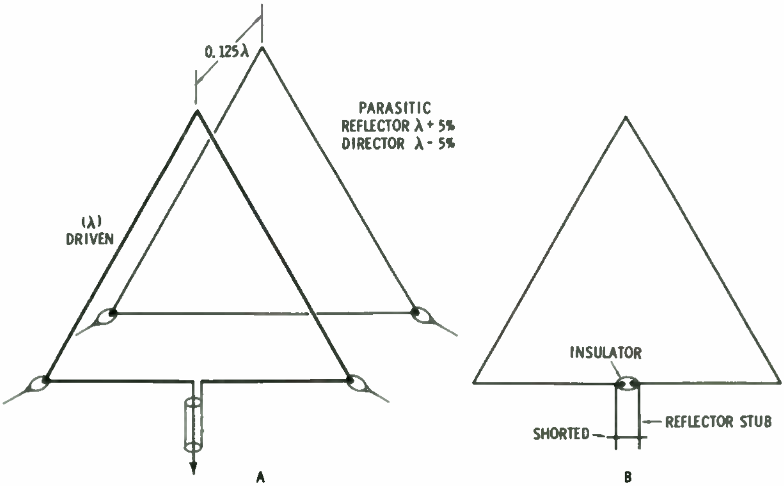


Fig. 113. Driven triangle and parasitic element.

operation is desired a shorted stub can be clipped on as shown in Fig. 113B. The triangular driven element and parasitics can be adjusted and measured in the same manner as the quad antenna elements using SWR meter, dip oscillator, or noise generator. A reflector should be

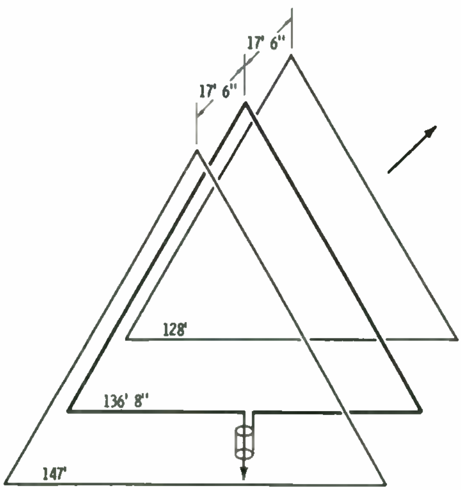


Fig. 114. Triangle beam.

tuned 5 percent lower than the resonant frequency of the triangle; a director, 5 percent higher in frequency.

Dimensions for a three-element 40-meter triangle are given in Fig. 114. A triangle reflector, driven element, and director are arranged in yagi-like fashion on separate masts. Spacing between elements is $\lambda/8$ (0.125λ). This is only about 17 feet on 40 meters. In fact, the 40-meter antenna occupies an area no greater than 60′ × 40′. Oriented for 45° on the east coast, European contacts became routine.

The apex height of the driven element was approximately 40′ while the reflector apex was 4′ higher and the director apex about 4′ lower. Similar type displacements were made for the triangle bases with the reflector being the lower and placed about 8 feet above ground.

For minimum loss, when there is a long transmission line span between transmitter and triangle driven element, a good quality 300-ohm TV line and balanced tuner (Appendix VII) can be employed. Refer to topics 1, 2, 3, 8, 12, 60, 61, 62, 63, 64, 65, 66, and 67.

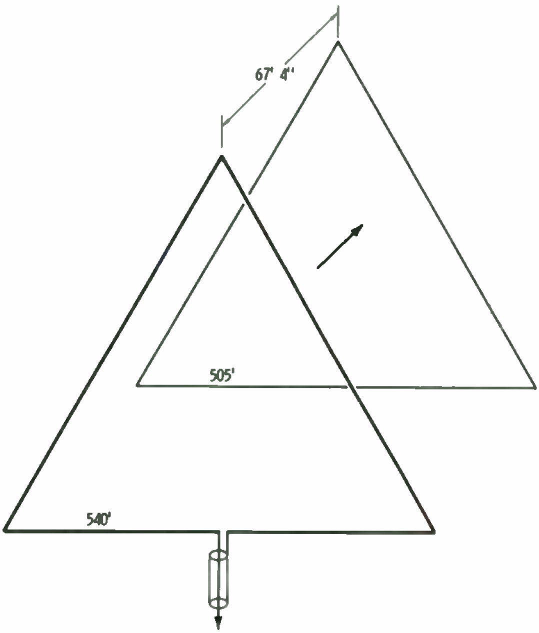


Fig. 115. Driven triangle and director for 160 meters.

69—160-Meter Two-Element Triangle

It is on the 160-meter band that it is difficult to obtain beam-like characteristics without requiring a lot of space and some costly high masts. The triangle is able to give you a beam-like characteristic in a relatively small area. At the same time a good low wave angle is maintained and only two supporting masts are needed (Fig. 115).

In a practical installation 60-foot telescoping masts were used. The apex of the director was dropped down five feet below that of the driven triangle. This well-performing 160-meter antenna is erected in an area 240′ × 70′. The antenna can be fed directly with coaxial transmission line or, for very long spans of transmission line, open-wire or good-quality TV line with a balanced tuner provides minimum line loss. Refer to topics 1, 2, 3, 8, 12, 67, and 68.

70—40-80 Three-Element Double Triangle

Like a quad antenna, double or triple driven and parasitic elements can be constructed to obtain multiband capability. Reflector, driven element, and director dimensions are shown in Fig. 116. The spacing between elements on the 75-meter band is made 0.1λ. This corresponds to a spacing of approximately 0.2λ on 40 meters.

A good dip meter can be used to tune the driven element as well as parasitic reflectors and directors. Of course, the parasitic elements must be open at the center of the base when making resonance measurements. In the practical antenna, insulators were used at the center of the base for both the director and the reflector to aid in making measurements. In normal operation a jumper is then connected across the director and reflector base insulators. Coaxial or balanced

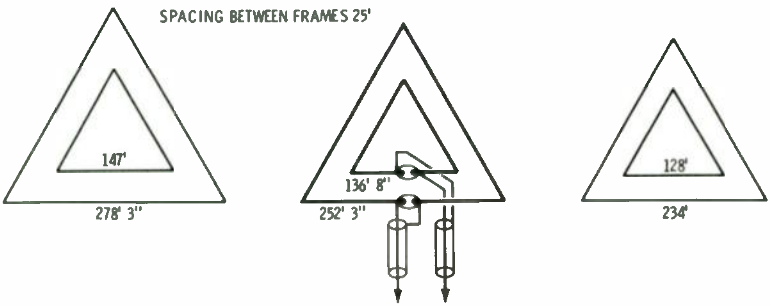


Fig. 116. Forty-and eighty-meter 3-element triangle.

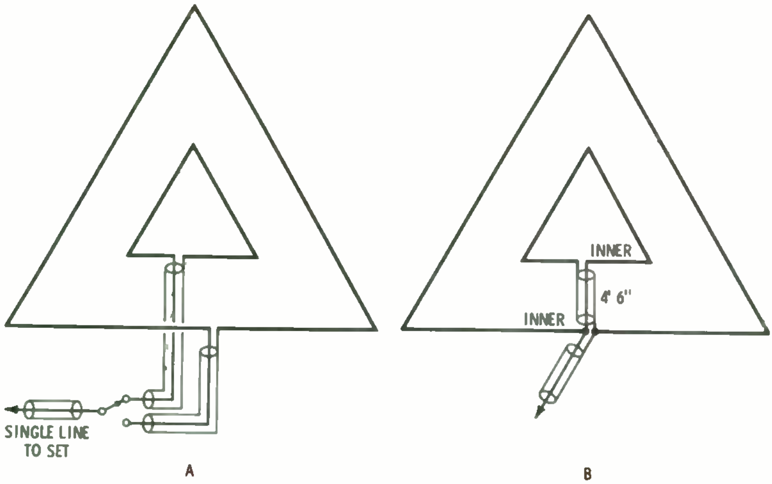


Fig. 117. Separate- and joint-feed arrangements.

parallel line can be used to feed the two driven elements separately.

Separate lines can be dropped down to reach-level as shown in Fig. 117. With a suitable connector, the transmission line from the transmitter can be attached to either one of the driven elements. Single-transmission-line feed can also be employed.

For joint operation the least influence on the performance of either antenna was obtained by connecting the transmission line to the 80-meter driven element and using a 4.5-foot segment of 70-ohm line between the 40-meter and 80-meter antenna feed points. Use transposed feed between elements by transposing the line or coaxial connector (as in Fig. 116). Refer to topics 1, 2, 3, 8, 12, 67, 68, and 69.

71 – Single-Mast Triangle and Parasitic

The triangle configuration is quite versatile and permits the construction of a rather directive low-frequency beam on a single support mast. This is accomplished, as shown in Fig. 118, by pulling the plane of the triangle away from the vertical. This pull out is such that the separation between the base of the driven element and the mast and the separation between the parasitic element and the mast is $\lambda/16$. By so doing, the separation between the bases of the two triangles is $\lambda/8$.

The apex of each triangle is attached to, but insulated from, the

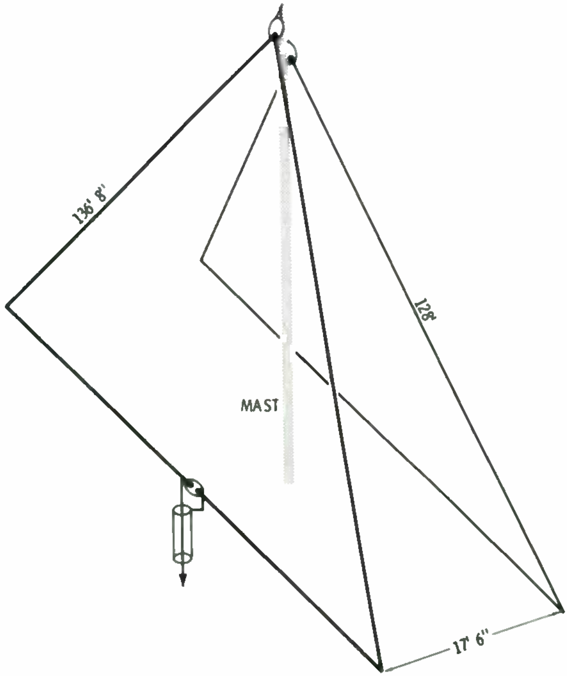


Fig. 118. Single-mast driven triangle and director.

mast. The apex of the driven triangle is at the very top of the mast with the director triangle apex approximately 4 feet below.

Dimensions are given for 40-meter operation. It is to be noted that the triangle bases separate from the mast by approximately 8.5 feet. Thus the departure from the vertical is really not great.

A parasitic-reflector, driven-element combination is also feasible. One mast can support the driven triangle and reflector. In fact, a second mast spaced $\lambda/4$ in front of the first one can support two director triangles in a similar manner. The apex of the reflector triangle is at the very top of mast 1, while the apex of the driven triangle is placed four feet lower. The two directors have their apex at the very top of the second mast. However, the top of this mast is approximately 8 feet lower than mast 1. There is a 30-foot separation between the two masts establishing the required $\lambda/8$ separations between all adjacent elements. Refer to topics 1, 2, 3, 8, 12, 67, 68, 69, and 70.

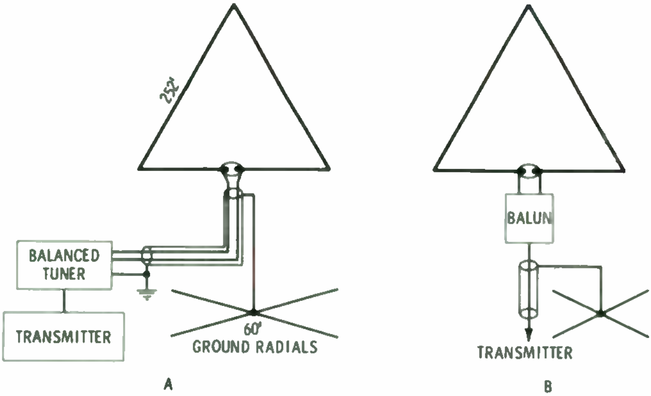


Fig. 119. Triangle antenna with radial ground system.

72—80-Meter Triangle With Ground Radial System

A triangle is a balanced driven element and operates well with the use of a balanced line and tuner. A rather unique feed system can be employed by using balanced TV line which includes an outer braid. In this arrangement (Fig. 119) the two balanced leads are connected to the triangle while the outer braid of the transmission line connects to the underground radial ground system. At the balanced tuner, the braid is connected to ground. This creates an attractive possibility for low-frequency antenna systems, the performance of which depends on a good low-resistance ground system.

An alternative method uses a 2-to-1 or 4-to-1 balun (whichever is needed) and the balun ground connection (outer braid of coaxial line) is connected to the ground radial system.

The dimensions shown in Fig. 119 are for 80 meters. Six $\lambda/4$ ground radials are employed. Results are gratifying, not reaching the peak of the three-element triangle of topic 70, but providing good low wave-angle performance in an omnidirectional manner. All the low-band triangle antennas are adaptable to grounded radials and balanced-line system. Refer to topics 1, 2, 3, 8, 12, 67, 70, and 71.

73—Triangle Turnstile

A triangle antenna with a more omnidirectional pattern and a lower antenna resistance than a single triangle can be erected by using two triangles mounted at right angles (Fig. 120). All four ends are returned to the mast. The ends from opposite pairs are joined and connected to the center insulator or coaxial connector. A similar arrangement can be used for 80 or 160 meters.

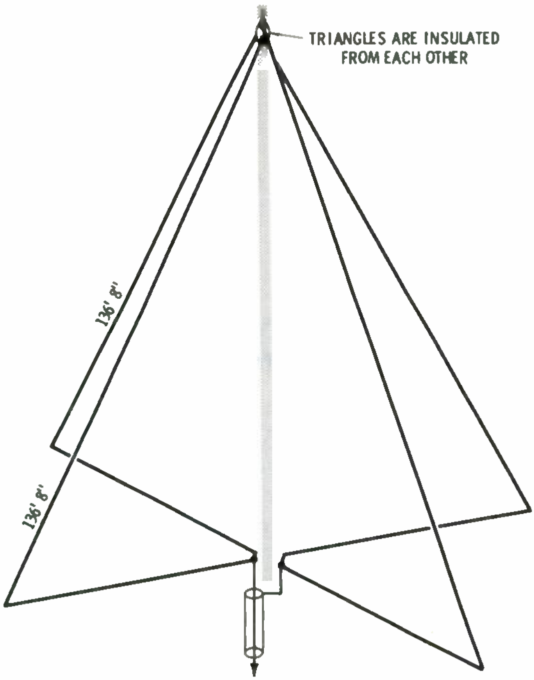


Fig. 120. Triangle turnstile.

A variety of feed arrangements is feasible. Direct connection to a coaxial line provides a fine match. If a 1-to-1 balun is employed, it is also possible to use a ground system that connects to the ground side of the balun input as shown in Fig. 119B. Shielded balanced line and balanced tuner provide an ideal feed system that operates in conjunction with a beneath-ground radial system. Refer to topic 72.

The turnstile idea also has two-band capability. A 40-meter triangle turnstile can be made to load on 80 meters, and an 80-meter turnstile can be made to load on 160 meters, using appropriate insulators and jumpers. On the higher-frequency band the antenna operates as the simple triangle turnstile discussed previously.

A different connection is used for operation on the lower-frequency band as shown in Fig. 121. The transmission line is connected to any two adjacent half-triangle ends. The remaining two ends are joined together, effectively doubling the total length of antenna wire connected

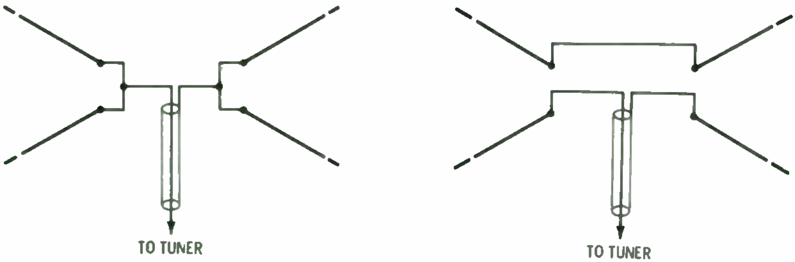


Fig. 121. Two-band operation of turnstile.

on each side of the point at which the transmission line is connected. This total length may be somewhat shorter or longer than that needed to establish resonance on the lower-frequency band. Consequently, it is advisable to use a tuner in the line. Either a balanced or unbalanced combination can be employed. Refer to topics 1, 2, 3, 8, 12, 67, 68, 69, 70, 71, and 72.

74—15-, 40-, and 80-Meter Triangles

Two different-frequency triangles can be attached to the same mast and connected to the same transmission line. If mounted in right-angle planes, there is a minimum of interaction. Also, triangles radiate well on odd multiples of a whole wavelength. Thus, a 40-meter triangle performs well on 15 meters, the triangle being *three* wavelengths long on this frequency.

A typical two-section triangle is shown in Fig. 122. There is a 40-meter triangle and at right angles to it an 80-meter triangle. They are insulated from each other at the apex but join at the point of transmission-line attachment. A low SWR is obtained on both bands. The antenna also loads on 15 meters with a satisfactory SWR. Refer to topics 1, 2, 3, 67, 68, 69, 70, 72, and 73.

75—High-Band Triangles

Like the quad or the dipole, the triangle can be used as an elevated high-band antenna. For 10-15-20 meter operation the high-

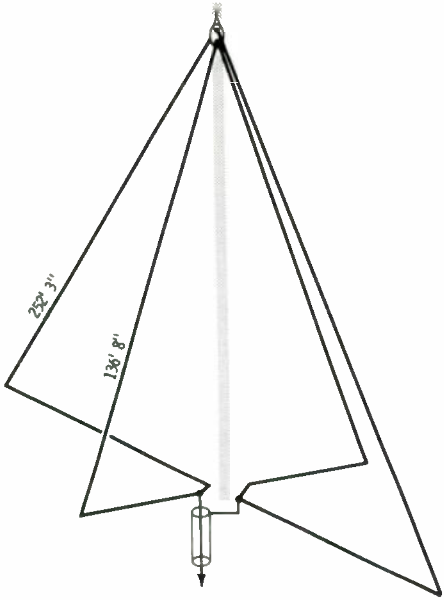


Fig. 122. Forty- and eighty-meter triangles at right angles to each other.

Fig. 123. High-band triangles.

frequency triangle can be constructed in two basic ways as shown in Fig. 123. A wire triangle can be constructed similar to the low-band type. Insulators and plastic clotheslines are attached to the base angles. These corner angles are pulled out and supported from ground level. The alternative approach is to use self-supporting tubing for the base of the triangle. A plastic sheet holds the base elements to the mast.

The ends of the tubing are then linked to the apex of the triangle with wire or additional tubing. Dimensions are given for 20-meter operation.

High-band triangles are mounted a considerable electrical distance above ground and display an impedance several times higher than that of coaxial line. Stub matching works very well. A line tuner can be used for matching. A low-loss arrangement would be balanced TV line and a balanced tuner at the transmitter. A 4-to-1 balun often does a fine matching job for high erection. Omnidirectional pattern

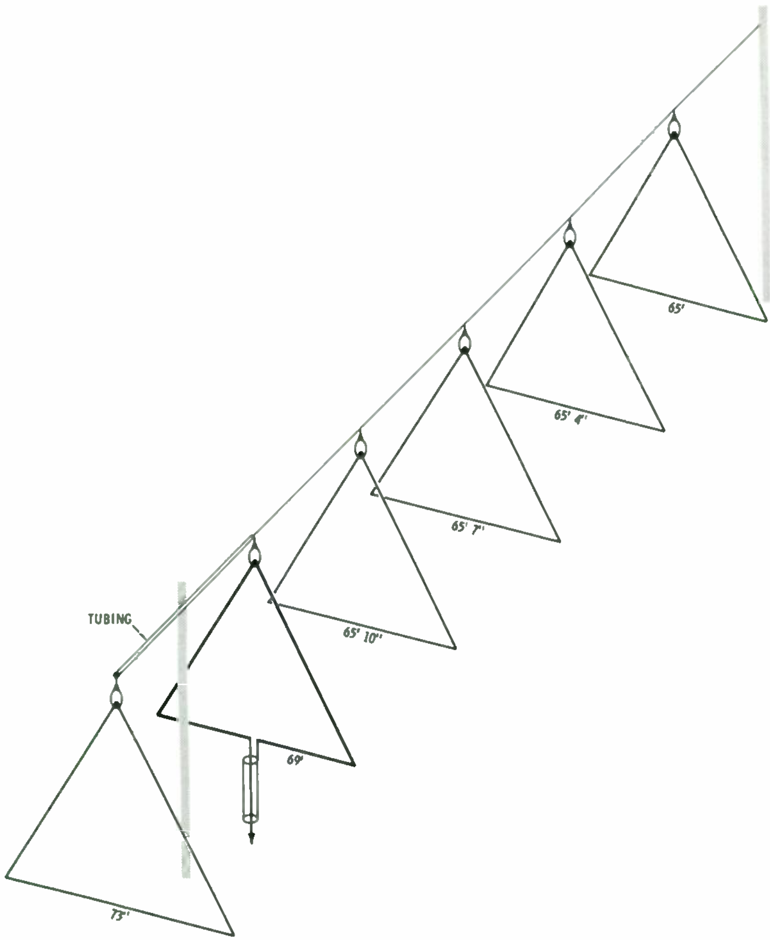


Fig. 124. High-band triangle beam suspended between 2 masts.

and lower antenna resistance are possible with a turnstile arrangement.

The triangle configuration can be used in the construction of high-band beams. The triangle is adaptable to the construction of fixed-mounted multielement high-band beams. Such an arrangement is shown in Fig. 124. The 20-meter triangle beam is suspended between two high masts. At the top of mast No. 1 there is a 10-foot cross piece which suspends the apex of the driven triangle and the reflector. A support wire runs from the driven end of the support piece to the second mast. Along this support wire there are suspended any number of directors, providing an easy method of building a triangular *Long-John* antenna. Plastic clotheslines are again used to pull out each of the triangles and support it from ground level. The match made to coaxial transmission line is good despite the multidirector arrangement. Of course, for a great separation between antenna and transmitter, use a balanced transmission line and tuner. Refer to topics 1, 2, 3, 8, 12, 41, 67, 68, 69, 70, 71, 72, 73, and 74.

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 are 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.

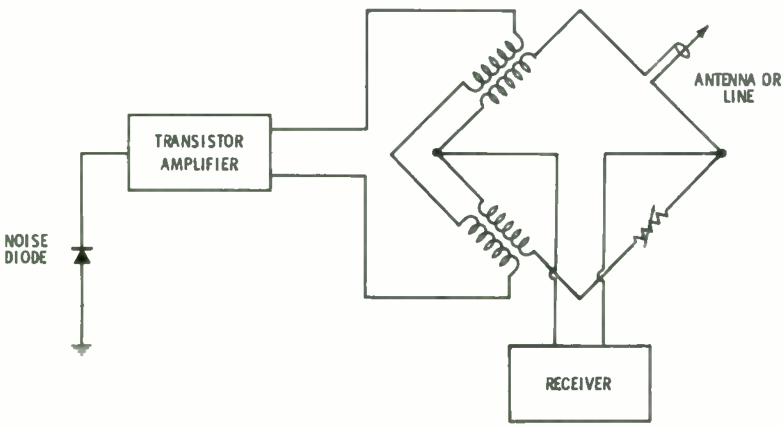


Fig. A-I-1. Omega-T antenna noise bridge.

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.

**Omega-T* Inc., Richardson, Texas 75080

The dial is calibrated in ohms of antenna resistance between 0 and 100 ohms.

The antenna or line to be measured is connected as the fourth leg of the bridge. The receiver is, of course, connected between the junctions of the two leg pairs. When the bridge is balanced, there is minimum signal applied to the receiver. This happens when the antenna resistance is of the same value as the setting of the bridge resistor. If reactive components are present, the bridge does not balance. Any such reactance is balanced out by tuning the receiver. In doing this you also determine the resonant frequency of the antenna system.

The general operating procedure is:

1. Set the bridge control to the appropriate antenna resistance that is to be expected; for many ham antenna systems that is 50 ohms.
2. Tune the receiver over the frequency band to which the antenna is to be resonated. Find the minimum noise frequency (minimum audio output from the speaker and minimum S-meter reading).
3. Adjust the bridge resistance for the best minimum (null). Jockey the receiver tuning and bridge controls slightly for the best minimum. The resonant frequency of the antenna system is read from the receiver dial, while the antenna radiation resistance is indicated on the noise-bridge dial.

The antenna noise bridge is a small test unit, is easy to hook up, and makes antenna system checking a lot easier.

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

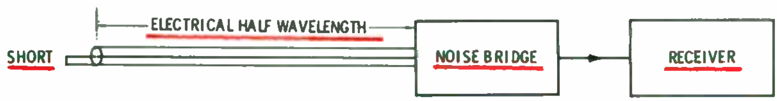


Fig. A-II-1. Determination of velocity factor of transmission line.

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:

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.

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

The length of a quarter-wave segment of line or an odd multiple of a quarter wavelength can be determined in the same way with the exception that the far end of the line is opened rather than shorted.

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:

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

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

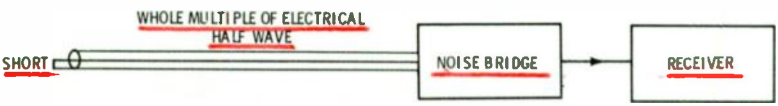


Fig. A-III-1. Method for cutting a transmission line to whole multiple of a half wavelength.

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:

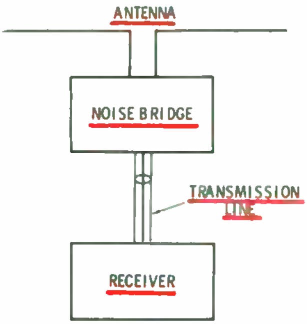
1. Set the bridge control slightly above zero. Set the receiver to the desired frequency band.
2. Tune the receiver over the band to obtain a good null. For some receivers a more pronounced null can be obtained by deactivating the avc circuit and/or reducing the receiver r-f gain.
3. If the frequency 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.

The velocity factor of some foam-type lines tends to be less than 0.81. Thus, resonance will appear at the low end of the band, or even off the low end of the band. Trim the line patiently to bring it into the band. When the overall length of your line is a *number* of whole multiples of a half wavelength long, a larger section of line must be trimmed off to obtain a given change in overall electrical length than if the line were only *one* half wavelength long.

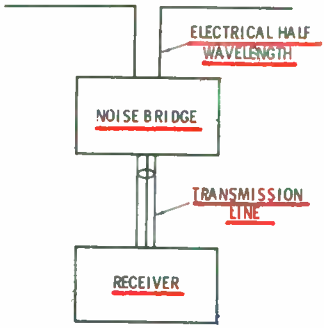
APPENDIX IV

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

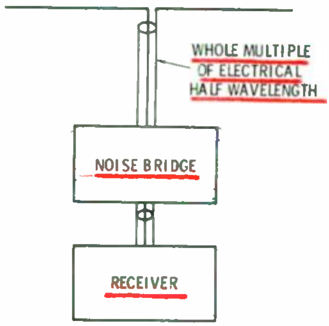
The antenna noise bridge is battery operated and can often be placed at the antenna feed point, Fig. A-IV-1. It is of small size and no external signal source is needed. A noise generator source is a part of the device.



(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.

The bridge can also be inserted into the line an exact electrical half wavelength away from the antenna terminals. A third alternative is to locate the noise bridge at the receiver, making certain that the overall length of the transmission line between the antenna and the bridge is a whole multiple of an electrical half wavelength for which the antenna is to be cut and measured. The transmission-line cutting procedures were covered in Appendices II and III.

The recommended operating procedure is as follows:

1. Set the noise bridge dial to the anticipated resistance of the antenna (usually 50 or 70 ohms).
2. Tune the receiver over the frequency band and locate the noise null (minimum speaker noise or minimum S-meter reading).
3. Adjust the antenna-noise-bridge dial for the best noise null.
4. The resonant frequency of the antenna can be read from the calibrated receiver dial while the antenna radiation resistance is indicated on the calibrated noise-bridge dial.
5. The two controls can be adjusted slightly for the very best null and the most accurate reading.

The most accurate readings are obtained when the transmission line is a whole multiple of an electrical half wavelength.

In the measurement and cutting of both lines and antennas, Charts 1 through 6 are employed. The physical lengths of lines and antennas indicated by the charts are invariably somewhat longer than the necessary cut for the desired resonant frequency. (Even the cut for a half-wavelength antenna using the end correction factor is usually a bit longer than necessary.) This is the favorable situation because the antenna or line can then be trimmed back to the desired higher resonant frequency.

Therefore, in using the antenna noise bridge, the null point is usually found lower than the desired operating frequency and may sometimes be even lower than the low-frequency end of the desired frequency band. You can then trim very carefully and observe the noise null rising higher toward the desired frequency.

As you well know, cutting a length that falls on the high side of the desired frequency presents the added problem of having to add on rather than trim off to reach the optimum frequency. This is certainly not the desired situation when using coaxial transmission line. Thus, the chart and formula information in this book tends to give you a long dimension rather than a short one. 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 the antenna arrangement shown.

APPENDIX V

Cutting an Antenna to Resonance Using an SWR Meter

The SWR meter and/or reflectometer arrangement has been used for years in checking out and monitoring ham antenna systems. Resonant antenna cuts can be made with the proper insertion of an SWR meter designed for the specific impedance of the transmission line. (For the usual SWR meter, optimum performance is obtained with 50- or 70-ohm coaxial lines.)

Two preferred arrangements are shown in Fig. A-V-1. True SWR measurements can be made by inserting the meter right at the antenna. Usually this is not a convenient arrangement. An alternative is to insert the meter one electrical half wavelength away from the antenna terminals or at some part of the line that is a whole multiple of an electrical half wavelength. The latter plan permits the SWR meter to be located near the transmitter. However, the very best accuracy in terms of the SWR reading and in determining the resonant length

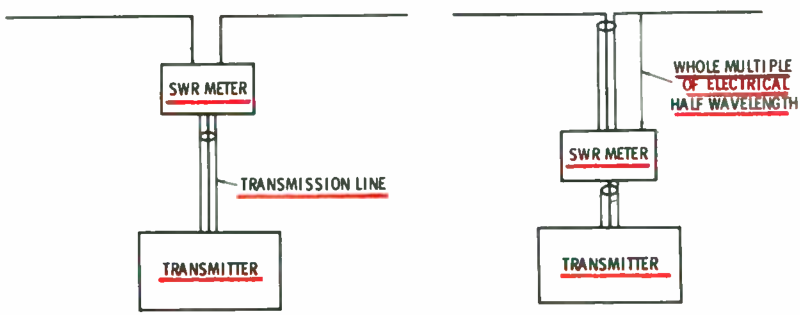


Fig. A-V-1. Measurement of SWR and antenna resonance.

of the antenna is feasible only when the exact length of line between the antenna and meter is a whole multiple of electrical half wavelengths. Under this condition the antenna terminal conditions are reflected to the meter, and the reactive effects of the transmission line are reduced. The 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.

APPENDIX VI

The Construction and Tuning of a Line Tuner

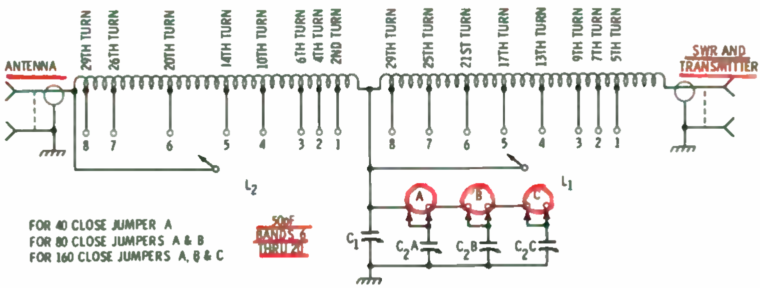


Fig. A-VI-1. Antenna line tuner.

- 2 *binding posts*
- 2 *coaxial receptacles*
- 1 *case 10" × 5" × 4"*
- 1 *50-pF variable capacitor*
- 1 *3-gang 365-pF variable capacitor*
- 2 *29 turns #14 wire, 1 ¾" dia. and 2 ⅜" length (AIR DUX 1411)*
- 2 *r-f switches, 1 pole and 8 positions*

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-, 80-, and 160-meter bands by connecting variable capacitors (C2, A, B, and C) of appropriate value across the variable capacitor (C1).

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.

In practice, the proper operating conditions are established by using a variable capacitor and two tapped inductors in accordance with the parts list. It has been customary in most designs to place the taps on the coils in some regular manner and let the tuner operating conditions fall where they may. However, if the very lowest standing-wave ratios are to be established, it is helpful to experiment with tap positions for the very best performance. You may wish to start out with uniform positioning of the taps to determine what the operating conditions are on each band. For most bands it is likely that optimum performance can be obtained. However, if you have difficulty bringing the SWR reading down on certain bands, you can experiment with the tap positions. This is particularly the case for the 10- and 15-meter bands.

For the tuner constructed by the author, the tap positions shown in Fig. A-VI-1 were found to be optimum. Coils L_1 and L_2 must be mounted at right angles to each other.

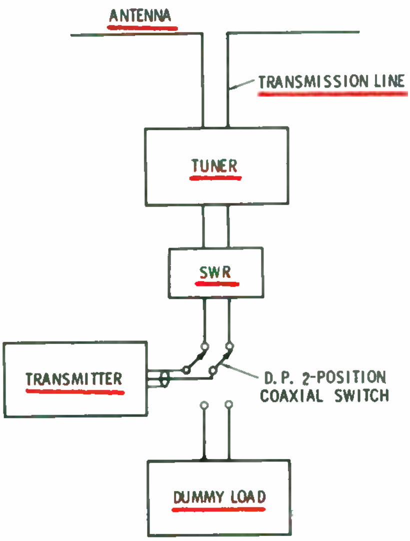


Fig. A-VI-2. Connection plan for adjusting a tuner.

Proper tuning is important if you are to derive the most benefit from your line tuner. The setup of Fig. A-VI-2 is a good one. The transmitter is first worked into a 50-ohm dummy load. Transmitter output-circuit settings (tuning and load) are set down in a notebook for specific frequencies. (You may wish to use the center frequencies of the 10-, 15-, and 20-meter phone bands.) This information helps you set the transmitter reasonably close to optimum, and then the line tuner can be adjusted in such a manner 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.

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.

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 load (Fig. A-VI-3). In this case there is little or no r-f energy present at the far end of the second leg of the antenna. Thus, if at all possible, you should check for the presence of r-f energy at the ends of both legs of the antenna. This is quite easy to do, for the inverted-vee antennas or the vee-beam types with sloping ends. False loading should be avoided when you wish no changes in the pattern characteristics of your antenna.

When the center-fed dipole or vee antenna approximates an odd number of quarter wavelengths on a leg, the tuner loads both legs. However, if the leg length approaches an even number of quarter

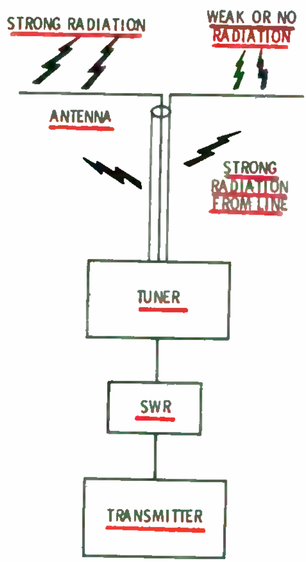


Fig. A-VI-3. Result of a tuner tuning the line and one antenna leg as random length of wire.

wavelengths the tuner tends to load one leg and the line. For example, when the antenna of topic 31 with 59-foot legs is loaded on 80 meters, it will tune in dipole fashion on 80 meters. However, the 40-meter dimension is so far off the quarter wavelength on a leg value that the tuner will simply load as a random wire with one leg more active than the other.

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 transmission line and the antenna. In the process, the SWR on the transmission line that links the tuner to the transmitter is brought down to a low value for suitable matching to the transmitter, and to ensure minimum transmission-line loss.

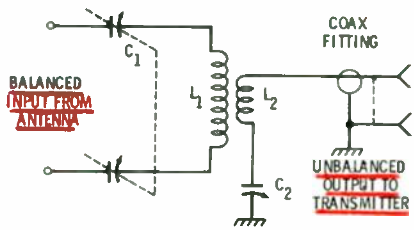


Fig. A-VII-1. Antenna tuner for vee, center-fed, long-wire, and rhombic antennas.

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 on all bands*

BANDS	L_1 TURNS	L_2 TURNS
6-10	4	1
10-15	6	2
15-20	10	3
20-40	14	4
40-80	32 (2010T)	8
80	44 (2010T)	10
160	64 CLOSEWOUND #14 ENAMELED 2½" DIAMETER	16

Resonant long-wire vees and rhombics usually have a low antenna resistance, and the step-up ratio between the transmission line and the antenna is not great. Hence, the rather simple tuner arrangement that matches a low-impedance unbalanced transmission line to a balanced antenna feed point of somewhat higher resistance is appropriate (Fig. A-VII-1). Both primary and secondary are series-tuned for minimum loss and lowest standing-wave ratio. Two sizes are given for most bands. Coil and component data are given in Fig. A-VII-1. If the very lowest SWR's for a variety of antennas are to be obtained, you may find one of these is better suited for a given situation.

The tuner adjusts very quickly and there is no need for making coil taps. An SWR meter is connected between the transmission line and the input of the tuner. Adjust the two tuner controls for a minimum SWR. Jockey back and forth between the two controls to obtain the very lowest minimum. The tuner must be readjusted, of course, when changing bands, or when changing from one end of the band to the other.

If you wish to construct a very versatile tuner that can meet almost any antenna situation around the amateur station, the author recommends highly the one described by Lew G. McCoy on page 58 of *QST*, July 1965. This tuner includes a standing-wave meter and has the flexibility needed to match both high and low antenna resistances.

APPENDIX VIII

Base Tuner for Vertical Antennas

It is convenient to use an antenna tuner for a vertical antenna because its base can be positioned near ground level. Such a tuner can be mounted in a weather-proof container and mounted permanently. The advantage of such a base tuner is that a vertical antenna of almost any practical length can be tuned and loaded on any band. The antenna can be loaded properly and there will be a minimum standing wave ratio and minimum loss on the transmission line that extends between the base tuner and the transmitter.

Again, it must be emphasized that a tuner ensures proper loading and efficient feeding of the antenna. However it does not overcome the limitations in the radiation characteristics of a given antenna. For example, if a vertical antenna is a wavelength or longer on a given operating frequency there is good high-angle radiation and a decline in low-angle radiation. Likewise, an antenna that is very short (less than an eighth wavelength) does not radiate as effectively as one which is at least a quarter wavelength. However, an antenna does perform well for any length that is somewhat less than a quarter wavelength on up to three quarter wavelength when good low-angle radiation is desired. An antenna can be much longer in terms of wavelength, if it is the high-angle radiation that is preferred.

A vertical antenna that is shorter than an electrical quarter wavelength displays an impedance that contains a capacitive component. An antenna that is longer than an electrical quarter wavelength but less than a half wavelength displays an impedance that contains an inductive component. Such antennas can be resonated by including the opposite reactance at the base. That is, inductance can be added to resonate a short antenna and capacitance can be added to resonate a long antenna. This can be done more effectively if the added inductance and capacitance is variable.

The base tuner of Fig. A-VIII-1 contains inductance and capacitance which can be inserted between the base of the vertical and the ground system. By using suitable inductive taps and a proper setting of the

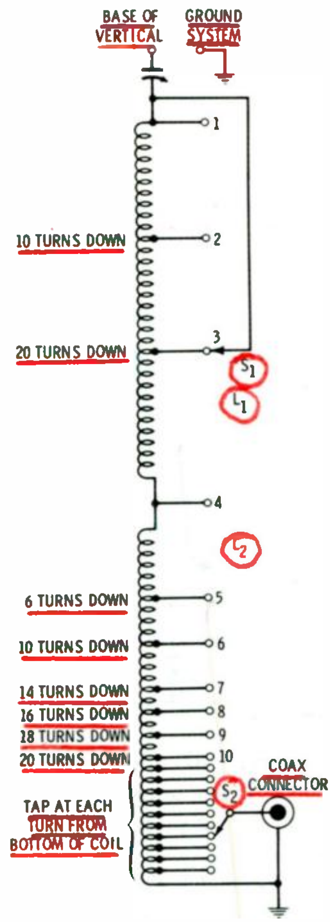


Fig. A-VIII-1. Base tuner for vertical antennas.

PARTS LIST

2 10-position, single-pole switches
2 30 turns No. 14 wire, 1¾" dia. and 2⅝" length (AIR DUX 1411)
1 400-pF variable capacitor
1 Coaxial connector

variable capacitance, a vertical antenna of random length can be resonated and loaded on a specific frequency. Proper tap position for antenna tuning is handled by switch S_1.

There are two sets of taps on the bottom inductor. The taps associated with switch S_2 connect to the coaxial transmission line that feeds back to the transmitter. The relative settings of switches S_1 and S_2 set up a transform ratio which provide a proper match between the tuned antenna system and the transmission line.

A base tuner of this type can reduce the standing-wave ratio on the transmission line to an exceedingly low value. It operates 10 through 80 meters and can be inserted in series between base and ground system of practically all of the vertical antennas covered in this book.

Schematic and parts list are given in Fig. A-VIII-1. Adjustments are made by connecting an SWR meter between the output of the tuner and the transmission line. Taps and variable capacitor are adjusted for a minimum standing-wave reading.

RS-106

73
VERTICAL, BEAM, and TRIANGLE ANTENNAS

by Edward M. Noll, W3FQJ

Antenna experimentation offers a unique opportunity to make amateur radio more than an "appliance operator" hobby. All you need are telescoping masts, wires, insulators, tubing, ingenuity, and a desire to experiment.

Antenna types from simple dipoles, through verticals and yagis, to quad and triangle beams are covered in this book, and the topics are arranged in a sequential manner. However, if the reader is interested in one particular type of antenna, he can go directly to that type.

The necessary mathematics are included, but no extensive knowledge is required to build the antennas described. Simple test instruments are shown which will enable the reader to optimize the designs and obtain maximum performance from his antenna.

Many of these antennas compete with, and some surpass the performance of commercial beams. The serious experimenter will find in **73 VERTICAL, BEAM, and TRIANGLE ANTENNAS** exactly what he needs.

ABOUT THE AUTHOR

In addition to being an accomplished author of technical books, lessons, articles, and instruction manuals, Ed Noll is also a consulting engineer and lecturer. His other books include:

73 Dipole and Long-Wire Antennas

First-Class Radiotelephone License Handbook

Second-Class Radiotelephone License Handbook

Radar License Endorsement Handbook

Radio Operators License Handbook

all published by
Howard W. Sams & Co., Inc.

EDITORS AND ENGINEERS, LTD.
New Augusta, Indiana

24021
$4.95 (In Canada $5.95)