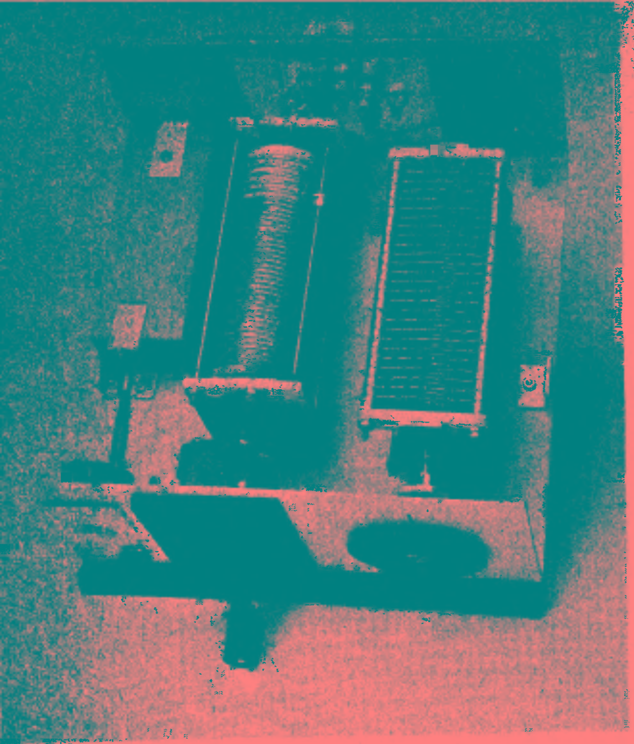


Fig. 21-35 — The Monimatch is at the upper left, covered by a metal enclosure. Connections from the roller inductor and the variable capacitor to the terminals on the jacks are made with thin strips of copper, although No. 12 or 14 wire can be used instead. The two antenna terminals are at the rear right. The top terminal is for use with a coax-fed antenna, if desired.

2) An antenna inside a frame building with wood exteriors is better than the same antenna in a steel-and-concrete building.

3) The higher above ground, inside or out, the better the antenna will work.

4) The bigger (or longer) you can make an indoor antenna, the better — even if it means running wire around corners.

5) Even a poor antenna *should* produce some contacts.

The Coupling Problem

Most transmitters are designed to work into a 50-ohm load, and contain little or no provision for adjusting the transmitter when the load is other than 50 ohms. Unfortunately, there is no random-length wire antenna that will present a 50-ohm load on all bands. What is required is a Transmatch. A Transmatch is simply an adjustable *LC* network that converts the unknown antenna impedance to 50 ohms. The unit, shown in Fig. 21-35, will cover the 80- through 10-meter bands and can handle 1 kW of rf power.

Circuit Details

The unit shown in Fig. 21-33 is designed to be used in three configurations. They are shown at B, C, and D. With one of the three hookups, it should be possible to match practically any antenna to the transmitter.

In order to get complete band coverage and avoid the complexities of band-switching, banana and jack plugs are used to change the circuit to the configuration needed. For example, if the setup shown at B is desired, jumper terminals 7 and 8, 1 and 3, and 4 and 5 should be used. Using the banana plugs makes for easy changing of the circuit.

Whenever a Transmatch is used, the operator should have a way of knowing when the unit is adjusted correctly. The answer to this need is a Monimatch or other SWR indicator.

Construction Details

The chassis for mounting the Transmatch is made from a piece of aluminum measuring 10 X 19 inches. The ends of the 19-inch length of aluminum are bent up to form a U-shaped chassis, the ends being 4 1/2 inches high to form a chassis 10 X 10 X 4 1/2 inches. The back side of the U has an opening cut out, 3 1/4 inches high by 4 1/2 inches long. A piece of Plexiglas is mounted over this opening. The jack-plug sockets are installed directly on the plastic. Connections from the roller inductor, L3, and variable capacitor, C1, are made to the banana jacks. Be careful when drilling the holes for the jacks to insure that they will mate with the plugs. Fig. 21-34 shows the details for a pc-board Monimatch. Methods for making etched circuit boards are given in detail in the Construction Practices chapter.

How to Tune Up

Using the Transmatch is not complicated. Although it takes some time to find the correct combination of settings, once determined, they can be logged for later reference. Use a short length of 50-ohm coax to connect the Transmatch to the transmitter. Attach the antenna to the Transmatch. Tune up the transmitter on the desired band, making sure that the final amplifier is resonated, but with the power output reduced. With the Monimatch in the forward-reading position, set the sensitivity control for a full-scale reading. Be sure to keep the final amplifier tank in resonance. Switch the meter to the reflected position, and then adjust L1 and C1, until the lowest indication of reflected power is obtained. It should be possible to get the meter to read zero, With a zero reading in the reflected position, versus full scale in the forward setting, the Transmatch is correctly adjusted, and the SWR is 1. The circuit may have to be changed to one of the other configurations in order to get a match, but one combination *should* work. Once the Transmatch is set properly, then adjust the transmitter to its rated power input. One other point: It isn't always possible to get a good ground connection in an apartment. Therefore, a connection to a cold-water pipe or earth ground should be used.

Try to make the antenna as long as possible, even if it must be run around corners. The length that will work best is from 120 to 130 feet. The end of the wire can be terminated at a window screen, which will get *part* of the antenna outside.

DIRECTIVE ARRAYS WITH PARASITIC ELEMENTS

With few exceptions, the antennas described so far in Chapter 21 have unity gain or less, and are either omnidirectional or bidirectional. In order for antennas to have gain and take on directional characteristics they must employ additional elements. Antennas with these properties are commonly referred to as "beam" antennas. This section will deal with the design and characteristics of directional antennas with gain.

Parasitic Excitation

In most of these arrangements the additional elements receive power by induction or radiation from the driven element generally called the "antenna," and reradiate it in the proper phase relationship to achieve the desired effect. These elements are called *parasitic* elements, as contrasted to the driven elements which receive power directly from the transmitter through the transmission line.

The parasitic element is called a director when it reinforces radiation on a line pointing to it from the antenna, and a reflector when the reverse is the case. Whether the parasitic element is a director or reflector depends upon the parasitic-element tuning, which usually is adjusted by changing its length.

Gain vs. Spacing

The gain of an antenna with parasitic elements varies with the spacing and tuning of the elements and thus for any given spacing there is a tuning condition that will give maximum gain at this spacing. The maximum front-to-back ratio seldom, if ever, occurs at the same condition that gives maximum forward gain. The impedance of the driven element also varies with the tuning and spacing, and thus the antenna system must be tuned to its final condition before the match between the line and the antenna can be completed. However, the tuning and matching may interlock to some extent, and it is usually necessary to run through the adjustments several times to insure that the best possible tuning has been obtained.

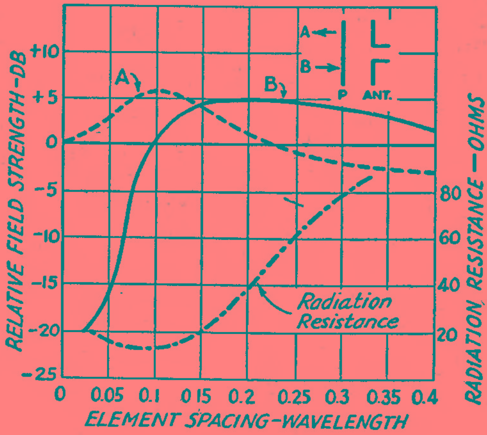


Fig. 21-36 -Gain vs. element spacing for an antenna and one parasitic alement. The reference point, 0 dB, is the field strength from a half-wave antenna alone. The greatest gain is in the direction A at spacings of less than 0.14 wavelength, and in direction B at greater spacings. The front-to-back ratio is the difference in dB between curves A and B. Variation in radiation resistance of the driven element is also shown. Thesa curves are for a self-resonant parasitic element. At most spacings the gain as a reflector can be increased by slight lengthening of tha parasitic element; the gain as a director can be increased by shortening. This also improves the front-to-back ratio.

Two-Element Beams

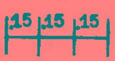
A 2-element beam is useful where space or other considerations prevent the use of the larger structure required for a 3-element beam. The general practice is to tune the parasitic element as a reflector and space it about 0.15 wavelength from the driven element, although some successful antennas have been built with 0.1-wavelength spacing and director tuning. Gain *vs.* element spacing for a 2-element antenna is given in Fig. 21-36, for the special case where the parasitic element is resonant. It is indicative of the performance to be expected under maximum-gain tuning conditions.

TABLE 21-II

Freq.	*Driven Element*		*Reflector*		*1st Director*		*2nd Director*	
	A	*B*	*A*	*B*	*A*	*B*	*A*	*B*
14050	33' 5 3/8"	33' 8"	35' 2 1/2"	35' 5 1/4"	31' 9 3/8"	31' 11 5/8"	31' 1 1/4"	31' 3 5/8"
14250	32' 11 3/4"	33' 2 1/4"	34' 8 1/2"	34' 11 1/4"	31' 4"	31' 6 3/8"	30' 8"	30' 10 1/2"
21050	22' 4"	22' 5 5/8"	23' 6"	23' 7 3/4"	21' 2 1/2"	21' 4"	20' 9 1/8"	20' 10 7/8"
21300	22' 3/4"	22' 2 3/8"	23' 2 5/8"	23' 4 1/2"	20' 11 1/2"	21' 1"	20' 6 1/4"	20' 7 3/4"
28050	16' 9"	16' 10 1/4"	17' 7 5/8"	17' 8 7/8"	15' 11"	16'	15' 7"	15' 9 1/2"
28600	16' 5 1/4"	16' 6 3/8"	17' 3 1/2"	17' 4 3/4"	15' 7 1/4"	15' 8 1/2"	15' 3 3/8"	15' 4 1/2"

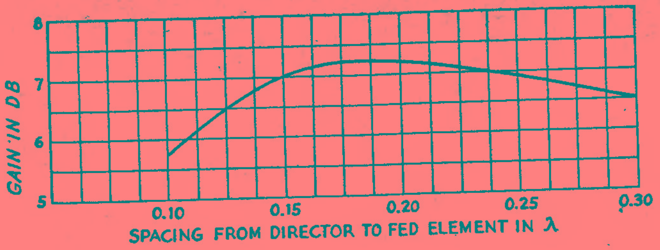
A

B



Element lengths for 20, 15 and 10 meters, phone and cw. These lengths are for 0.2 or .15 wavelength element spacing.

Fig. 21-37 — Gain of 3-element Yagi versus director spacing, the reflector spacing being fixed at 0.2 wavelength.



Three-Element Beams

A theoretical investigation of the 3-element case (director, driven element and reflector) has indicated a maximum gain of slightly more than 7 dB. A number of experimental investigations have shown that the optimum spacing between the driven element and reflector is in the region of 0.15 to 0.25 wavelength, with 0.2 wavelength representing probably the best overall choice. With 0.2-wavelength reflector spacing, Fig. 21-37 shows the gain variation with director spacing. It is obvious that the director spacing is not especially critical, and that the overall length of the array (boom length in the case of a rotatable antenna) can be anywhere between 0.35 and 0.45 wavelength with no appreciable difference in gain.

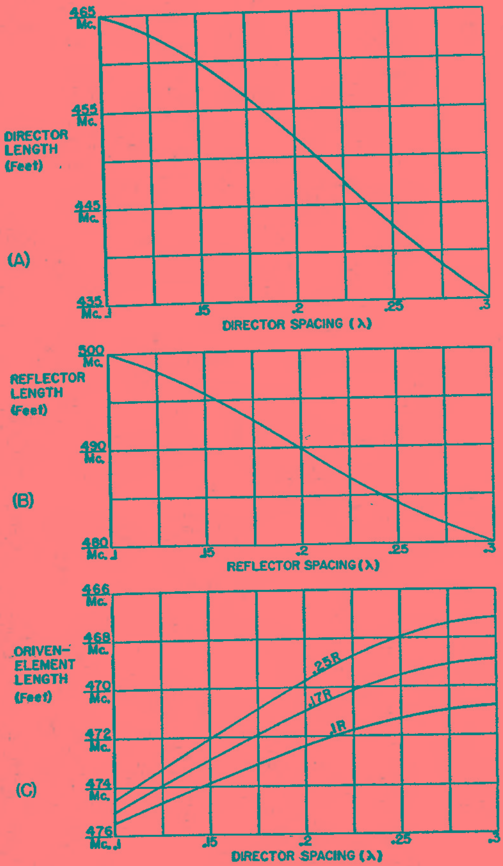


Fig. 21-38 — Element lengths for a 3-element beam. These lengths will hold closely for tubing elements supported at or near the center.

Wide spacing of both elements is desirable not only because it results in high gain but also because adjustment of tuning or element length is less critical and the input resistance of the driven element is higher than with close spacing. The latter feature improves the efficiency of the antenna and makes a greater bandwidth possible. However, a total antenna length, director to reflector, of more than 0.3 wavelength at frequencies of the order of 14 MHz introduces considerable difficulty from a constructional standpoint, so lengths of 0.25 to 0.3 wavelength are frequently used for this band, even though they are less than optimum.

In general, the gain of the antenna drops off less rapidly when the reflector length is increased beyond the optimum value than it does for a corresponding decrease below the optimum value. The opposite is true of a director. It is therefore advisable to err, if necessary, on the long side for a reflector and on the short side for a director. This also tends to make the antenna performance less dependent on the exact frequency at which it is operated, because an increase above the design frequency has the same effect as increasing the length of both parasitic elements, while a decrease in frequency has the same effect as shortening both elements. By making the director slightly short and the reflector slightly long, there will be a greater spread between the upper and lower frequencies at which the gain starts to show a rapid decrease.

When the over-all length has been decided upon, the element lengths can be found by referring to Fig. 21-38. The lengths determined by these charts will vary slightly in actual practice with the element diameter and the method of supporting the elements, and the tuning of a beam should always be checked after installation. However, the lengths obtained by the use of the charts will be close to correct in practically all cases, and they can be used without checking if the beam is difficult of access.

In order to make it even easier for the Yagi builder, Table 21-II can be used to determine the element lengths needed. Both cw and phone lengths are included for the three bands, 20, 15, and 10 meters. The 0.2 wavelength spacing will provide greater bandwidth than the 0.15 spacing. Antenna gain is essentially the same with either spacing. The element lengths given will be the same whether the beam has 2, 3 or 4 elements. It is recommended that "Plumber's Delight" type construction be used where all the elements are

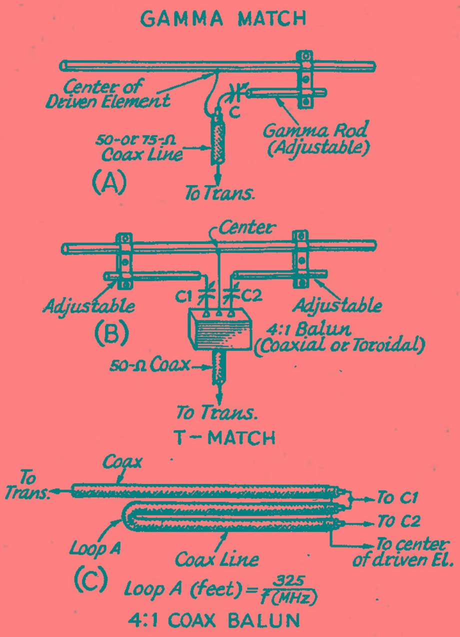


Fig. 21-39 – Illustrations of gamma and T-matching systems. At A, the gamma rod is adjusted along with C until the lowest possible SWR is obtained. A T-match is shown at B. It is the same as two gamma-match rods. The rods and C1 and C2 are alternately adjusted for a 1:1 SWR. A coaxial 4:1 balun transformer is shown at C. A toroidal balun can be used in place of the coax model shown. Details for the toroidal version are given in Chapter 20, and it has a broader frequency range than the coaxial version. The T-match is adjusted for 200 ohms and the balun steps this *balanced* value down to 50 ohms, *unbalanced*. Or, the T-match can be set for 300 ohms, and the balun used to step this down to 75 ohms, unbalanced. Dimensions for the gamma and T-match rods cannot be given by formula. Their lengths and spacing will depend upon the tubing size used, and the spacing of the parasitic elements of the beam. Capacitors C, C1 and C2 can be 140 pF for 14-MHz beams. Somewhat less capacitance will be needed at 21 and 28 MHz.

mounted directly on and grounded to the boom. This puts the entire array at dc ground potential, affording better lightning protection. A gamma section can be used for matching the feed line to the array.

Tuning Adjustments

The preferable method for checking the beam is by means of a field-strength meter or the S meter of a communications receiver, used in conjunction with a dipole antenna located at least 10 wavelengths away and as high as or higher than the beam that is being checked. A few watts of power fed into the antenna will give a useful signal at the observation point, and the power input to the transmitter (and hence the antenna) should be held constant for all of the readings.

Preliminary matching adjustments can be done on the ground. The beam should be set up so that the reflector element rests on earth with the remaining elements in a vertical configuration. In other words, the beam should be aimed straight up. The matching system is then adjusted for 1:1 SWR between the feed line and driven element. When the antenna is raised into its operating height, only slight touch-up of the matching network will be required.

A great deal has been printed about the need for tuning the elements of a Yagi-type beam. However, experience has shown that lengths given in Fig. 21-38 and Table II are close enough to the desired length that no further tuning should be required. This is true for Yagi arrays made from metal tubing. However, in the case of quad antennas, made from wire, the reflectors and directors *should* be tuned with the antenna in its operating location. The reason is that it is practically impossible to cut and install wire to the *exact* dimensions required for maximum gain or front-to-back.

Simple Systems: The Rotary Beam

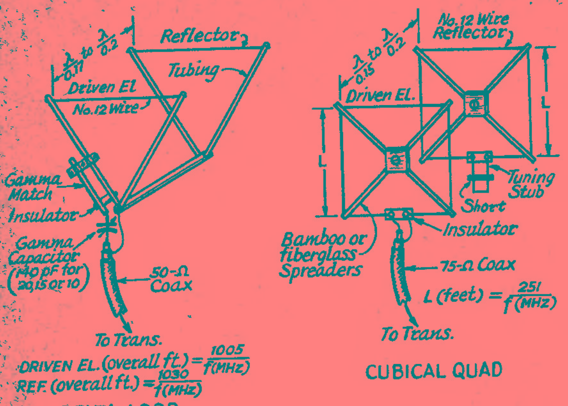
Two- and three-element systems are popular for rotary-beam antennas, where the entire antenna system is rotated, to permit its gain and directivity to be utilized for any compass direction. They may be mounted either horizontally (with the plane containing the elements parallel to the earth) or vertically.

A four-element beam will give still more gain than a three-element one, provided the support is sufficient for about 0.2 wavelength spacing between elements. The tuning for maximum gain involves many variables, and complete gain and tuning data are not available.

The elements in close-spaced (less than one-quarter wavelength element spacing) arrays preferably should be made of tubing of one-half to one-inch diameter. A conductor of large diameter not only has less ohmic resistance but also has lower *Q*; both these factors are important in close-spaced arrays because the impedance of the driven element usually is quite low compared to that of a simple dipole antenna. With three- and four-element close-spaced arrays the radiation resistance of the driven element may be so low that ohmic losses in the conductor can consume an appreciable fraction of the power.

Feeding the Rotary Beam

Any of the usual methods of feed (described later under "Matching the Antenna to the Line") can be applied to the driven element of a rotary beam. The popular choices for feeding a beam are the gamma match with series capacitor and the T match with series capacitors and a half-wavelength phasing section, as shown in Fig. 21-39. These methods are preferred over any others because they permit adjustment of the matching and the use of coaxial line feed. The variable capacitors can be housed in small plastic cups for weatherproofing; receiving types with close spacing can be used at powers up to a few hundred watts. Maximum



DELTA LOOP

CUBICAL QUAD

Fig. 21-40 — Information on building a quad or a Delta-Loop antenna. The antennas are electrically similar, but the Delta-Loop uses "plumber's delight" construction. Additional information is given in the text.

capacitance required is usually 140 pF at 14 MHz and proportionately less at the higher frequencies.

If physcially possible, it is better to adjust the matching device after the antenna has been installed at its ultimate height, since a match made with the antenna near the ground may not hold for the same antenna in the air.

Sharpness of Resonance

Peak performance of a multielement parasitic array depends upon proper phasing or tuning of the elements, which can be exact for one frequency only. In the case of close-spaced arrays, which because of the low radiation resistance usually are quite sharp-tuning, the frequency range over which optimum results can be secured is only of the order of 1 or 2 percent of the resonant frequency, or up to about 500 kHz at 28 MHz. However, the antenna can be made to work satisfactorily over a wider frequency range by adjusting the director or directors to give maximum gain at the *highest* frequency to be covered, and by adjusting the reflector to give optimum gain at the *lowest* frequency. This sacrifices some gain at all frequencies, but maintains more uniform gain over a wider frequency range.

The use of large-diameter conductors will broaden the response curve of an array because the larger diameter lowers the *Q*. This causes the reactances of the elements to change rather slowly with frequency, with the result that the tuning stays near the optimum over a considerably wider frequency range than is the case with wire conductors.

Combination Arrays

It is possible to combine parasitic elements with driven elements to form arrays composed of collinear driven and parasitic elements and combination broad-side-collinear-parasitic elements. Thus two or more collinear elements might be provided with a collinear reflector or director set, one parasitic element to each driven element. Or both directors and reflectors might be used. A broadside-collinear array can be treated in the same fashion.

DELTA LOOPS AND QUAD BEAMS

One of the more effective DX arrays is called the "cubical quad" or, simply, "quad" antenna. It consists of two or more square loops of wire supported by a bamboo or fiberglass cross-arm assembly. The loops are a quarter wavelength per side (full wavelength overall) one loop being driven, and the other serving as a parasitic element – usually a reflector. A variation of the quad is called the Delta Loop. The electrical properties of both antennas are the same, generally speaking, though some operators report better DX results with the Delta Loop. Both antennas are shown in Fig. 21-40. They differ mainly in their physical properties, one being of "Plumber's Delight" construction, while the other uses insulating support members. One or more directors can be added to either antenna if additional gain and directivity is desired, though most operators use the two-element arrangement.

It is possible to interlace quads or "deltas" for two or more bands, but if this is done the formulas given in Fig. 21-40 may have to be changed slightly to compensate for the proximity effect of the second antenna. For quads the length of the full-wave loop can be computed from

$$\textit{Full-wave loop}\ (\mathrm{ft}) = \frac{1005}{f\,(\mathrm{MHz})} \qquad \textbf{21-H}$$

If multiple arrays are used, each antenna should be tuned up separately for maximum forward gain as noted on a field-strength meter. The reflector stub on the quad should be adjusted for the foregoing condition. The Delta-Loop gamma match should be adjusted for a 1:1 SWR. No reflector tuning is needed. The Delta-Loop antenna has a broader frequency response than the quad, and holds at an SWR of 1.5:1 or better across the band it is cut for.

TABLE 21-III

Quantity	*Length (ft.)*	*Diameter (in.)*	*Reynolds No.*
2	8	1	9A
4	8	3/4	8A
1	8	1 1/4	10A
1	6	7/8	4231

2 U-bolts, TV antenna to mast type, 1 variable capacitor, 150 pF maximum, any type, 1 plastic freezer container, approximately 5 X 5 X 5 inches, to house gamma capacitor.

Gamma rod, 3/8- to 1/2-inch diameter aluminum tubing, 36 inches long. (Aluminum curtain rod or similar.)

The resonance of the quad antenna can be found by checking the frequency at which the lowest SWR occurs. The element length (driven element) can be adjusted for resonance in the most-used portion of the band by lengthening or shortening it.

It is believed that a two-element quad or Delta-Loop antenna compares favorably with a three-element Yagi array in terms of gain (see *QST*, May, 1963, and *QST*, January 1969 for additional information). The quad and Delta-Loop antennas perform very well at 50 and 144 MHz. A discussion of radiation patterns and gain, quads vs. Yagis, was presented by Lindsay in *QST*, May, 1968.

A SHORT 20-METER YAGI

Described here is a small, yet effective, three-element 20-meter Yagi that offers gain and good directivity. This system exhibits a front-to-back ratio in excess of 18 dB as measured with a good quality communications receiver.

Construction

The boom and all the elements are made from 1-1/4-inch diameter aluminum tubing available at most hardware stores. The two boom sections and the two pieces which make up the center portion of the driven element are coupled together using 15-inch sleeves of 1-3/8-inch OD aluminum tubing. Sheet metal screws should be used to secure the sections within the coupling sleeves.

The loading coils are wound on 1-1/8-inch diameter Plexiglas rod. Details are shown in Fig. 1. Be sure to slit the ends of the aluminum tubing where the compression clamps are placed. The coils are made from No. 14 enameled copper wire. The specified number of turns are equally spaced to cover the entire nine inches of Plexiglas.

The capacitance hats are constructed from 3/4-inch angle aluminum. Two pieces two feet in length are required for each hat. The model shown in the diagrams has the angle aluminum fastened to the element using aluminum strips however No. 8 sheet metal screws provide a suitable substitute. Solder lugs are fastened to the ends of the angle aluminum and No. 12 or 14 wire connects the ends of the aluminum resulting in a square loop. The wires should be soldered at each of the solder lugs.

All of the elements are secured to the boom with TV U-bolt hardware. Plated bolts are desirable to prevent rust from forming. An aluminum plate nine inches square by 1/4-inch thick was used as the boom-to-mast plate.

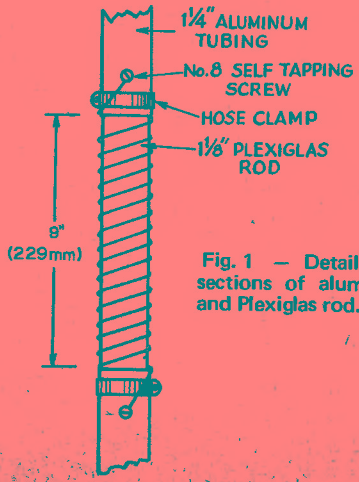


Fig. 1 — Details for joining sections of aluminum tubing and Plexiglas rod.

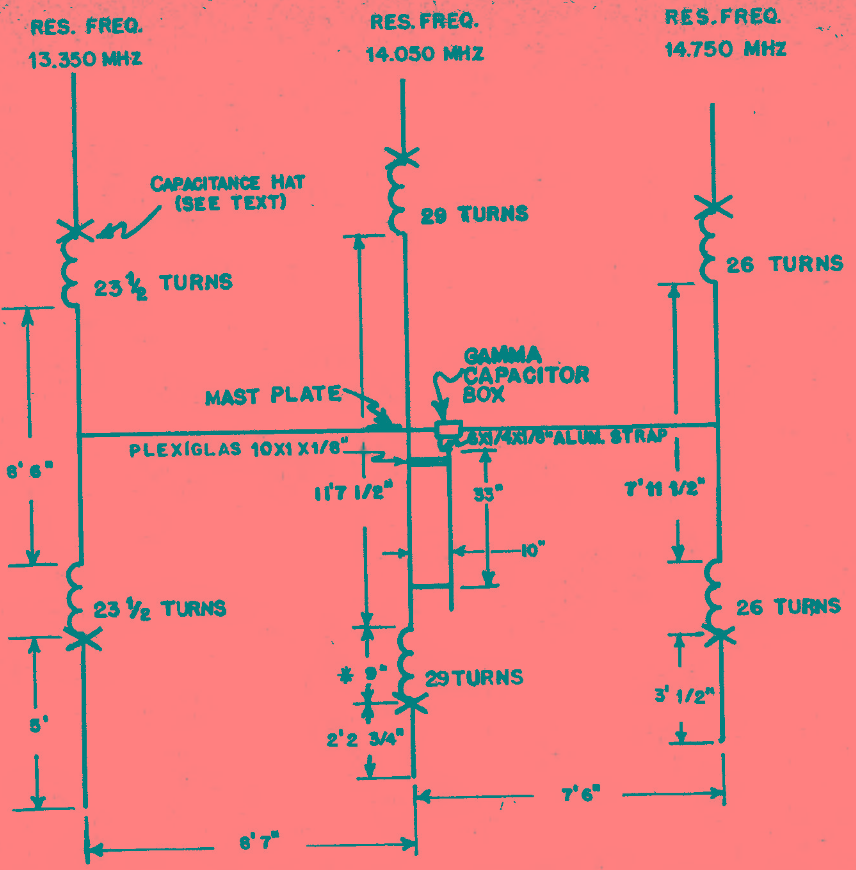
TABLE I

Complete parts list for the short beam.

QTY	*MATERIAL*
2	10-foot lengths of 1-1/4-inch dia. aluminum tubing (one for the reflector center section, one for the reflector end sections).
3	Eight-foot lengths of 1-1/4-inch die. aluminum tubing (two lengths for the boom, one length for the director element center).
4	Six-foot lengths of 1-1/4-inch dia. aluminum tubing (two lengths for the driven element center, two lengths for the director and driven element ends).
2	15-inch lengths of 1-5/8-inch dia. aluminum tubing.
1	40-inch length of 3/8-inch dia. aluminum tubing.
4	Six-foot lengths of 3/4-inch angle aluminum.
6	12-inch lengths of 1-1/8-inch dia. Plexiglas rod.
1	Nine-inch square, 1/4-inch thick aluminum plate.
8	U-bolts.
12	Compression hose clamps.
8	Crutch caps.
38′	No. 12 enameled copper wire.
60′	No. 14 enameled copper wire.

A boom strut is recommended because the weight of the elements is sufficient to cause the boom to sag. A 1/8-inch diameter nylon line is plenty strong. A U-bolt clamp is placed on the mast several feet above the antenna and provides

Shown here is WA1LNQ standing near the twenty-meter beam mounted atop the tower. Keep in mind the longest element is only 20 feet.



* ALL 6 PLEXIGLAS INSULATORS HAVE 9"(229MM) OF LENGTH EXPOSED

Fig. 2 – Constructional details for the 20-meter beam. The coils on each side of the element are identical. The gamma capacitor is a 140-pF variable unit manufactured by E. F. Johnson Co.

the attachment point for the center of the truss line. To reduce the possibility of water accumulating in the element tubing and subsequently freezing, crutch caps are placed over the ends. Rubber feet suitable for keeping furniture from scratching hardwood floors would serve the same purpose.

A piece of Plexiglas was mounted inside an aluminum Minibox to provide support and insulation for the gamma capacitor. A plastic refrigerator box would serve the purpose just as well. The capacitor housing is mounted to the boom by means of a U-bolt. The gamma rod is made of 3/8-inch aluminum 40-inches long and is connected to the gamma capacitor by a 6-inch length of strap aluminum.

Tune-Up and Operation

The builder is encouraged to follow the dimensions given in Fig. 1 as a starting point for the position of the gamma rod shorting strap. Connect the coaxial cable and install the antenna near or at the top of the tower. The gamma capacitor should be adjusted for minimum SWR at 14.100 MHz as indicated by an SWR meter (or power meter) connected in the feedline at the gamma capacitor box. If a perfect match cannot be obtained a slight repositioning of the gamma short might be required. The dimensions given favor the cw portion of the band. At 14.050 MHz the SWR is 1.1:1 and at 14.350 MHz the SWR is less than 2:1 making this antenna useful for phone as well as cw.

AN OPTIMUM-GAIN TWO-BAND ARRAY

If optimum performance is desired from a Yagi, the dual-4-element array shown in Fig. 21-43 will be of interest. This antenna consists of four elements on 15 meters interlaced with the same number for 10. Wide spacing is used, providing excellent gain and good bandwidth on both bands. Each driven element is fed separately with 50-ohm coax; gamma-matching systems are employed. If desired, a single feed line can be run to the array and then switched by a remotely controlled relay.

The element lengths shown in Fig. 21-44 are for the phone portions of the band, centered at 21,300 and 28,600 kHz. If desired, the element lengths can be changed for cw operation, using the dimensions given in Table 21-II. The spacing of the

Fig. 21-43 — Ready for erection, this is the completed dual-band beam.

elements will remain the same for both phone and cw.

Construction Details

The elements are supported by commercially made U-bolt assemblies. Or, muffler clamps make excellent element supports. The boom-to-mast support is also a manufactured item that is designed to hold a 2-inch diameter boom and that can be used with mast sizes up to 2 1/2 inches in diameter. Another feature of this device is that it permits the beam to be tilted after it is mounted in place on the tower, providing access to the elements if they need to be adjusted once the beam has been mounted on the tower.

The elements are made from 6061-T6 aluminum tubing, which is available from metal suppliers. The tubing comes in 12-foot lengths and can be purchased in telescoping sizes. The center sections of the 15-meter beam elements are 1-inch outside diameter and the 10-meter sections are 3/4-inch. The ends of the tubing are slit with a hack saw, and hose clamps are used to hold the telescoping portions.

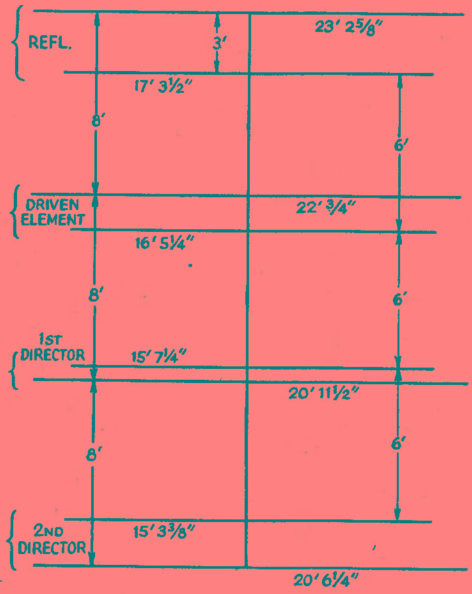
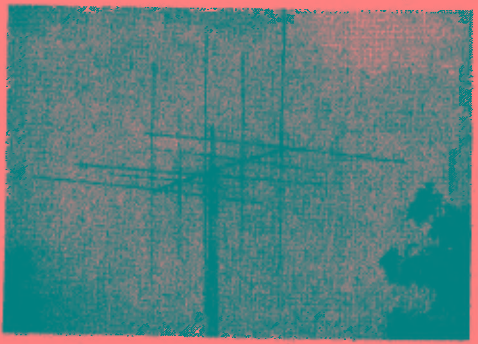


Fig. 21-44 — The element lengths shown are for the phone sections of the bands. Table 21-II provides the dimensions for cw frequencies.

Fig. 21-45 — This is the boom-to-mast fixture that holds the two 12-foot boom sections together. The unit is made by Hy-Gain Electronics, P. O. Box 5407-HE, Lincoln, NE 68505.

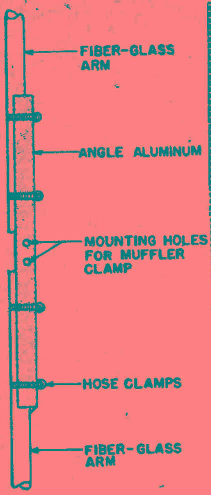
A THREE-BAND QUAD ANTENNA SYSTEM

Quads have been popular with amateurs during the past few decades because of their light weight, relatively small turning radius, and their unique ability to provide good DX performance when mounted close to the earth. A two-element three-band quad, for instance, with the elements mounted only 35 feet above the ground, will give good performance in situations where a triband Yagi will not. Fig. 1 shows a large quad antenna which can be used as a basis for design for either smaller or larger arrays.



The three-band quad antenna.

Five sets of element spreaders are used to support the three-element 20-meter, four-element 15-meter, and five-element 10-meter wire-loop system. The spacing between elements has been chosen to provide optimum performance con-



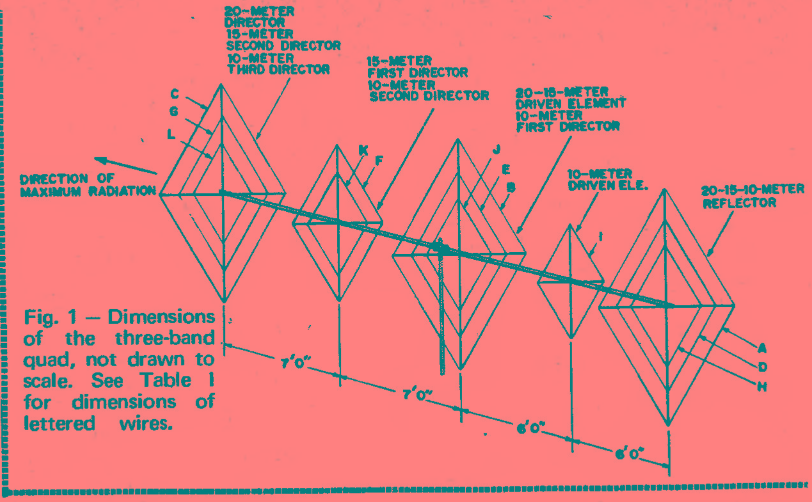


Fig. 1 — Dimensions of the three-band quad, not drawn to scale. See Table I for dimensions of lettered wires.

Fig. 2 — Details of one of two assemblies for a spreader frame. The two assemblies are jointed to form an X with a muffler clamp mounted at the position shown.

TABLE I

Three-Band Quad Loop Dimensions

Band	*Reflector*	*Driven Element*	*First Director*	*Second Director*	*Third Director*
20 Meters	(A) 72' 8"	(B) 71' 3"	(C) 69' 6"	–	–
15 Meters	(D) 48' 6½"	(E) 47' 7½"	(F) 46' 5"	(G) 46' 5"	–
10 Meters	(H) 36' 2½"	(I) 35' 6"	(J) 34' 7"	(K) 34' 7"	(L) 34' 7"

Letters indicate loops identified in Fig. 1

sistent with boom length and mechanical construction. Each of the parasitic loops is closed (ends soldered together) and requires no tuning. All of the loop sizes are listed in Table I and are designed for a center frequency of 14.1, 21.1, and 28.3 MHz. Since quad antennas are rather broad-tuning devices excellent performance is achieved in both cw and ssb band segments of each band (with the possible exception of the very high end of 10 meters). Changing the dimensions to favor a frequency 200 kHz higher in each band to create a "phone" antenna is not necessary.

One question which comes up quite often is whether to mount the loops in a diamond or a square configuration. In other words, should one spreader be horizontal to the earth, or should the wire be horizontal to the ground (spreaders mounted in the fashion of an X)? From the electrical point of view, it is probably a trade-off. While the square configuration has its lowest point higher above ground than a diamond version (which may lower the angle of radiation slightly), the top is also lower than that of a diamond shaped array. Some authorities indicate that separation of the current points in the diamond system gives slightly more gain than is possible with a square layout. It should be pointed out, however, that there never has been any substantial proof in favor of one or the other, electrically.

Spreader supports (sometimes called spiders) are available from many different manufacturers. If the builder is keeping the cost at a minimum, he should consider building his own. The expense is about half that of a commercially manufactured equivalent and, according to some authorities, the homemade arm supports described below are less likely to rotate on the boom as a result of wind pressure.

A three-foot long section of one-inch-per-side steel angle stock is used to interconnect the pairs of spreader arms. The steel is drilled at the center to accept a muffler clamp of sufficient size to clamp the assembly to the boom. The fiber glass is attached to the steel angle stock with automotive hose clamps, two per pole. Each quad-loop spreader frame consists of two assemblies of the type shown in Fig. 2.

A 20-METER VERTICAL BEAM

An excellent parasitic array for 20 meters is a 3-element vertical beam originally described by W2FMI in June, 1972, *QST*. The antenna is actually one-half of a Yagi array using quarter-wave elements with spacing between elements of 0.2 wavelength (12-1/2 feet on 20 meters). This spacing results in a good compromise between gain and input impedance. Closer spacing would reduce the input impedance, and hence the efficiency, because of the inherent earth losses with vertical antennas. This vertical symmetrical Yagi allows for electrical beam switching (changing a director into a reflector by switching in a loading coil at the base) while maintaining a constant input impedance at the driven element. The dimensions of the three-element antenna, when used as a fixed or a switched array, are shown in Table 21-IV. The elements are constructed using 1/16-inch-wall aluminum tubing and consist of three telescoping sections with one-inch OD tubing used for the bottom portions. This results in a self-supporting structure. Actually, many choices are available, including No. 14 or 12 wire taped to bamboo poles.

The three-element array with the full image plane presents an input impedance of 15 ohms. Matching is accomplished with the step-down transformer, a 4:1 unbalanced-to-unbalanced toroidal balun. This transformer is also shown in Fig. 21-52 connected to the driven element.

Fig. 21-53 shows the geometry of the image plane. The inner square has a diagonal of 4/10 wavelength (25 feet). The outer wires of these sections are No. 14 wire and the inner wires are No. 18. All cross-connected wires were wire-wrapped and soldered. The pattern was chosen to give an easy path for the surface currents of a five-element array (parasitic elements at the four corners). The outer radials were all 0.4 wavelength long and also of No. 18 wire. Twenty-five wires emanated from each corner and nine from the sides.

TABLE 21-IV

Dimensions of 20-Meter Parasitic 3-Element Array

1) Fixed Array	
Director	15 ft 8 in.
Driven Element	16 ft
Reflector	17 ft 7 in.
Spacing Between Elements	12-1/2 ft
2) Switched Array	
Director and Reflector	15 ft
Driven Element	16 ft
Spacing Between Elements	12-1/2 ft
Loading Coil	2 ft No. 12 wire wound 3 turns with 3 in. dia. Length adjusted for max. F/B ratio

Fig. 21-52 — Base hardware of the driven element and the matching transformer.

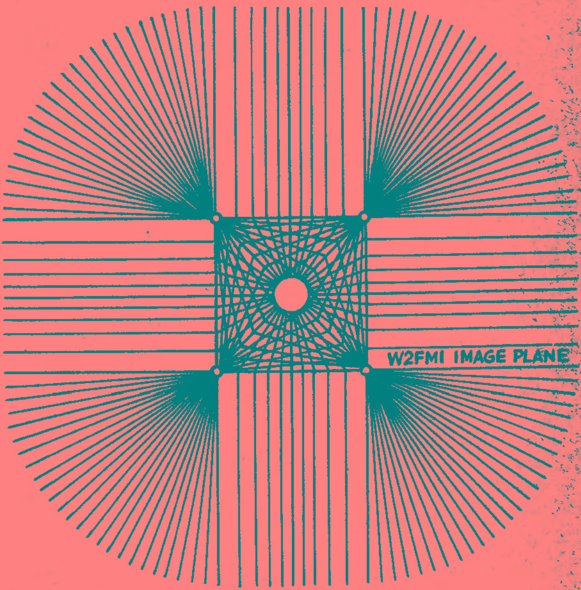


Fig. 21-53 — Geometry of the image plane used in this investigation. The pattern was chosen to approximete lines of current flow.

Fig. 21-54 — Base of one of the parasitic elements showing the relay enclosure, loading coil, and the indicator meter of the field-strength detector, which was located 2 wavelengths away.

STANDARD SIZES OF ALUMINUM TUBING

Many hams like to experiment with antennas but one problem in making antennas using aluminum tubing is knowing what sizes of tubing are available. If you want to build a beam, many questions about tubing sizes, weights, what size tubing fits into what other size, and so forth must be answered.

Table 21-V gives the standard sizes of aluminum tubing that are stocked by most aluminum suppliers or distributors in the United States and Canada. Note that all tubing comes in 12-foot lengths and also that any diameter tubing will fit into the next larger size, if the larger size has a 0.058-inch wall thickness. For example, 5/8-inch tubing has an outside diameter of 0.625 inches and will fit into 3/4-inch tubing with a 0.058-inch wall which has an inside diameter of 0.634 inches. Having used quite a bit of this type tubing it is possible to state that 0.009-inch clearance is just right for a slip fit or for slotting the tubing and then using hose clamps. To repeat, always get the next larger size and specify a 0.058-inch wall to obtain the 0.009-inch clearance.

With the chart, a little figuring will provide all the information needed to build a beam, including what the antenna will weigh. The 6061-T6 type of aluminum is a relatively high strength and has good workability, plus being highly resistant to corrosion and will bend without taking a "set."

Check the Yellow Pages for aluminum dealers.

TABLE 21-V

6061-T6 (61S-T6) ROUND ALUMINUM TUBE

In 12-Foot Lengths

O. D.	WALL THICKNESS		I. D.	APPROX. WEIGHT	
Inches	Inches	Stubs Ga.	Inches	Per Foot	Per Length
3/16"	.035	(No. 20)	.117	.019 lbs.	.228 lbs.
	.049	(No. 18)	.089	.025 lbs.	.330 lbs.
1/4"	.035	(No. 20)	.180	.027 lbs.	.324 lbs.
	.049	(No. 18)	.152	.036 lbs.	.432 lbs.
	.058	(No. 17)	.134	.041 lbs.	.492 lbs.
5/16"	.035	(No. 20)	.242	.036 lbs.	.432 lbs.
	.049	(No. 18)	.214	.047 lbs.	.564 lbs.
	.058	(No. 17)	.196	.055 lbs.	.660 lbs.
3/8"	.035	(No. 20)	.305	.043 lbs.	.516 lbs.
	.049	(No. 18)	.277	.060 lbs.	.720 lbs.
	.058	(No. 17)	.259	.068 lbs.	.816 lbs.
	.065	(No. 16)	.245	.074 lbs.	.888 lbs.
7/16"	.035	(No. 20)	.367	.051 lbs.	.612 lbs.
	.049	(No. 18)	.339	.070 lbs.	.840 lbs.
	.065	(No. 16)	.307	.089 lbs.	1.068 lbs.
1/2"	.028	(No. 22)	.444	.049 lbs.	.588 lbs.
	.035	(No. 20)	.430	.059 lbs.	.708 lbs.
	.049	(No. 18)	.402	.082 lbs.	.984 lbs.
	.058	(No. 17)	.384	.095 lbs.	1.040 lbs.
	.065	(No. 16)	.370	.107 lbs.	1.284 lbs.
5/8"	.028	(No. 22)	.569	.061 lbs.	.732 lbs.
	.035	(No. 20)	.555	.075 lbs.	.900 lbs.
	.049	(No. 18)	.527	.106 lbs.	1.272 lbs.
	.058	(No. 17)	.509	.121 lbs.	1.452 lbs.
	.065	(No. 16)	.495	.137 lbs.	1.644 lbs.
3/4"	.035	(No. 20)	.680	.091 lbs.	1.092 lbs.
	.049	(No. 18)	.652	.125 lbs.	1.500 lbs.
	.058	(No. 17)	.634	.148 lbs.	1.776 lbs.
	.065	(No. 16)	.620	.160 lbs.	1.920 lbs.
	.083	(No. 14)	.584	.204 lbs.	2.448 lbs.
7/8"	.035	(No. 20)	.805	.108 lbs.	1.308 lbs.
	.049	(No. 18)	.777	.151 lbs.	1.810 lbs.
	.058	(No. 17)	.759	.175 lbs.	2.100 lbs.
	.065	(No. 16)	.745	.199 lbs.	2.399 lbs.
1"	.035	(No. 20)	.930	.123 lbs.	1.476 lbs.
	.049	(No. 18)	.902	.170 lbs.	2.040 lbs.
	.058	(No. 17)	.884	.202 lbs.	2.424 lbs.
	.065	(No. 16)	.870	.220 lbs.	2.640 lbs.
1"	.083	(No. 14)	.834	.281 lbs.	3.372 lbs.
1 1/8"	.035	(No. 20)	1.055	.139 lbs.	1.668 lbs.
	.058	(No. 17)	1.009	.228 lbs.	2.736 lbs.
1 1/4"	.035	(No. 20)	1.180	.155 lbs.	1.860 lbs.
	.049	(No. 18)	1.152	.210 lbs.	2.520 lbs.
	.058	(No. 17)	1.134	.256 lbs.	3.072 lbs.
	.065	(No. 16)	1.120	.284 lbs.	3.408 lbs.
	.083	(No. 14)	1.084	.357 lbs.	4.284 lbs.
1 3/8"	.035	(No. 20)	1.305	.173 lbs.	2.076 lbs.
	.058	(No. 17)	1.259	.282 lbs.	3.384 lbs.
1 1/2"	.035	(No. 20)	1.430	.180 lbs.	2.160 lbs.
	.049	(No. 18)	1.402	.260 lbs.	3.120 lbs.
	.058	(No. 17)	1.384	.309 lbs.	3.708 lbs.
	.065	(No. 16)	1.370	.344 lbs.	4.128 lbs.
	.083	(No. 14)	1.334	.434 lbs.	5.208 lbs.
	*.125	1/8"	1.250	.630 lbs.	7.416 lbs.
	*.250	1/4"	1.000	1.150 lbs.	14.832 lbs.
1 5/8"	.035	(No. 20)	1.555	.206 lbs.	2.472 lbs.
	.058	(No. 17)	1.509	.336 lbs.	4.032 lbs.
1 3/4"	.058	(No. 17)	1.634	.363 lbs.	4.356 lbs.
	.083	(No. 14)	1.584	.510 lbs.	6.120 lbs.
1 7/8"	.058	(No. 17)	1.759	.389 lbs.	4.668 lbs.
2"	.049	(No. 18)	1.902	.350 lbs.	4.200 lbs.
	.065	(No. 16)	1.870	.450 lbs.	5.400 lbs.
	.083	(No. 14)	1.834	.590 lbs.	7.080 lbs.
	*.125	1/8"	1.750	.870 lbs.	9.960 lbs.
	*.250	1/4"	1.500	1.620 lbs.	19.920 lbs.
2 1/4"	.049	(No. 18)	2.152	.398 lbs.	4.776 lbs.
	.065	(No. 16)	2.120	.520 lbs.	6.240 lbs.
	.083	(No. 14)	2.084	.660 lbs.	7.920 lbs.
2 1/2"	.065	(No. 16)	2.370	.587 lbs.	7.044 lbs.
	.083	(No. 14)	2.334	.740 lbs.	8.880 lbs.
	*.125	1/8"	2.250	1.100 lbs.	12.720 lbs.
	*.250	1/4"	2.000	2.080 lbs.	25.440 lbs.
3"	.065	(No. 16)	2.870	.710 lbs.	8.520 lbs.
	*.125	1/8"	2.700	1.330 lbs.	15.600 lbs.
	*.250	1/4"	2.500	2.540 lbs.	31.200 lbs.

*These sizes are extruded. All other sizes are drawn tubes.

A SMALL YAGI FOR 40 METERS

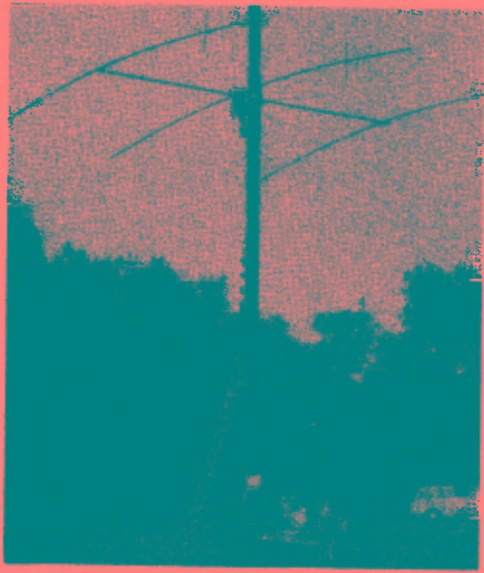


Fig. 1 — The short 40-meter Yagi resembles a large 20-meter system.

A 7-MHz antenna for most amateur installations consists of a half-wave dipole attached between two convenient supports and fed power at the center with coaxial cable. When antenna gain is a requirement on this frequency, the dimensions of the system can become overwhelming. A full size three-element Yagi typically would have 68-foot elements and a 36-foot boom. Accordingly, half size elements present some distinct mechanical as well as economical advantages. Reducing the spacing between elements is not recommended since it would severely restrict the bandwidth of operation and make the tuning critical. Good directivity and reasonable gain are features of this array, yet the mechanical design allows the use of a "normal" heavy-duty rotator and a conventional tower support. Element loading is accomplished by lumped inductance and capacitance hats along the 38-foot elements.

Construction

The system described here is similar to the three-element antenna for 20 meters described earlier in this chapter. Some minor changes have been made to allow the use of standard sizes and lengths of aluminum tubing. All three elements are the same length; the tuning of the inductor is slightly different on each element, however. The two parasitic elements are grounded at the center with the associated boom-to-element hardware. A helical hairpin match is used to provide a proper match to the split and insulated driven element. Two sections of steel angle stock are used to reinforce the driven-element mounting plate since the Plexiglas center insulating material is not rigid and element sag might otherwise result. The parasitic element center sections are continuous sections of aluminum tubing and additional support is not needed here. Figs. 2 and 3 show the details clearly.

The inductors for each element are wound on 1-1/8-inch diameter solid Plexiglas cast rod. Each end of the coil is secured in place with a solder lug and the Plexiglas is held in position with an automotive compression clamp. The total number of turns needed to resonate the elements correctly is given in Fig. 5. The capacitance hats consist of 1/2-inch tubing three feet long (two pieces used) attached to the element directly next to the coil on each parasitic element and two inches away from

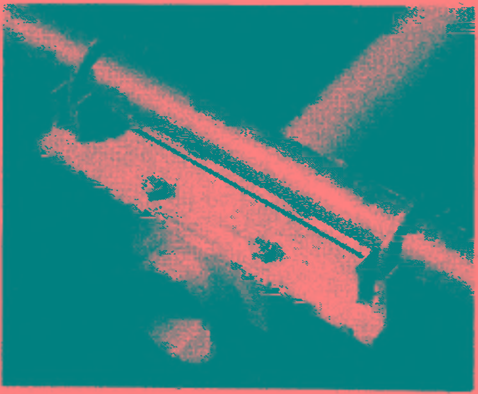


Fig. 2 — The parasitic elements are held in position with a small plate and four automotive muffler clamps.

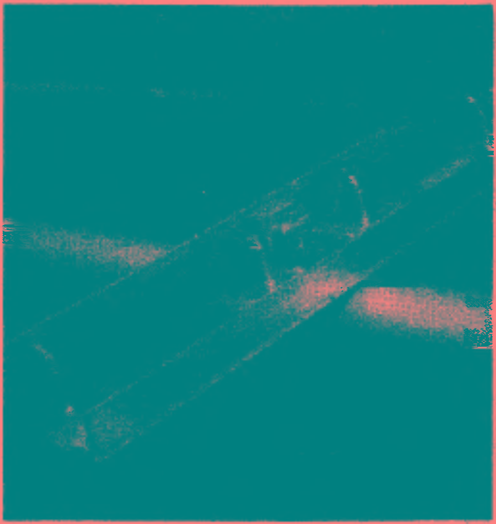


Fig. 3 — The driven element needs to be insulated from the boom. Insulation is provided by PVC tubing held in place on sheet plastic with U bolts.

the coil for the driven element. Complete details are given in Fig. 4.

The boom is constructed from three sections of aluminum tubing which measures 2-1/2 inches diameter and 12 feet long. These pieces are joined together with inner tubes made from 2-1/4-inch stock shimmed with aluminum flashing. Long strips, approximately one inch wide, are wound on the inner tubing before it is placed inside the boom sections. A pair of 3/8 × 3-1/2 inch steel bolts are placed at right angles to each other at every connection point to secure the boom. Caution: do not over tighten the bolts since this will distort the tubing making it impossible to pull apart sections, should the need arise. It is much better to install locking nuts over the original ones to assure mechanical security.

The helical hairpin details are given in Fig. 6. Quarter inch copper tubing is formed into seven turns approximately four inches long and 2-1/4 inches ID.

Tuning and Matching

The builder is encouraged to carefully follow the dimensions given in Fig. 5. Tuning the elements with the aid of a grid-dip oscillator has proved to be somewhat unreliable and accordingly, no resonant frequencies will be given.

The hairpin matching system may not resemble the usual form but its operation and adjustment are essentially the same. For a detailed explanation of this network, see the Transmission Line chapter of *The ARRL Antenna Book*, thirteenth edition. The driven element resonant frequency required for the hairpin match is determined by the placement of the capacitance hats with respect to the ends of the coils. Sliding the capacitance hats away from the ends of the coils increases the resonant frequency (capacitive reactance) of the element to cancel the effect of the hairpin inductive reactance. The model shown here had capacitance hats mounted 2-1/2 inches out from the ends of the coils (on the driven element only). An SWR indicator or wattmeter should be installed in series with the feed line *at the antenna*. The hairpin coil may be spread or compressed with an insulated tool (or by hand if power is removed!) to provide minimum reflected power at 7.050 MHz. The builder should not necessarily strive for a perfect match by changing the position of the capacitance hats since this may reduce the bandwidth of the matching system. An SWR of less than 2 to 1 was achieved across the entire 40-meter band with the antenna mounted atop an 80-foot tower.

Fig. 4 — Each loading coil is wound on Plexiglas rod. The capacitance hats for the parasitic elements are mounted next to the coil, as shown here. The hose clamps compress the tubing against the Plexiglas rod. Each capacitance hat consists of two sections of tubing and associated muffler clamps.

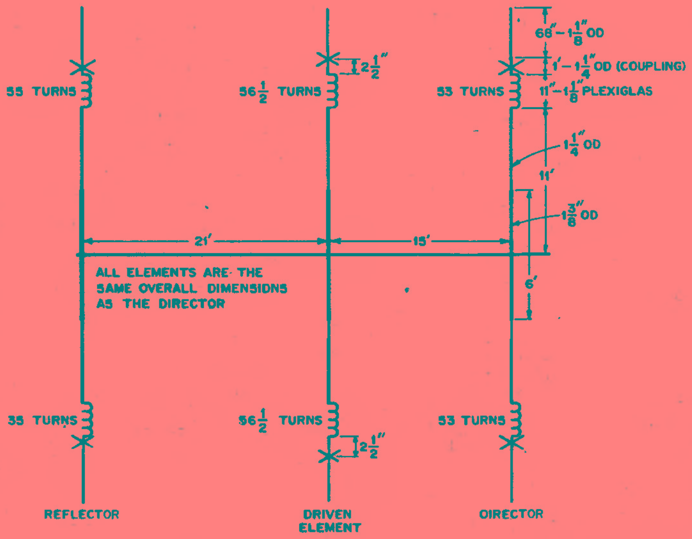


Fig. 5 — Mechanical details and dimensions for the 40-meter Yagi. Each of the elements uses the same dimensions; the difference is only the number of turns on the inductors and the placement of the capacitance hats. See the text for more details.

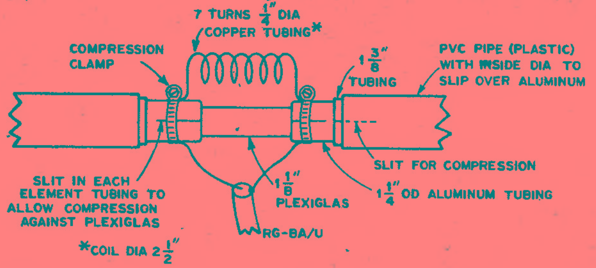


Fig. 6 — Driven-element hairpin matching details.

The tuning of the array can be checked by making front-to-back ratio measurements across the band. With the dimensions given here, the best figures of front-to-back (approximately 25 to 30 dB) should be noticed in the cw portion of the band. Should the builder suspect the tuning is incorrect or if the antenna is mounted at some height greatly different than 80 feet, retuning of the elements may be necessary.

ANTENNA SUPPORTS

"A"-FRAME MAST

The simple and inexpensive mast shown in Fig. 1 is satisfactory for heights up to 35 or 40 feet. Clear, sound lumber should be selected. The completed mast may be protected by two or three coats of house paint.

If the mast is to be erected on the ground, a couple of stakes should be driven to keep the bottom from slipping and it may then be "walked up" by a pair of helpers. If it is to go on a roof, first stand it up against the side of the building and then hoist it from the roof, keeping it vertical. The whole assembly is light enough for two men to perform the complete operation — lifting the mast, carrying it to its permanent berth, and fastening the guys — with the mast vertical all the while. It is entirely practicable, therefore, to errect this type of mast on any small, flat area of roof.

By using 2 X 3s or 2 X 4s, the height may be extended up to about 50 feet. The 2 X 2 is too flexible to be satisfactory at such heights.

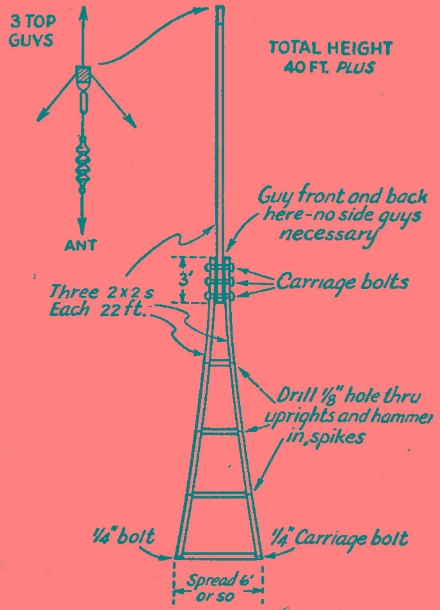


Fig. 1 — Details of a simple 40-foot "A"-frame mast suitable for erection in locations where space is limited.

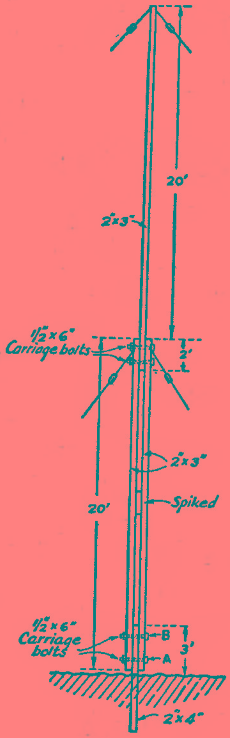


Fig. 2 — A simple and sturdy mast for heights in the vicinity of 40 feet, pivoted at the base for easy erection. The height can be extended to 50 feet or more by using 2 X 4s instead of 2 X 3s.

Fig. 3 — While guys are not normally required for the homemade tower, they provide an extra measure of protection against high winds. An inverted V can serve here as two of the guy lines.

SIMPLE 40-FOOT MAST

The mast shown in Fig. 2 is relatively strong, easy to construct, readily dismantled, and costs very little. Like the "A"-frame, it is suitable for heights of the order of 40 feet.

The top section is a single 2 X 3, bolted at the bottom between a pair of 2 X 3s with an overlap of about two feet. The lower section thus has two legs spaced the width of the narrow side of a 2 X 3. At the bottom the two legs are bolted to a length of 2 X 4 which is set in the ground. A short length of 2 X 3 is placed between the two legs about halfway up the bottom section, to maintain the spacing.

The two back guys at the top pull against the antenna, while the three lower guys prevent buckling at the center of the pole.

The 2 X 4 section should be set in the ground so that it faces the proper direction, and then made vertical by lining it up with a plumb bob. The holes for the bolts should be drilled beforehand. With the lower section laid on the ground, bolt *A* should be slipped in place through the three pieces of wood and tightened just enough so that the section can turn freely on the bolt. Then the top section may be bolted in place and the mast pushed up, using a ladder or another 20-foot 2 X 3 for the job. As the mast goes up, the slack in the guys can be taken up so that the whole structure is in some measure continually supported. When the mast is vertical, bolt *B* should be slipped in place and both *A* and *B* tightened. The lower guys can then be given a final tightening, leaving those at the top a little slack until the antenna is pulled up, when they should be adjusted to pull the top section into line.

Chapter 22

VHF and UHF Antennas

Improving his antenna system is one of the most productive moves open to the vhf enthusiast. It can increase transmitting range, improve reception, reduce interference problems, and bring other practical benefits. The work itself is by no means the least attractive part of the job. With even high-gain antennas, experimentation is greatly simplified, at vhf and uhf, because an array is a workable size, and much can be learned about the nature and adjustment of antennas. No large investment in test equipment is necessary.

Whether we buy or build our antennas, we soon find that there is no one "best" design for all purposes. Selecting the antenna best suited to our needs involves much more than scanning gain figures and prices in a manufacturer's catalog. The first step should be to establish priorities.

OBJECTIVES

Gain: Shaping the pattern of an antenna, to concentrate radiated energy, or received-signal pickup, in some directions at the expense of others is the only way to develop gain. This is best explained by starting with the hypothetical **isotropic antenna**, which would radiate equally in all directions. A point source of light illuminating the inside of a globe uniformly, from its center, is a visual analogy. No practical antenna can do this, so all antennas have "gain over isotropic" (dBi). A half-wave dipole in free space has 2.1 dBi. If we can plot the radiation pattern of antenna in all planes, we can compute its gain, so quoting it with respect to isotropic is a logical base for agreement and understanding. It is rarely possible to erect a half-wave antenna that has anything approaching a free-space pattern, and this fact is responsible for much of the confusion about true antenna gain.

Radiation patterns can be controlled in various ways. One is to use two or more driven elements, fed in phase. Such collinear arrays provide gain without markedly sharpening the frequency response, compared to that of a single element. More gain per element, but with a sacrifice in frequency coverage, is obtained by placing parasitic elements longer and shorter than the driven one, in the plane the first element, but not driven from the feedline. The reflector and directors of a Yagi array are highly frequency sensitive and such an antenna is at its best over frequency changes of less than one percent of the operating frequency.

Frequency Response: Ability to work over an entire vhf band may be important in some types of work. The response of an antenna element can be broadened somewhat by increasing the conductor diameter, and by tapering it to something approximating cigar shape, but this is done mainly with simple antennas. More practically, wide frequency coverage may be a reason to select a collinear array, rather than a Yagi. On the other hand, the growing tendency to channelize operations in small segments of our bands tends to place broad frequency coverage low on the priority list of most vhf stations.

Radiation Pattern: Antenna radiation can be made omnidirectional, bidirectional, practically unidirectional, or anything between these conditions. A vhf net operator may find an omnidirectional system almost a necessity, but it may be a poor choice otherwise. Noise pickup and other interference problems tend to be greater with such antennas, and those having some gain are especially bad in these respects. Maximum gain and low radiation angle are usually prime interests of the weak-signal DX aspirant. A clean pattern, with lowest possible pickup and radiation off the sides and back, may be important in high-activity areas, or where the noise level is high.

Height Gain: In general, the higher the better in vhf antenna installations. If raising the antenna clears its view over nearby obstructions, it may make dramatic improvements in coverage. Within reason greater height is almost always worth its cost, but height gain must be balanced against increased transmission-line loss. The latter is considerable, and it increases with frequency. The best available line may be none too good, if the run is long in terms of wavelength. Give line-loss information, shown in table form in Chapter 20, close scrutiny in any antenna planning.

Physical Size: A given antenna design for 432 MHz will have the same gain as one for 144 MHz, but being only one-third the size it will intercept only one-third as much energy in receiving. Thus, to be equal in communication effectiveness, the 432-MHz array should be at least equal in *size* to the 144-MHz one, which will require roughly three times as many elements. With all the extra difficulties involved in going higher in frequency, it is well to be on the big side, in building an antenna for the higher band.

DESIGN FACTORS

Having sorted out objectives in a general way, we face decisions on specifics, such as polarization, type of transmission line, matching methods and mechanical design.

Polarization: Whether to position the antenna elements vertical or horizontal has been a moot point since early vhf pioneering. Tests show little evidence on which to set up a uniform polarization policy. On long paths there is no consistent advantage, either way. Shorter paths tend to yield higher signal levels with horizontal in some kinds of terrain. Man-made noise, especially ignition interference, tends to be lower with horizontal. Verticals are markedly simpler to use in omnidirectional systems, and in mobile work.

Early vhf communication was largely vertical, but horizontal gained favor when directional arrays became widely used. The major trend to fm and repeaters, particularly in the 144-MHz band, has tipped the balance in favor of verticals in mobile work and for repeaters. Horizontal predominates in other communication, on 50 MHz and higher frequencies. It is well to check in advance in any new area in which you expect to operate, however, as some localities still use vertical almost exclusively. A circuit loss of 20 dB or more can be expected with cross-polarization.

Transmission Lines: There are two main categories of transmission lines: balanced and unbalanced. The former include open-wire lines separated by insulating spreaders, and Twin-Lead, in which the wires are embedded in solid or foamed insulation. Line losses result from ohmic resistance, radiation from the line, and deficiencies in the insulation. Large conductors, closely spaced in terms of wavelength, and using a minimum of insulation, make the best balanced lines. Impedances are mainly 300 to 500 ohms. Balanced lines are best in straight runs. If bends are unavoidable, the angles should be as obtuse as possible. Care should be taken to prevent one wire from coming closer to metal objects than the other. Wire spacing should be less than 1/20 wavelength.

Properly built, open-wire line can operate with very low loss in vhf and even uhf installations. A total line loss under 2 dB per hundred feet at 432 MHz is readily obtained. A line made of No. 12 wire, spaced 3/4 inch or less with Teflon spreaders, and running essentially straight from antenna to station, can be better than anything but the most expensive coax, at a fraction of the cost. This assumes use of baluns to match into and out of the line, with a short length of quality coax for the moving section from the top of the tower to the antenna. A similar 144-MHz setup could have a line loss under 1 dB.

Small coax such as RG-58 or 59 should never be used in vhf work if the run is more than a few feet. Half-inch lines (RG-8 or 11) work fairly well at 50 MHz, and are acceptable for 144-MHz runs of 50 feet or less. If these lines have foam rather than solid insulation they are about 30 percent better. Aluminum-jacket lines with large inner conductors and foam insulation are well worth their cost. They are readily water-proofed, and can last almost indefinitely. Beware of any "bargains" in coax for vhf or uhf uses. Lost transmitter power can be made up to some extent by increasing power, but once lost, a weak signal can never be recovered in the receiver.

Effects of weather should not be ignored. A well-constructed open-wire line works well in nearly any weather, and it stands up well. Twin-Lead is almost useless in heavy rain, wet snow or icing. The best grades of coax are impervious to weather. They can be run underground, fastened to metal towers without insulation, or bent into any convenient position, with no adverse effects on performance.

Impedance Matching

Theory and practice in impedance matching are given in detail in earlier chapters, and theory, at least, is the same for frequencies above 50 MHz. Practice may be similar, but physical size can be a major modifying factor in choice of methods. Only the matching devices used in practical construction examples later in this chapter will be discussed in detail here. This should not rule out consideration of other methods, however, and a reading of relevant portions of Chapters 20 and 21 is recommended.

Universal Stub: As its name implies, the double-adjustment stub of Fig. 22-1A is useful for many matching purposes. The stub length is varied to resonate the system, and the transmission line is tapped onto the stub at the point where line and stub impedances are equal. In practice this involves moving both the sliding short and the point of line connection for zero reflected power, as indicated on an SWR bridge connected in the line.

The universal stub allows for tuning out any small reactance present in the driven part of the

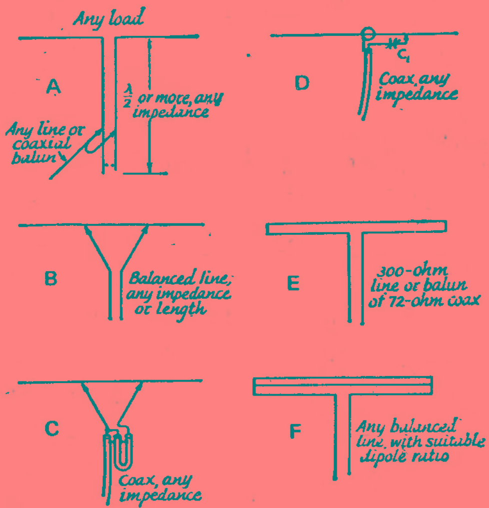


Fig. 22-1 – Matching methods commonly used in vhf antennas. The universal stub, A, combines tuning and matching. The adjustable short on the stub, and the points of connection of the transmission line, are adjustad for minimum reflected power in the line. In the delta match, B and C, the line is fanned out to tap on the dipole at the point of best impedance match. Impedances need not be known in A, B and C. The gamma-match, D, is for direct connection of coax. C1 tunes out inductance in the arm. Foldad dipole of uniform conductor size, E, steps up antanna impedance by a factor of 4. Using a larger conductor in the unbroken portion of the folded dipole, E, gives higher orders of impedance transformation.

system. It permits matching antenna to line without knowledge of the actual impedances involved. The position of the short yielding the best match gives some indication of amount of reactance present. With little or no reactive component to be tuned out, the stub will be approximately a half-wavelength from load to short.

The stub should be stiff bare wire or rod, spaced no more than 1/20 wavelength. Preferably it should be mounted rigidly, on insulators. Once the position of the short is determined, the center of the short can be grounded, if desired, and the portion of the stub no longer needed can be removed.

It is not necessary that the stub be connected directly to the driven element. It can be made part of an open-wire line, as a device to match into or out of the line with coax. It can be connected to the lower end of a delta match, or placed at the feedpoint of a phased array. Examples of these uses are given later.

Delta Match: Probably the first impedance match was made when the ends of an open line were fanned out and tapped onto a half-wave antenna, at the point of most efficient power transfer, as in Fig. 22-1B. Both the side length and the points of connection either side of the center of the element must be adjusted for minimum reflected power in the line, but as with the universal stub, the impedances need not be known. The delta makes no provision for tuning out reactance, so the universal stub is often used as a termination for it, to this end.

Once thought to be inferior for vhf applications because of its tendency to radiate if improperly adjusted, the delta has come back to favor, now that we have good methods for measuring the effects of matching. It is very handy for phasing multiple-bay arrays with open lines, and its dimensions in this use are not particularly critical. It should be checked out carefully in applications like that of Fig. 22-1C, having no tuning device.

Gamma Match: An application of the same principle to direct connection of coax is the gamma match, Fig. 22-1D. There being no rf voltage at the center of a half-wave dipole, the outer conductor of the coax is connected to the element at this point, which may also be the junction with a metallic or wooden boom. The inner conductor, carrying the rf current, is tapped out on the element at the matching point. Inductance of the arm is tuned out by means of C1, resulting in electrical balance. Both the point of contact with the element and the setting of the capacitor are adjusted for zero reflected power, with a bridge connected in the coaxial line.

The capacitor can be made variable temporarily, then replaced with a suitable fixed unit when the required capacitance value is found, or C1 can be mounted in a waterproof box. Maximum should be about 100 pF for 50 MHz and 35 to 50 pF for 144. The capacitor and arm can be combined in one coaxial assembly, with the arm connecting to the driven element by means of a sliding clamp, and the inner end of the arm sliding inside a sleeve connected to the inner conductor of the coax. A commercially supplied assembly of this type is used in a 50-MHz array described later, or one can be constructed from concentric pieces of tubing, insulated by plastic sleeving. Rf voltage across the capacitor is low, once the match is adjusted properly, so with a good dielectric, insulation presents no great problem, if the initial adjustment is made with low power level. A clean, permanent high-conductivity bond between arm and element is important, as the rf current flow is high at this point.

Folded Dipole: The impedance of a half-wave antenna broken at its center is 72 ohms. If a single conductor of uniform size is folded to make a half-wave dipole as shown in Fig. 22-1E, the impedance is stepped up four times. Such a folded dipole can thus be fed directly with 300-ohm line with no appreciable mismatch. Coaxial line of 70 to 75 ohms impedance may also be used, if a 4:1 balun is added. (See balun information presented later in this chapter.) Higher impedance step up can be obtained if the unbroken portion is made larger in cross-section than the fed portion, as in 22-1F. For design information, see Chapter 20.

Baluns and Transmatches: Conversion from balanced loads to unbalanced lines, or vice versa, can be performed with electrical circuits, or their equivalents made of coaxial line. A balun made from flexible coax is shown in Fig. 22-2A. The looped portion is an electrical half-wavelength. The physical length depends on the propagation factor of the line used, so it is well to check its resonant frequency, as shown at B. The two ends are shorted, and the loop at one end is coupled to a dip-meter coil. This type of balun gives an impedance stepup of 4 to 1 in impedance, 50 to 200 ohms, or 75 to 300 ohms, typically.

Coaxial baluns giving 1-to-1 impedance transfer are shown in Fig. 22-3. The coaxial sleeve, open at the top and connected to the outer conductor of the line at the lower end (A) is the preferred type. A conductor of approximately the same size as the line is used with the outer conductor to form a quarter-wave stub, in B. Another piece of coax, using only the outer conductor, will serve this purpose. Both baluns are intended to present an infinite impedance to any rf current that might otherwise tend to flow on the outer conductor of the coax.

The functions of the balun and the impedance

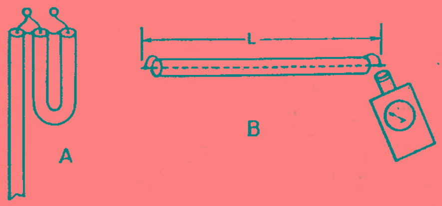


Fig. 22-2 — Conversion from unbalanced coax to a balanced load can be done with a half-wave coaxial balun, A. Electrical length of the looped section should be checked with a dip-meter, with ends shorted, B. The half-wave balun gives a 4:1 impedance step up.

transformer can be handled by various tuned circuits. Such a device, commonly called an antenna coupler or Transmatch, can provide a wide range of impedance transformations. A versatile example is described at the end of this chapter.

The *Q* Section: The impedance transforming property of a quarter-wave line is treated in Chapter 20. The parallel-bar Q section is not useful in low-impedance vhf matching situations, but Q sections of flexible coaxial line may be handy in phasing and matching vhf and uhf arrays. Such sections can be any odd multiple of a quarter-wave-length. An example of two 3/4-wave 75-ohm Q sections, used to phase and match a pair of Yagi bays, each of which has 50 ohms impedance, is given later in this chapter.

Mechanical Design

The small size of vhf and, especially, uhf arrays opens up a wide range of construction possibilities. Finding components is becoming difficult for home constructors of ham gear, but it should not hold back antenna work. Radio and TV distributors have many useful antenna parts and materials. Hardware stores, metals suppliers, lumber yards, welding-supply and plumbing-supply houses and even junkyards should not be overlooked. With a little imagination, the possibilities are endless.

Wood or Metal? Wood is very useful in antenna work, and it is almost universally available, in a great variety of shapes and sizes. Rug poles of wood or bamboo make fine booms. Round wood stock (dowelling) is found in many hardware stores in sizes suitable for small arrays. Square or rectangular boom and frame materials can be ripped to order in most lumber yards, if they are not available from the racks in suitable sizes.

There is no rf voltage at the center of a half-wave dipole or parasitic element, so no insulation is required in mounting elements that are centered in the support, whether the latter is wood or metal. Wood is good for the framework of multibay arrays for the higher bands, as it keeps down the amount of metal in the active area of the array.

Wood used for antenna construction should be well-seasoned and free of knots or damage. Available materials vary, depending on local sources. Your lumber dealer can help you better than anyone else in choosing suitable materials. Joining wood members at right angles is often done advantageously with gusset plates. These can be of thin outdoor-grade plywood or Masonite. Round materials can be handled in ways similar to those used with metal components, with U clamps and with other hardware.

Metal booms have a small "shorting effect" on elements that run through them. With materials sizes commonly employed, this is not more than one percent of the element length, and may not be noticeable in many applications. It is just perceptible with 1/2-inch tubing booms used on 432 MHz, for example. Formula lengths can be used as given, if the matching is adjusted in the frequency range one expects to use. The center frequency of an all-metal array will tend to be 0.5 to 1 percent higher than a similar system built of wooden supporting members.

Element Materials and Dimensions: Antennas for 50 MHz need not have elements larger than 1/2-inch diameter, though up to 1 inch is used occasionally. At 144 and 220 MHz the elements are usually 1/8 to 1/4 inch in diameter. For 420, elements as small as 1/16 inch in diameter work well, if made of stiff rod. Aluminum welding rod, 3/32 to 1/8 inch in diameter is fine for 420-MHz arrays, and 1/8 inch or larger is good for the 220 band. Aluminum rod or hard-drawn wire works well at 144 MHz. Very strong elements can be made with stiff-rod inserts in hollow tubing. If the latter is slotted, and tightened down with a small clamp, the element lengths can be adjusted experimentally with ease.

Sizes recommended above are usable with formula dimensions given in Table 22-I. Larger diameters broaden frequency response; smaller ones sharpen it. Much smaller diameters than those recommended will require longer elements, especially in 50-MHz arrays.

The driven element(s) of a vhf array may be cut from the formula

$$L \text{ (inches)} = \frac{5600}{\text{Freq. (MHz)}}$$

This is the basis for Table 22-I driven-element information. Reflectors are usually about 5 percent longer, and directors 5 percent shorter, though element spacing and desired antenna bandwidth affect parasitic-element lengths. The closer the reflector and director (especially the latter) are to the driven element the nearer they must be to the driven-element length to give optimum gain. This is another way of saying that close-spaced arrays tend to work effectively over narrower bandwidths than

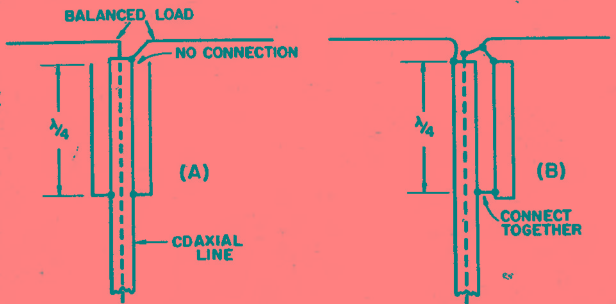


Fig. 22-3 — The balun conversion function, with no impedance change, is accomplished with quarter-wave lines, open at the top and connected to the coax outer conductor at the bottom. Coaxial sleeve, A, is the preferred type.

TABLE 22-I

Dimensions for VHF Arrays in Inches

*Freq. (MHz)**	*50**	*144**	*220**	*432**
Driven Element	111	38 5/8	25 7/16	13
Change per MHz	2	1/4	1/8	1/32
Reflector	116 1/2	40 1/2	26 3/4	13 1/2
1st Director	105 1/2	36 5/8	24 1/8	12 11/32
2nd Director	103 1/2	36 3/8	24	12 9/32
3rd Director	101 1/2	36 1/8	23 7/8	12 7/32
1.0 Wavelength	236	81 1/2	53 5/8	27 1/4
0.625 Wavelength	149	51	33 1/2	17
0.5 Wavelength	118	40 3/4	26 13/16	13 5/8
0.25 Wavelength	59	20 3/8	13 7/8	6 13/16
0.2 Wavelength	47 3/4	16 1/4	10 3/4	5 7/16
0.15 Wavelength	35 1/2	12 1/4	8	4

* Dimensions are for the *most-used* section of each band: 50 to 50.6 MHz, 144 to 145.5 MHz, 220 to 222 MHz, and 432 to 434 MHz. The element lengths should be adjusted for each megahertz difference in frequency by the amount given in the third line of the table. Example: If optimum performance is wanted much above 145 MHz, shorten all elements by about ¼ inch. For above 146 MHz, shorten by ½ inch. See text.

Element spacings are not critical, and table figures may be used, regardless of element lengths chosen. Parasitic element lengths are optimum for collinear arrays and small Yagis, having 0.2-wavelength spacing.

wide-spaced ones, though maximum gain may be possible with many different combinations of lengths and spacings.

Parasitic-element lengths of Table 22-I are based on spacings of about 0.2 wavelength, common in relatively short Yagis and collinear arrays. Dimensions given later in the individual descriptions of antennas may be at variance with those of the table. Where this is evident, the length differences result from use of different element spacings, for the most part. Some designs are for maximum gain, without consideration of bandwidth. Still others have slightly modified spacings, to give optimum results with a particular boom length.

ANTENNAS FOR 50 MHz

Simple antennas such as dipoles, groundplanes, mobile whips and the like are covered adequately elsewhere in this *Handbook*. Adaptation of them to vhf work involves mainly reference to Table 22-I for length information. We will be concerned here with arrays that give appreciable gain, or other properties needed in vhf communication.

Yagis, Short and Long: The Yagi array is practically standard for 50-MHz directive use. Usual sizes are three to six elements, though up to eight or nine in line are seen in ambitious installations. Director spacing, after the first three, must be very wide to be worthwhile, so boom lengths of 30 feet or more are needed for more than 6 elements. Though long Yagis certainly are desirable, it should be emphasized that the first two or three elements provide very high gain per unit of space. Even a 3-element Yagi, on as short a boom as 6 feet, is good for 7.5 dB over a dipole. To double the gain (add 3 dB) requires going to only 6 elements – but it takes a boom more than 20 feet long. If it is possible to put up a rotatable antenna at all, there is usually room for at least a 3-element structure, and the gain such an antenna provides is very helpful. Dimensions can follow those given for the first three elements of larger arrays described here.

Stacking Yagis: Where suitable provision can be made for supporting them, two Yagis mounted one above the other and fed in phase may be preferable to one long Yagi having the same theoretical or measured gain. The pair will require a much smaller turning space, for the same gain, and their lower radiation angle can provide interesting results. On long ionospheric paths a stacked pair occasionally may show an *apparent* gain much greater than the 2 to 3 dB that can be measured locally as the gain due to stacking.

Optimum spacing for Yagis of 5 elements or more is one wavelength, but this may be too much for many builders of 50-MHz antennas to handle. Worthwhile results can be obtained with as little as one half-wavelength (10 feet), and 5/8 wavelength (12 feet) is markedly better. The difference between 12 and 20 feet may not be worth the added structural problems involved in the wider spacing, at 50 MHz, at least. The closer spacings give lower measured gain, but the antenna patterns are cleaner than will be obtained with one-wavelength spacing. The extra gain with wider spacings

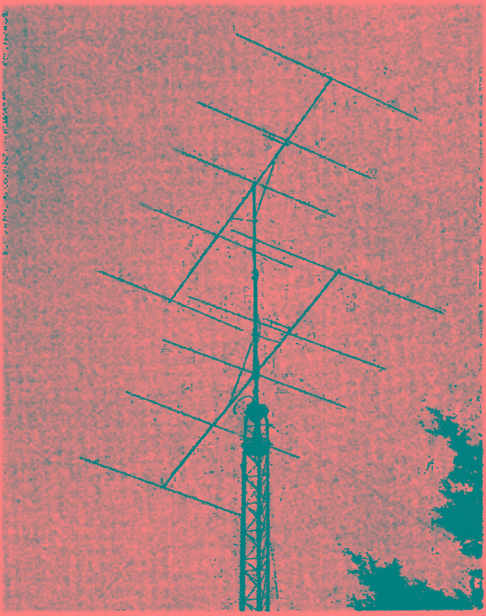


Fig. 22-4 – 5-over-5 stacked-Yagi array for 50 MHz, with all-coax feed.

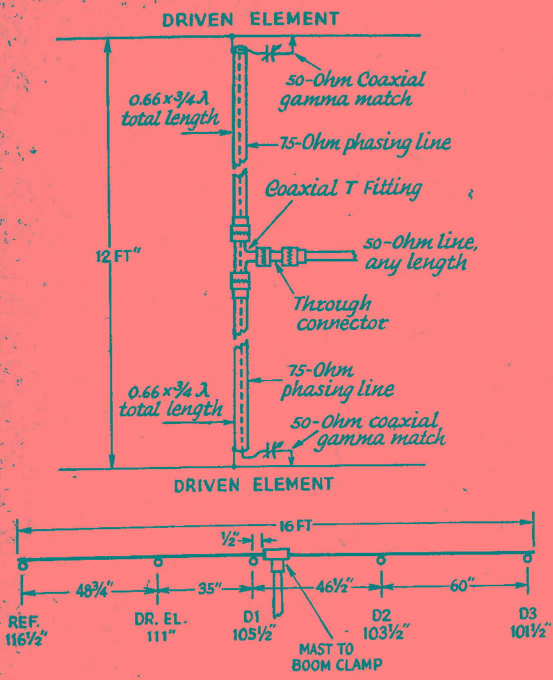


Fig. 22-5 – Principal dimensions of the 50-MHz 5-over-5, with details of the 3/4-wavelength *Q*-section matching system. The propagation factor of 0.66 applies only with solid-dielectric coax. Gamma-matching assemblies are coaxial-capacitor units (Kirk Electronics C6M).

is usually the objective on 144 MHz and higher bands, where the structural problems are not severe.

5-OVER-5 FOR 50 MHz

The information provided in Fig. 22-5 is useful for a single 5-element Yagi, or for the stacked pair of Fig. 22-4, either to be fed with a 50-ohm line. The phasing and matching arrangement may be used for any pair of Yagis designed for 50-ohm feed individually. With slight modification it will serve with Yagis designed for 200-ohm balanced feed.

Mechanical Details

Construction of the single Yagi bay or a stacked pair is simplified by use of components that should be available to most builders. Element-to-boom and boom-to-mast mounts are aluminum castings designed for these applications by Kirk Electronics, 134 Westpark Road, Dayton, Ohio 45459. The gamma matches shown schematically in Fig. 22-5 are of coaxial construction, waterproofed for long life, available from the same supplier.

Booms are made of two 8-foot lengths of 1 1/4-inch aluminum (Reynolds) found in many hardware stores. Reynolds makes a special fitting for joining sections of the tubing, but these are not widely available from the usual hardware-store stocks, so a handmade splice was substituted. A piece of the same-diameter tubing as the booms, 12 inches or more in length, is slotted with a hacksaw, and then compressed to fit inside the ends of the two 8-foot lengths, as seen in Fig. 22-6. If the splice is held in the compressed position with large pipe pliers or a hose clamp, the ends will slide inside the boom sections readily. When the splice is released from compression, the two tubes can be driven together. Self-tapping screws should be run through the tubes and the splice, to hold the assembly firm. Use at least two on each side of the splice.

Elements are 1/2-inch aluminum tubing, Alcoa alloy 6061-T6. Almost any aluminum should be suitable. Kirk Yagi clamps, one-piece aluminum castings designed for this job, are available for 3/8 as well as 1/2-inch elements, and 1 1/4-inch boom. The eyes through which the elements pass are drilled, but must be tapped for 10-32 setscrews to tighten the elements firmly in place, two screws per element. The portion of the clamp that surrounds the boom can be spread slightly to allow the clamp to slide along the boom to the desired point. The interior surface is slightly rough, so tightening the yoke with the screw provided with the clamps makes the element set firmly on the boom. The reflector, driven element and first director are all in back of the boom splice.

The vertical member of the stacked array is 1 1/4-inch thick-wall anodized steel tubing, commonly used in large antenna installations for home TV. Do not use thin-wall aluminum or light galvanized steel masting. The aluminum is not strong enough, and inexpensive steel masting rusts inside, weakening the structure and inviting failure.

Spacing between bays can be a half wavelength (10 feet), 5/8 wavelength (12 feet), or a full wavelength (20 feet), though the wide spacing imposes mechanical problems that may not be worth the effort for most builders. The 5/8-wave spacing is a good compromise between stacking gain and severe support problems, and is recommended with the materials used here.

The 10-foot lengths of steel masting could be used, with the bottom 8 feet running through the tower bearing to the rotator. A heavier main support is preferable, however, and it is "1-inch water pipe" in this installation. This is iron, about 1 3/8-inch outside diameter, extending about 8 feet out of the tower. The steel masting between the Yagi bays is fastened to the pipe with four TV-type U-clamps, spaced evenly in the overlapping area of the two supports.

The booms are braced to the mast fore and aft, using the longest pieces of element stock left over when the forward directors are cut from 12-foot lengths. Ends of the braces are flattened about one inch, and bent to the proper angle. Outer ends fasten to the booms with two self-tapping screws each. The mast ends are clamped to the support with one TV U-clamp for each pair. This bracing is good insurance against fluttering of the booms and elements, which can cause failures after long periods, even though a structure appears adequately strong.

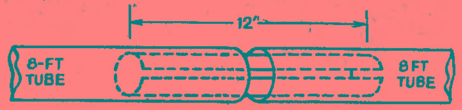


Fig. 22-6 — Details of the boom splices used in the 5-element 50-MHz Yagis. Two 8-foot lengths of 1 1/4-inch tubing are joined to make the 16-foot booms.

Phasing and Matching

A single 5-element Yagi can be fed directly with 50-ohm coax, through the Kirk coaxial gamma-match assembly (Type C6M). This has an adjustable coaxial capacitor, and an arm that connects to the driven element with a sliding clip. Both the capacitor and the point of connection should be adjusted for minimum reflected power, at the center of the frequency range most used. Doing this between 50.2 and 50.4 MHz is suitable for most operators, other than those using fm above 52.5 MHz. Each bay of the stacked pair should be set in this way. The pair can then be fed through a double *Q*-section of 75-ohm coax, as shown in Fig. 22-5.

The Kirk gamma-match assembly has an SO-239 coaxial fitting built in, so the phasing lines are fitted with PL-259 coaxial connectors at both ends. The inner ends attach to a matching coaxial T fitting. The main run of 50-ohm line connects to the center of the T, with a coaxial through-connector and a PL-259 fitting. When the antenna is installed all connectors should be wrapped tightly with plastic tape, and sprayed with Krylon or other protective spray. Dow-Corning Silastic RTV-732 sealant is also good for this use. If the coaxial phasing sections are wrapped around the booms and vertical support a few times, they will just reach the T-fitting, when 12-foot spacing is used.

The lines should be any odd multiple of a quarter-wavelength. If both are the same length the gamma arms should attach to the same side of the driven elements. If there is a half-wavelength difference in the lines, the arms should connect to opposite sides. The length given in Fig. 22-5 is nominal for solid-dielectric coax. If foam-dielectric line is used, the propagation factor given by the maker should be substituted for the 0.66 figure. It is best to grid-dip the line sections for resonant frequency, in any case. Cut the line three inches or more longer than the expected length. Solder a loop of wire between the center pin and the mounting flange of an SO-239 connector. Attach this to the PL-259 connector at one end of the line, and couple it to the dip-meter coil. Trim the line length until resonance at the midpoint of the intended frequency range is indicated. This will not change appreciably when the other coaxial connector is attached.

The line used in the model described is RG-59A/U, which is satisfactory for any amateur power level, so long as the SWR is kept low. Larger coax, such as RG-11A/U, is recommended for a greater margin of safety.

Adjustment and Testing

An individual Yagi can be tested and matched properly by mounting it a half-wavelength above ground, in a large area that is clear of obstructions for many wavelengths. The boom can also be tilted up, until the ground-reflected wave is not a factor in the field-strength meter reading. The SWR bridge should be connected at the gamma match, or an electrical half-wavelength therefrom. Apply low power (not over 10 watts) and adjust the gamma capacitor and the point of connection to the driven element for zero reflected power, at the desired frequency range. The model was flat from 50.2 to 50.4 with just perceptible reflected power showing at 50.1 to 50.5. Adjusted in this way the array should work well up to about 51 MHz.

The best way to check operation of the stacked pair is to support the array with the reflectors resting on the ground and the booms pointing straight up. A 6-foot step-ladder can be used for a temporary support. The bays can be fed separately with 50-ohm line, in this position, and the gamma settings should be the same as obtained in the first check, described above. Now connect the two 75-ohm phasing lines, and insert the SWR bridge in the 50-ohm line to the T fitting. The SWR should be the same as when the bays are fed separately through the 50-ohm line; close to 1:1. The array can be dismantled and reassembled atop the tower, and matching should remain correct.

The matching-phasing system described is useful for any two loads designed for 50-ohm feed. The 5/8-wave spacing is usable with up to at least 6-element bays, though wider bay spacing is needed for maximum gain with long Yagis. Individual antennas intended for 200-ohm balanced feed can be matched with 75-ohm coax in the phasing harness and baluns at each load.

Bay spacing is not critical. Close spacing gives somewhat lower gain, but a very clean pattern. The main lobe gets sharper and larger as spacing is increased, but minor lobes also increase. These take over from the main lobe if spacing of bays is carried too far. The effect of increasing bay spacing is shown graphically in Fig. 8-11 of *The Radio Amateur's VHF Manual*, and associated text.

144 OVER 50

Four phased 144-MHz Yagis are shown mounted above a 50-MHz 6-element Yagi in Fig. 22-7. The latter can be mechanically similar to the 5-element antennas of Fig. 22-4, though this two-band system was built almost entirely by hand. Element spacings are closer than in the 5-element 6-meter arrays, in order to fit 6 elements onto a 20-foot boom. The individual bays of the 2-meter array can be used singly, in pairs, or in the 4-bay system shown. Feed details are given for each application.

6-Element 50-MHz Yagi

The 6-meter elements were designed for light weight, with 1/2-inch tubing for half their length and thin-wall fuel-line tubing inserts for the outer

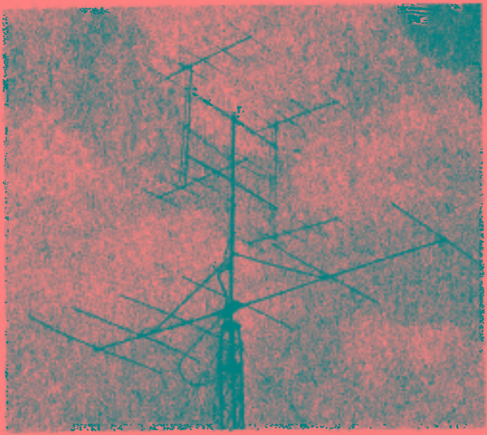


Fig. 22-7 – Antennas for two bands on a single support. Four 5-element Yagis for 144 MHz, top, have one-wavelength spacing each way. The 50-MHz Yagi is set up to make optimum use of 6 elements on a 20-foot boom.

portions. One-piece half-inch elements are equally good, though a bit bulkier. Elements can be run through the boom and held in place with clamps, as in Fig. 22-8, or mounted in Kirk castings. (See 5-element array description.) Lengths are 116, 110 1/2, 105 1/2, 104, 102 3/4, and 101 1/2 inches. Spacings, in the same order, are 36, 36, 42, 56 and 66 inches. The boom is made of two 10-foot aluminum mast sections, braced from above with 3/4-inch tubing. See Fig. 22-8.

The gamma matching was handled in two different ways. A coaxial capacitor and moving arm was hand-made, as shown in Fig. 22-9 using 1/2-inch and 1/4-inch tubes, insulated from one another by plastic sleeves that just fit inside the 1/2-inch fixed portion. The inner tubing can be wrapped with plastic tape to build up the needed thickness, to the same end. The arm is supported at two points with 1-inch ceramic pillars.

A second and simpler matching arrangement uses merely an extension of the main coaxial line, with a 100-pF fixed transmitting-type capacitor in series with the inner conductor and the sliding contact. The matching point was about 20 inches out from the boom with a 100-pF capacitor. It is suggested that the matching be done first with a variable capacitor, substituting a fixed one when the desired value is found.

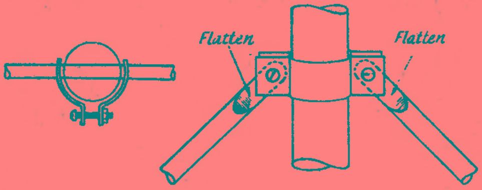


Fig. 22-8 – Elements may be run through a wood or metal boom, and held in place with simple aluminum clamps, left. At the right is a clamp for holding boom braces on the vertical support in the 50-MHz 6-element array.

An element-mounting clamp no longer available appears in Fig. 22-9. The Kirk 1/2-to-1 1/4-inch element-mounting clamps (see 5-over-5 description) do this job nicely.

5-Element 144-MHz Yagis

An optimum design for 5-element 2-meter Yagis, to be used singly or combined in stacked systems, is shown in Fig. 22-10. Dimensions given work well from 144 to 146 MHz, if the matching is adjusted at 145. Lengths should be reduced 1/4 inch for each megahertz higher center frequency than 145 MHz. The original elements have center sections of 1/4-inch aluminum tubing, with 5/32-inch rod inserts that slide into the center members. One-piece elements of 1/8 to 1/4-inch tubing or rod will work equally well. The larger size will permit fastening in place with self-tapping screws bearing on the elements. For smaller sizes, use a clamp like that of Fig. 22-8. The booms are 3/4- or 1-inch diameter aluminum. Wood dowelling could be used equally well.

Feed Methods: A delta match is used in conjunction with a coaxial-line balun to feed a single 5-element Yagi. Some experimentation with delta dimensions may be required to achieve the best match. (See Fig. 22-1C and detailed description of the delta match earlier in this chapter.) This arrangement makes a fine small Yagi that can be dismantled readily, for carrying about in portable work.

Fig. 22-9 – A hand-made coaxial gamma match for 50-MHz arrays. A 1/4-inch rod or tube 14 inches or longer slides inside a 1/2-inch sleeve that is connected to the coaxial fitting above the boom. The rod slides on plastic sleeves inside the larger section. Separation is maintained with two ceramic pillars mounted with wrap-around clips. Both the coaxial capacitor and the sliding clip between rod and element are adjusted for minimum reflected power in the coaxial line.

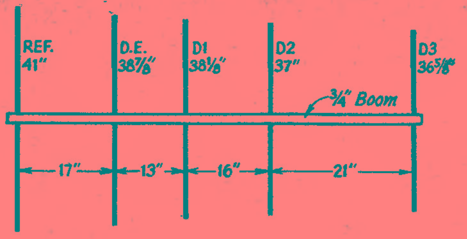


Fig. 22-10 – Optimum design for a 2-meter Yagi, using 5 elements on a 6-foot boom. When used singly, this antenna can be fed as shown in Fig. 22-1C, with 4-inch delta arms connected 3 inches either side of center. The balun loop would be about 27 inches long. With lengths shown, the antenna works well from 144 to above 146 MHz, but gain drops sharply above 147 MHz.

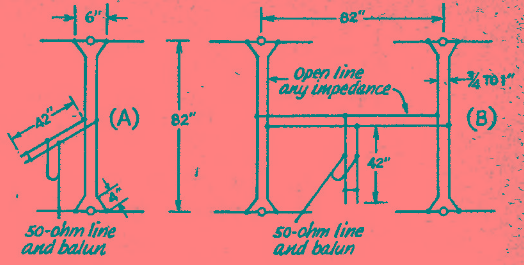


Fig. 22-11 – Stacking details for the 5-element Yagis of Fig. 22-7 and 22-10. The short on the universal stub, and the point of connection of the main transmission line, are adjusted for minimum reflected power in the latter. Balanced line could be connected similarly for the main turn.

Use of two 5-element Yagis with 1-wavelength spacing is shown in Fig. 22-11A. The phasing harness can be any open-wire line, preferably not spaced more than one inch. Delta dimensions are not critical in this application, as the matching is done with the universal stub at the center of the harness.

The 4-bay 20-element system in Fig. 22-7 and 22-11B uses two sets of 5-over-5, connected between centers with another 1-wavelength line. The universal stub is connected at the center of the horizontal section. In each case, the stub length and line-connection point are adjusted for minimum reflected power in the main line.

An interesting phasing method was used in the 4-bay array. Common electric zipcord, available in any hardware store, was split into its two parts. The insulation was left on, and spreaders made of ordinary 1/2-inch wood dowel were used to hold the wires one inch apart. Holes were drilled in these of such size that the zipcord could just be pulled through them. They are held in place with any good cement. If supported with TV-type screweyes that grip the spreaders, such a low-cost line is very durable. The array shown was taken down after two years of use in a very exposed location, and no deterioration was apparent. There was no breakage, even under several heavy ice loads each winter. Using several supports on each harness section is the key to this long life.

The transmission line was switched between the six- and two-meter arrays by means of a waterproofed antenna relay. To avoid the dangers of a 115-volt line run, 6.3-volt transformers were used at each end. This one-line hookup makes it possible to use a single rather expensive line to its fullest potential on two bands.

13-ELEMENT YAGI FOR 144 MHz

Many combinations of element lengths and spacings work well in long Yagis. The 13-element array detailed in Fig. 22-12 is the product of many months of joint experimental work by W2NLY and W6QKI. First described in *QST* for January, 1956, it has been a winner ever since. Elements are 1/8-inch hard-drawn aluminum wire, except for the folded-dipole driven element. This is the step up variety, intended to give a feed impedance of 200 ohms, for feeding with 50-ohm line and a coaxial balun.

The 24-foot boom carries a light load, and can

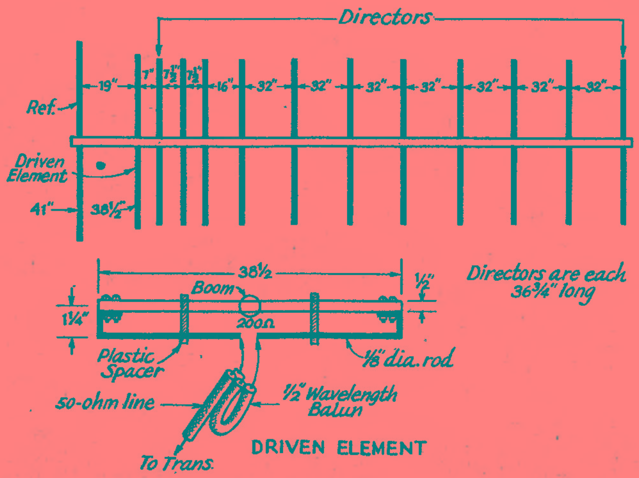


Fig. 22-12 – High-performance long Yagi for 144 MHz, from experimental work by W2NLY and W6QKI. Dimensions are for maximum gain between 144 and 145 MHz.

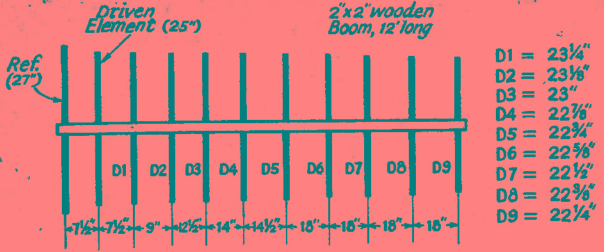


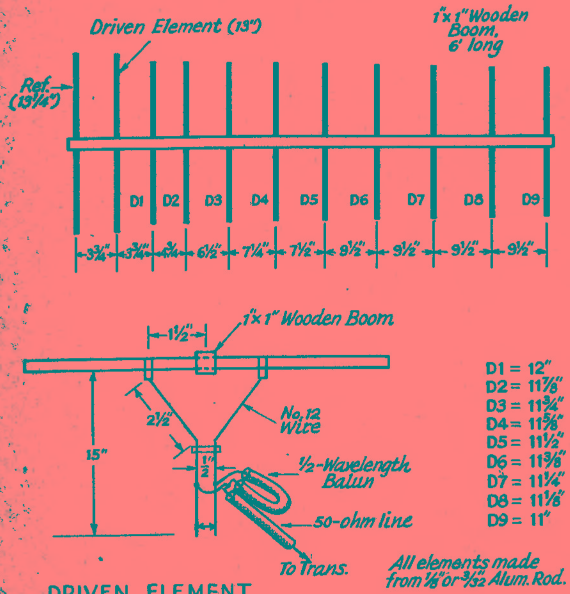
Fig. 22-13 – 11-element Yagi for 220 MHz. Dimensions are for maximum gain in the lower 2 MHz of the band. Recommended feed method is a delta match, with universal stub and balun. Delta sides should be about 3 inches, tapped 2 inches either side of the element midpoint.

be made of thin-wall tubing if braced in the manner of the 50-MHz arrays previously described. Elements run through the boom and are held in place with clamps, as in Fig. 22-8. Lengths are for optimum gain between 144 and 145 MHz. Gain drops rapidly above 145.2 MHz. For a center frequency of 145 MHz, cut element lengths 1/8 inch. Broader frequency response can be obtained by tapering element lengths 1/8 inch per element, beginning with the second director.

Effective stacking of such long Yagis requires bay spacing of 1 1/2 to 2 wavelengths. Pairs or pairs of pairs can be fed in the manner of Fig. 22-15, using dimensions of Table 22-I.

11-ELEMENT YAGIS FOR 220 AND 432 MHz

High-gain antennas are almost a necessity for any serious work on 220 MHz and higher frequencies. The 11-element Yagis shown in Figs. 22-13 and 14 were worked out experimentally for maximum gain per element. They are intended primarily to be used in stacked pairs or sets of four, as shown (for 432 MHz) in Fig. 22-15.



DRIVEN ELEMENT

Fig. 22-14 – 11-element Yagi for 432 MHz, designed for optimum performance on a 6-foot boom. Operation should be uniform between 432 and 436 MHz, if the stub matching is adjusted when moving more than one megahertz in frequency.

Elements are stiff wire or welding rod, 1/8-inch diameter for 220, 3/32 or 1/8 inch for 432. Wood booms are shown, and are recommended for stacked arrays, particulary for 432. Metal booms should be 1/2-inch diameter for 432 and 3/4 to 1 inch for 220. Element lengths should be increased 0.5 to 1 percent if metal booms are used.

Frequency coverage without appreciable loss of gain, and no readjustment of matching, is about 1 percent of the operating frequency. Lengths of elements given are for 220 to 222 MHz and 432 to 434 MHz. Coverage can be extended somewhat higher by readjusting the matching for the desired higher frequency.

Recommended phasing is by open-wire line two wavelengths long each way. No. 12 wire spaced 1/2 to 3/4 inch with Teflon spreaders is ideal. If a metal supporting structure is used, it should preferably be entirely in back of the plane of the reflector elements.

COLLINEAR ANTENNAS

Information given thus far is mainly on parasitic arrays, but the collinear antenna has much to recommend it. Inherently broad in frequency response, it is a logical choice where coverage of an entire band is wanted. This tolerance also makes a collinear easy to build and adjust for any vhf application, and the use of many driven elements is popular in very large phased arrays, such as may be required for moonbounce (EME) communication.

Omnidirectional Verticals

Two or more half-wave elements mounted in a vertical line and fed in phase are often used to build up some gain, without directivity. A simple omnidirectional collinear of rugged construction is shown in Fig. 22-16. It is made entirely of copper pipe and matching elbow fittings, obtainable from plumbing supply houses and some hardware stores.

Initially the phasing stub was operated in the manner of Fig. 22-1A. When the optimum dimensions were found, the assembly was completed by making the angles with plumbing fittings, and the balun connections with bolts, nuts and star lugs.

Preferably the antenna should be mounted on a wooden support, though the center of the stub can be grounded for lightning protection. Dimensions given are for the upper half of the 2-meter band,

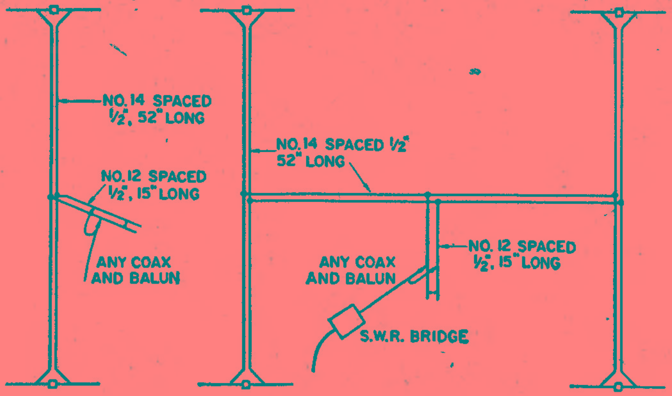


Fig. 22-15 – Phasing methods for using two or four 11-element Yagis for 432 MHz, with 2-wavelength spacing. Universal-stub match permits use of any type of transmission line.

though it works well enough all the way down to 144 MHz.

Any number of radiators can be used, if quarter-wave phasing stubs are connected between them. Commonly an odd number is used, and the center radiator is broken at its midpoint and fed with a universal stub. This type of antenna can be made of wire and strung up in a horizontal position. The pattern is bidirectional when this type of collinear is mounted horizontally.

Large Collinear Arrays

Bidirectional curtain arrays of 4, 6 and 8 half-waves in phase are shown in Fig. 22-17. Usually reflector elements are added, normally at about 0.2 wavelength in back of each driven element, for more gain and a unidirectional pattern. Such parasitic elements are omitted from the sketch in the interest of clarity. Dimensions are not critical, and may be taken from Table 22-I.

When parasitic elements are added, the feed impedance is low enough for direct connection open line or Twin-Lead, connected at the points indicated by black dots. With coaxial line and a balun, it is suggested that the universal stub match, Fig. 22-1A, be used at the feedpoint. All elements should be mounted at their electrical centers, as indicated by open circles in Fig. 22-17. The framework can be metal or insulating material, with equally good results. A model showing the preferred method of assembling an all-metal antenna is pictured in Fig. 22-18. Note that the metal supporting structure is entirely in back of the plane of the reflector elements. Sheet-metal clamps can be cut from scraps of aluminum to make this kind of assembly, which is very light in weight and rugged as well. Collinear elements should always be mounted at their centers, where rf voltage is zero – never at their ends, where the voltage is high and insulation losses and detuning can be very harmful.

Collinear arrays of 32, 48, 64 and even 128 elements can be made to give outstanding performance. Any collinear should be fed at the center of the system, for balanced current distribution. This is very important in large arrays, which are treated as sets of 6 or 8 driven elements each, and fed through a balanced harness, each section of which is a resonant length, usually of open-wire line. A 48-element collinear array for 432 MHz, Fig. 22-19, illustrates this principle.

PLANE AND PARABOLIC REFLECTORS

A reflecting plane, which may be sheet metal, wire mesh, or even closely-spaced elements of tubing or wire, can be used in place of parasitic reflectors. To be effective, the plane reflector must extend on all sides to at least a quarter-wavelength beyond the area occupied by the driven elements. The plane reflector provides high front-to-back ratio, a clean pattern, and somewhat more gain than parasitic elements, but large physical size rules it out for amateur use below 420 MHz. An interesting space-saving possibility lies in using a

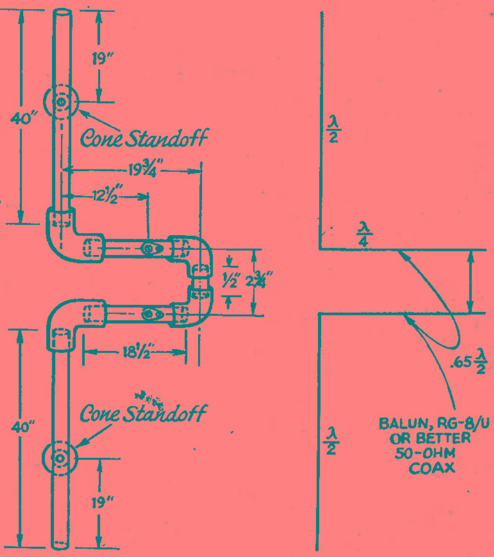


Fig. 22-16 – Rugged 2-meter omnidirectional vertical antenna made entirely of 1/2-inch copper pipe and elbows. The midpoint of the stub can be grounded, for lightning protection.

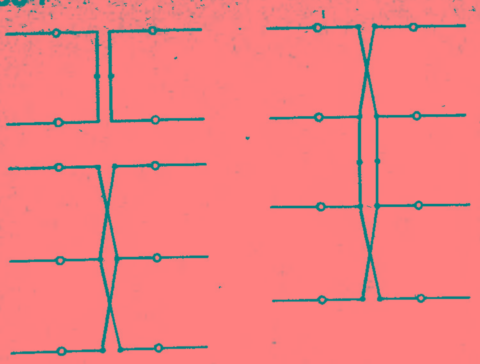


Fig. 22-17 – Element arrangements for 8, 12 and 16-element collinear arrays. Parasitic reflectors, omitted here for clarity, are 5 percent longer and 0.2 wavelength in back of tha driven elements. Feed points are indicated by black dots. Open circles are recommended support points. The elements can run through wood or metal booms, without insulation, if supported at their centers in this way. Insulators at the element ends (points of high rf voltage) tend to detune and unbalance the systam.

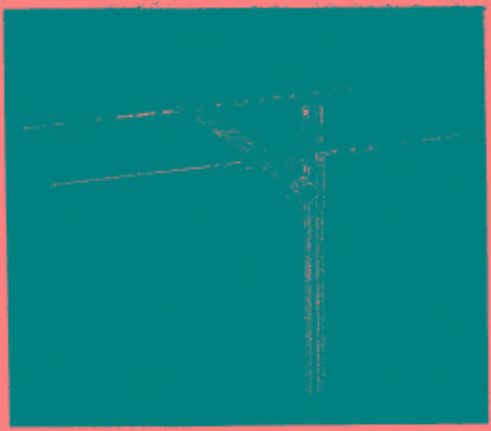


Fig. 22-18 – Model showing recommended method for assembling all-metal arrays. Suitable assembling clips can be cut and bent from sheet aluminum. Supporting structure should be in back of all active elements of the array.

single plane reflector with elements for two different bands mounted on opposite sides. Reflector spacing from the driven element is not critical. About 0.2 wavelength is common.

The reflector can be formed into parabolic shape for a focussing effect, similar to that in a searchlight. Parabolic reflectors must be very large in terms of wavelength. Principles involved in parabolic reflector design are discussed by WA9HUV in *QST* for June, 1971, page 100.

CIRCULAR POLARIZATION

Polarization is described as "horizontal" or "vertical," but these terms have no meaning once the reference of the earth's surface is lost. Many propagation factors can cause polarization change: reflection or refraction, passage through magnetic fields (Faraday rotation) and, satellite rolling, for examples. Polarization of vhf waves is often random, so an antenna capable of accepting any polarization is useful. Circular polarization, generated with helical antennas or with crossed elements fed 90 degrees out of phase, has this quality.

The circularly-polarized wave, in effect, threads its way through space, and it can be left- or right-hand polarized. These polarization "senses" are mutually exclusive, but either will respond to any plane polarization. A wave generated with right-hand polarization comes back with left-hand, when reflected from the moon, a fact to be borne in mind in setting up EME circuits. Stations communicating on direct paths should have the same polarization sense.

Both senses can be generated with crossed dipoles, with the aid of a switchable phasing harness. With helical arrays, both senses are provided with two antennas, wound in opposite directions.

Helical Antenna for 432 MHz

The 8-turn helix of Fig. 22-20 is designed for 432 MHz, with left-hand polarization. It is made

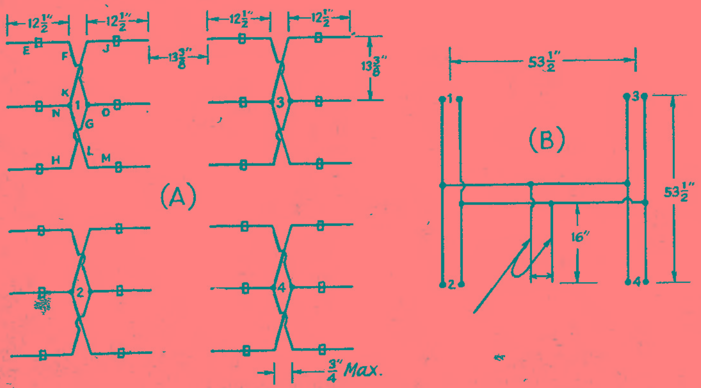


Fig. 22-19 – Large collinear arrays should be fed as sets of no more than 8 driven elements each, intar-connected by phasing lines. This 48-element array for 432 MHz (A) is treated as if it were four 12-element collinears. Reflector elements are omitted for clarity. Phasing harness is shown at B.

Fig. 22-20 – An 8-turn 432-MHz helical array, wound from aluminum clothesline wire. Left-hand polarization is shown. Each turn is one wavelength, with a pitch of 0.25 wavelength. Feed is with 50-ohm coax, through an 84-ohm *Q* section.

from 213 inches of aluminum clothesline wire, including 6 inches that are used for cutting back to adjust the feed impedance.

Each turn is one wavelength long, and the pitch is about 0.25 wavelength. Turns are stapled to the wooden supports, which should be water-proofed with liquid fiber glass or exterior varnish. The reflecting screen is one wavelength square, with a Type N coaxial fitting soldered at its center, for connection of the required coaxial *Q* section.

The nominal impedance of a helical antenna is 140 ohms, calling for an 84-ohm matching section to match to a 50-ohm line. This can be approximated with copper tubing of 0.4-inch inside diameter, with No. 10 inner conductor, both 6 1/2 inches long. With the antenna and transformer connected, apply power and trim the outer end of the helix until reflected power approaches zero.

The support arms are made from sections of 1 X 1 wood and are each 60 inches long. The spacing between them is 8.25 inches, outer dimension. The screen of the antenna in Fig. 22-20 is tacked to the support arms for temporary use. A wooden framework for the screen would provide a more rugged antenna structure. The theoretical gain of an 8-turn helical is approximately 14 decibels. Where both right- and left-hand circularity is desired, two antennas can be mounted on a common framework, a few wavelengths apart, and wound for opposite sense.

A TRANSMATCH FOR 50 AND 144 MHz

The antenna couplers as shown in Fig. 22-21 will permit unbalanced transmitter output lines (50-75 ohms) to be matched to balanced feeders in the 300 to 450-ohm impedance range. Also, "coax-to-coax" matching is possible with this circuit, permitting 50-ohm lines to be matched to 75-ohm lines, or vice versa. In situations where a high SWR condition exists where an antenna is being used in a part of the band to which it has not been tuned, this coupler will enable the transmitter to look into a flat load, thus permitting maximum loading for better efficiency.

Couplers of this type are beneficial in the reduction of harmonic energy from the transmitter, an aid to TVI reduction. It should be possible to realize a 30-dB or greater decrease in harmonic level by using this Transmatch between the transmitter and the feed line. When connected ahead of the receiver as well – a common arrangement – the added selectivity of the coupler's tuned circuits will help to reduce images and other undesired receiver responses from out-of-band signals. It is wise to remember that the use of devices of this kind will not correct for any mismatch that exists at the antenna end of the line. Although it assures a good match between the transmitter and the line, it can only disguise the fact that a mismatch exists at the antenna.

The Circuit

Balanced circuits are used for both bands, Fig. 22-22. Butterfly capacitors are employed to aid in securing good circuit symmetry. The links of each tuned circuit, L2 and L3, are series tuned by single-ended capacitors to help tune out reactance in the line.

Construction

A 4-1/2 x 4-1/2 x 2-inch homemade cabinet houses the 2-meter Transmatch; A Ten-Tec JW-5 is used as an enclosure for the 50-MHz unit. Other commercially made cabinets would be suitable, also. The two tuning controls are mounted in a line across the front of each cabinet. The main coil in each Transmatch is supported by a ceramic standoff insulator on one end and by the connection to the TUNING capacitor on the other. The links are self supporting. The coil taps are effected by bending standard No.6 solder lugs

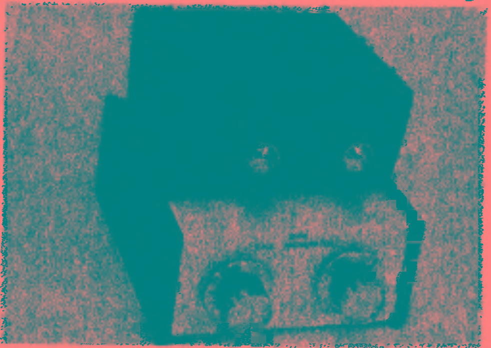


Fig. 22-21 – These 6- and 2-meter Transmatches may be used with powers up to 500 watts. They can be employed with either balanced or unbalanced feeders.

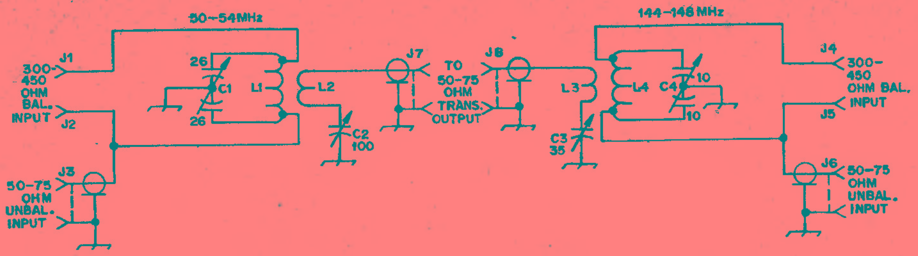


Fig. 22-22 – The schematic diagram of the vhf Transmatches. Capacitance is in pF unless otherwise noted. Resistance is in ohms, k = 1000.

C1 – 26-pF per section butterfly (E.F. Johnson 167-22).

C2 – 100-pF miniature variable (Millen 20100).

C3 – 35-pF miniature variable (Millen 20035).

C4 – 10-pF per section butterfly (E.F. Johnson 167-21).

J1-J4, incl. – Insulated binding post.

J5-J8, incl. – SO-239-style chassis connector.

L1 – 7 turns No. 10 copper wire, 1 1/2-inch dia, spaced one wire thickness between turns. Tap 2 1/2 turns from each end.

L2 – 2 turns No. 14 enam. or spaghetti-covered bare wire, 2-inch dia, over center of L1.

L3 – 2 turns No. 14 enam. or spaghetti-covered bare wire, 1 1/2-inch dia. over center of L4.

L4 – 5 turns No. 10 copper wire, 1-inch dia, spaced one wire thickness between turns. Tap 1 1/2 turns from each end.

Fig. 22-23 – Inside view of the two Transmatches.

around the coil wire at the proper spots, then soldering the lugs in place. No. 20 bus wire is used to connect the taps of L1 to jacks J1 and J2. When operating coax-to-coax style, a short jumper wire connects J1 to its ground lug, or J4 to its ground lug, depending on the band being operated. The jumper must be removed for balanced-feeder operations.

Operation

Attach the vhf transmitter to J7 or J8 with a short length of coax cable. Connect a balanced feeder to J1 and J2 (for 50-MHz operation), or to J4 and J5 (for 144-MHz operation). A reflected-power meter or SWR bridge connected between the Transmatch and the transmitter will aid in the adjustment process. Adjust C1 and C2, alternately (for 50-MHz operation) for minimum meter reading on the SWR indicator. For 144-MHz operation, tune C3 and C4 in the same manner. Repeat the tuning until no further reduction in reflected power is possible. The meter should fall to zero, indicating a 1:1 match. No further adjustments will be needed until the transmitter frequency is moved 50 kHz or more. The tuning procedure is identical for matching coax to coax. In doing so, however, the antenna feed line (coax) is connected to either J3 or J6 and the shorting strap (discussed earlier) must be connected to J1 or J4. In some situations, it may be possible to get a better match by leaving the shorting strap off.

After the coupler is tuned up, the transmitter power can be increased to its normal level. These units will handle power levels up to 500 watts (transmitter output power) provided the coupler is tuned for a matched condition at all times. Reduced power (less than 50 watts) should be used during initial tune up, thus preventing parts from being damaged by heating or arcing. The coupler should never be operated without a load connected to its output terminals.

AN INEXPENSIVE DIRECTIONAL COUPLER

Precision in-line metering devices that are capable of reading forward and reflected power over a wide range of frequencies are very useful in amateur vhf and uhf work, but their rather high cost puts them out of the reach of many vhf enthusiasts. The device shown in Fig. 22-25 is an inexpensive adaptation of their basic principles. You can make it yourself for the cost of a meter, a few small parts, and bits of copper pipe and fittings that can be found in the plumbing stocks at many hardware stores.

Construction

The sampler consists of a short section of hand-made coaxial line, in this instance of 50 ohms impedance, with a reversible probe coupled to it. A small pickup loop built into the probe is terminated with a resistor at one end and a diode at the other. The resistor matches the impedance of the loop, not the impedance of the line section. Energy picked up by the loop is rectified by the diode, and the resultant current is fed to a meter equipped with a calibration control.

The principal metal parts of the device are a brass plumbing T, a pipe cap, short pieces of 3/4-inch ID and 5/16-inch OD copper pipe, and two coaxial fittings. Other available tubing combinations for 50-ohm line may be usable. The ratio of outer-conductor ID to inner-conductor OD should be 2.4/1. For a sampler to be used with other impedances of transmission line, see Chapter 20 for suitable ratios of conductor sizes. The photographs and Fig. 22-26 just about tell the rest of the story.

Soldering of the large parts can be done with a 300-watt iron or a small torch. A neat job can be done if the inside of the T and the outside of the pipe are tinned before assembling. When the pieces are reheated and pushed together, a good mechanical and electrical bond will result. If a torch is used, go easy with the heat, as an over-heated and discolored fitting will not accept solder well.

Coaxial connectors with Teflon or other heat-resistant insulation are recommended. Type N, with split-ring retainers for the center conductors, are preferred. Pry the split-ring washers out with a knife point or small screwdriver. Don't lose them, as they'll be needed in the final assembly.

The inner conductor is prepared by making eight radial cuts in one end, using a coping saw with a fine-toothed blade, to a depth of 1/2 inch. The fingers so made are then bent together, forming a tapered end, as seen in Fig. 22-26. Solder the center pin of a coaxial fitting into this, again being careful not to overheat the work.

In preparation for soldering the body of the coax connector to the copper pipe, it is convenient to use a similar fitting clamped into a vise as a holding fixture, with the T assembly resting on top, held in place by its own weight. Use the partially prepared center conductor to assure that the coax connector is concentric with the outer conductor. After being sure that the ends of the pipe are cut exactly perpendicular to the axis, apply heat to the coax fitting, using just enough so that a smooth fillet of solder can be formed where the flange and pipe meet.

Fig. 22-24 — Major components of the line sampler. The brass T and two end sections are at the back of the picture. A completed probe assembly is at the right. The N connectors have their center pins removed. The pins are shown with one inserted in the left end of the inner conductor and the other lying in the right foreground.

Before completing the center conductor, check its length. It should clear the inner surface of the connector by the thickness of the split ring on the center pin. File to length; if necessary, slot as with the other end, and solder the center pin in place. The fitting can now be soldered onto the pipe, to complete the 50-ohm line section.

The probe assembly is made from a 1-1/2-inch length of the copper pipe, with a pipe cap on the top to support the upper feedthrough capacitor, C2. The coupling loop is mounted by means of small Teflon standoffs on a copper disk, cut to fit inside the pipe. The disk has four small tabs around

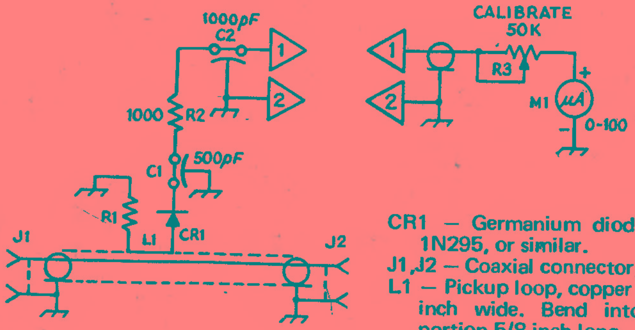


Fig. 22-25 — Circuit diagram for the line sampler.
C1 — 500-pF feedthrough capacitor, solder-in type.
C2 — 1000-pF feedthrough capacitor, threaded type.
CR1 — Germanium diode 1N34, 1N60, 1N270, 1N295, or similar.
J1,J2 — Coaxial connector, type N (UG-58A/U).
L1 — Pickup loop, copper strap 1 inch long × 3/16 inch wide. Bend into "C" shape with flat portion 5/8-inch long.
M1 — 0-100-μA meter.
R1 — Composition resistor, 82 to 100 ohms. See text.
R3 — 50,000-ohm composition control, linear taper.

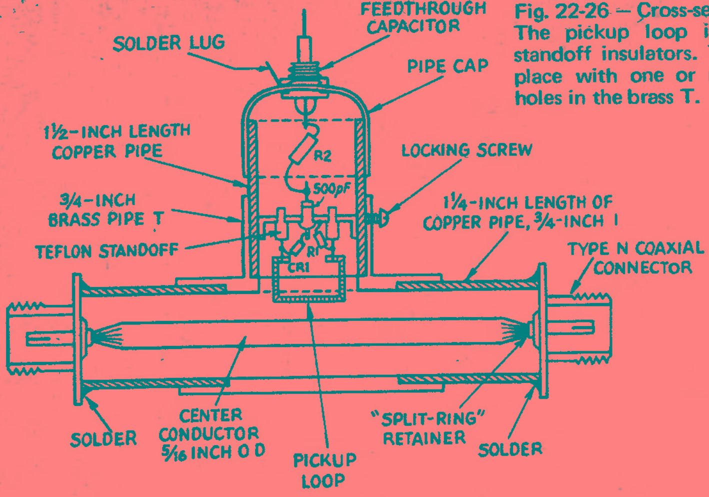


Fig. 22-26 — Cross-section view of the line sampler. The pickup loop is supported by two Teflon standoff insulators. The probe body is secured in place with one or more locking screws through holes in the brass T.

the edge for soldering inside the pipe. The diode, CR1, is connected between one end of the loop and a 500-pF feedthrough capacitor, C1, soldered into the disk. The terminating resistor, R1, is connected between the other end of the loop and ground, as directly as possible.

When the disk assembly is completed, insert it into the pipe, apply heat to the outside, and solder the tabs in place by melting solder into the assembly at the tabs. The position of the loop with respect to the end of the pipe will determine the sensitivity of a given probe. For power levels up to 200 watts the loop should extend beyond the face of the pipe about 5/32 inch. For use at higher power levels the loop should protrude only 3/32 inch. For operation with very low power levels the probe position can be determined by experiment.

The decoupling resistor, R2, and feedthrough capacitor, C2, can be connected, and the pipe cap put in place. The threaded portion of the capacitor extends through the cap. Put a solder lug over it before tightening its nut in place. Fasten the cap with two small screws that go into threaded holes in the pipe.

Calibration

The sampler is very useful for many jobs, even if it is not accurately calibrated, though it is desirable to calibrate it against a wattmeter of known accuracy. A good 50-ohm dummy load is a must.

The first step is to adjust the inductance of the loop or the value of the terminating resistor, for lowest reflected-power reading. The loop is the easier to change. Filing it to reduce its width will increase its impedance. Increasing the cross-section of the loop will lower it, and this can be done by coating it with solder. When the reflected-power reading is reduced as far as possible, reverse the probe and calibrate for forward power, by increasing the transmitter power output in steps and making a graph of the meter readings obtained. Use the calibration control, R3, to set the maximum reading.

Variations

Rather than use one sampler for monitoring both forward and reflected power by repeatedly reversing the probe, it is better to make two assemblies by mounting two T fittings end-to-end, using one for forward and one for reflected power. The meter can be switched between the probes, or two meters can be used.

The sampler described was calibrated at 146 MHz, as it was intended for 2-meter repeater use. On higher bands the meter reading will be higher for a given power level, and it will be lower for lower-frequency bands. Calibration for two or three adjacent bands can be achieved by making the probe depth adjustable, with stops or marks to aid in resetting for a given band. And, of course, more probes can be made, with each calibrated for a given band, as is done in some of the commercially available units.

Other sizes of pipe and fittings can be used, by making use of information given in Chapter 20 to select conductor sizes required for the desired impedances. (Since it is occasionally possible to pick up good bargains in 72-ohm line, you might like to make up a sampler for this impedance.)

Type N fittings were used because of their constant impedance, and their ease of assembly. Most have the split-ring retainer, which is simple to use in this application. Some have a crimping method, as do apparently all BNC connectors. If a fitting must be used that cannot be taken apart, drill a hole large enough to clear a soldering iron tip in the copper-pipe outer conductor. A hole of up to 3/8-inch diameter will have very little effect on the operation of the sampler.

Chapter 23

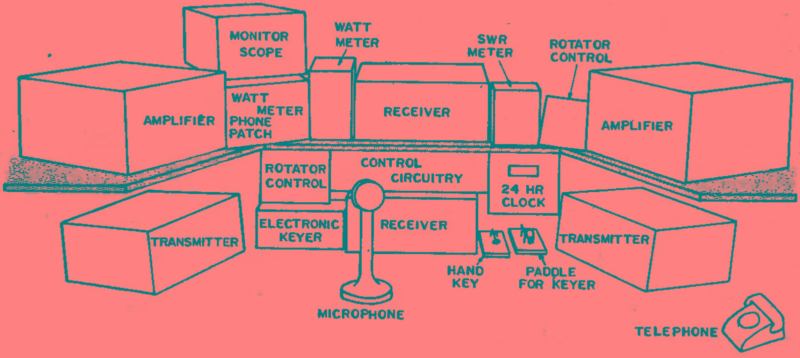
Assembling a Station

The actual location inside the house of the "shack" – the room where the transmitter and receiver are located – depends, of course, on the free space available for amateur activities. Fortunate indeed is the amateur with a separate room that he can reserve for his hobby, or the few who can have a special small building separate from the main house. However, most amateurs must share a room with other domestic activities, and amateur stations will be found tucked away in a corner of the living room, a bedroom, or even a large closet! A spot in the cellar or the attic can almost be classed as a separate room, although it may lack the "finish" of a normal room.

Regardless of the location of the station, however, it should be designed for maximum operating convenience and safety. It is foolish to have the station arranged so that the throwing of several switches is required to go from "receive" to "transmit," just as it is silly to have the equipment arranged so that the operator is in an uncomfortable and cramped position during his operating hours. The reason for building the station as safe as possible is obvious, if you are interested in spending a number of years with your hobby!

CONVENIENCE

The first consideration in any amateur station is the operating position, which includes the operator's table and chair and the pieces of equipment that are in constant use (the receiver, send-receive switch, and key or microphone). The table should be as large as possible, to allow sufficient room for the receiver or receivers, transmitter frequency control, frequency-measuring equipment, monitoring equipment, control switches, and keys and microphones, with enough space left over for the logbook, a pad and pencil. Suitable space should be included for radiogram blanks and a Callbook, if these accessories are in frequent use. If the table is small, or the number of pieces of equipment is large, it is often necessary to build a shelf or rack for the auxiliary equipment, or to mount it in some less convenient location in or under the table. If one has the facilities, a semicircular "console" can be built of wood, or a simpler solution is to use two small wooden cabinets to support a table top of wood or Masonite. A flush-type door will make an excellent table top. Homebuilt tables or consoles can be finished in any of the available oil stains, varnishes, paints or lacquers. Surplus com-



This neatly arranged station belongs to W0TDR in Missouri. The equipment is mounted in a homemade console placed on top of a desk. All controls are easily reachable. A telephone is conveniently located to the right of the operating position. Directly in front of the operator, above the lower receiver, is the control panel which handles antenna and station component switching. This layout is ideal for the right-handed operator.

ASSEMBLING A STATION

An amateur station need not be complicated and expensive. This modern, homemade station built by W1CER is equipped for use in the hf bands. All controls are within easy reach of the operator. The station layout often dictates the overall performance and the on-the-air effectiveness, ragardless of the power level and type of antenna.

puter furniture is readily available through various channels. Many of these consoles are ideal for an operating position. Many operators use a large piece of plate glass over part of their table, since it furnishes a good writing surface and can cover miscellaneous charts and tables, prefix lists, operating aids, calendar, and similar accessories.

CONTROLS

The placement of the equipment is the next important consideration. Two questions should be asked before any placement of station equipment begins. What are my basic operating interests and what equipment or controls are most often used? The particular interest(s) dictates the actual station arrangement. The receiver or transceiver can be located directly in front of the operator where the tuning dial is at a comfortable level for the hand. In general, the station components should be laid out such that the most often used items are in direct view and control of the operator. The equipment of lesser importance is set either right and left, or above and below, the basic units. The photograph illustrates how such an arrangement would appear. A semicircular operating position will accomodate this particular setup most efficiently. If the major interests never require frequent band or mode changing (or frequency changing within a band) the transmitter can be located slightly out of the main operating area, but still within viewing range for checking the meters. If frequent band or mode changing are a part of the usual operating procedure, the transmitter, antenna switches, and any other device which is essential should be located close by the operator.

Another consideration when arranging a station is that of equipment ventilation. Amplifiers or other accessories which generate great amounts of heat in normal operation should be placed in an area where adequate air circulation can be obtained. In some instances, this may not be possible, however. A small blower or whisper fan can be placed on the unit to *draw out heat.*

For right-handed operators, probably the best arrangement of the receiver and transmitter is to have the receiver at the left, and the transmitter at the right. This setup leaves the left hand free for tuning the receiver dial and the right hand for writing or using the key paddle. The reverse of the aforementioned should be applied for left-handed operators. Amplifiers, rotator controls, keyer controls, antenna switching, and rf-output indicators can be placed in the immediate area where very little effort needs to be exerted for actuation or observation.

The hand key, semiautomatic "bug," or paddles for an electronic keyer should be fastened securely to the table in a line just outside the right shoulder and far enough back from the front edge of the table so that the elbow can rest on the table. Some operators prefer to mount the key in front of them on the left, so that the right forearm rests on the table parallel to the front edge. However, the latter position can prove inconvenient while handling any paper work or notes.

The best location for the microphone is directly in front of the operator so that he doesn't have to shout across the table into it, or turn up the speech-amplifier gain so high that all types of external sounds are picked up. If a boom or flexible gooseneck is used to support the microphone, it can be placed in front of the operator without its base taking up valuable table space.

If headphones are normally used, the cabling should be routed around the writing surface or under the table. A simple method of eliminating this cable problem is to mount a phone jack under the table near where the operator sits. Its location should be such as not to interfere with legs or knees.

In any amateur station worthy of the name, it should be necessary to throw *no more than one switch to go from the "receive" to the "transmit" condition.* Many modern transmitter-receiver combinations or transceivers handle this function internally, thus providing the operator greater simplicity in the station. In phone stations, the control of this switching function can be done at the microphone, or with the use of a foot switch. Voice-operated control, or simply VOX, will make operating completely "hands off." While operating cw, a foot switch or a switch located to the right or left of the key will be convenient to control the T-R switching, although some operators prefer to have it mounted on the left-hand side of the operating position and work it with the left hand while the right hand is on the key. On some rigs, a semi-break-in mode is possible with cw. Control of the transceiver or transmitter is via the key. When the key is actuated, the transmitter is automatically switched to the transmit mode.

If a rotary antenna is used, the control should be convenient to the operator. Sometimes the direction indicator is designed for continuous monitoring. A few do not have this option and could be modified to provide constant information

Power Connections and Control

A shelf made from 1/2- or 3/4-inch plywood can support several different pieces of equipment. The rotator control is visible to the left of the operator (K4FU), with other essential items located close by. A lerge sheet of glass makes an excellent writing surface.

to the operator. This system is advantageous to the contest or DX operator. The indicator, however, can be located anywhere within sight of the operator, and does not have to be on the operating table unless it is included with the control.

Frequency Spotting

The operator should be able to turn on *only* the oscillator (or low-level stages) of his transmitter so that he can spot accurately his location in the band with respect to other stations. Turning on just the oscillator or low level stages to provide enough signal within the shack to facilitate spotting should be accomplished without putting a signal into the antenna.

Frequency spotting must be effortless. A foot switch or another type of switch which is easy to reach and simple to operate is desirable. A small Microswitch located at the key will provide easy control and very little hand motion for actuation. Other systems can be designed to provide even simpler ways of spotting. The use of a touch sensitive switch located around the VFO dial has been used. This slightly more sophisticated approach allows the operator to spot simply by moving the dial.

Comfort

Of prime importance is the comfort of the operator. If you find yourself getting tired after a short period of operating, examine your station to find what causes the fatigue. It may be that the chair is too soft, does not have a straight back, or is the wrong height for you. The location of some frequently used piece of equipment could be located so that you assume an uncomfortable position while using it. The lighting of the writing area may be poor or the table top could be too low or high. If you get sleepy fast, the ventilation may be at fault. A careful view of the entire situation will help track down any potential discomfort.

POWER CONNECTIONS AND CONTROL

Following a few simple rules in wiring your power outlets and control circuits will make it an easy job to change units within the station. If the station is planned in this way from the start, or if the rules are recalled when you are rebuilding, you will find it a simple matter to revise your station from time to time without a major rewiring job.

It is neater and safer to run a three-wire cable and box from a wall outlet over to the operating table or some central point, than to use a number of adapters and cube plugs at the wall outlet. If several outlets are located slightly above the table height, it will be convenient to reach the various plugs. Cable ties can be used for wrapping power cords to maintain a neat arrangement. The operating table should be positioned away from the wall slightly so it will be easier to reach the rear of equipment.

The power wiring should never be overloaded. Check the wire size to assure that the ratings are

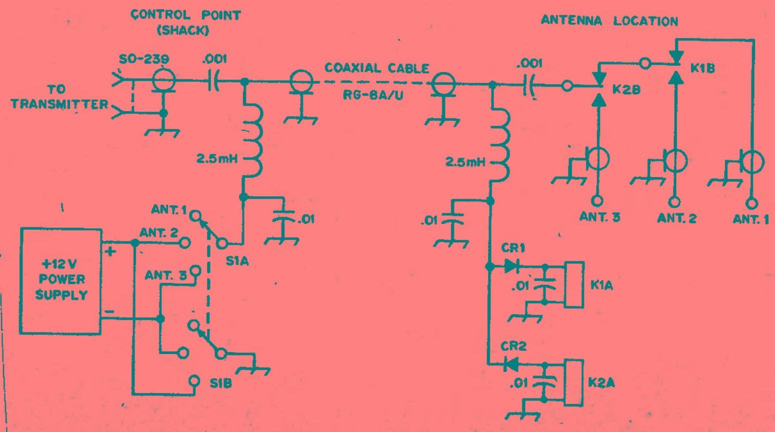


Fig. 23-1 — A remote antenna switching system using low voltage relays hendles three different antennas. The coaxial cable is used as the control line. CR1 and CR2 can be any low voltage silicon diodes (Motorola 1N4001 or equiv.). K1 and K2 can be any 12-V dc relays with suitable contect ratings (Potter and Brumfield KA5DG or equiv.). The rotary switch should have at least two sections and three positions.

A bulletin board mounted near the operating position allows members of this club station, W6YRA, to post information for the benefit of club members. The operating position is made from plywood. The hinged sheet of plywood at the top serves to hide and protect the equipment when it is not in use.

not exceeded. Consult an electrician for details on power handling capabilities of your house wiring. A 234-V ac line should be available with suitable current ratings. The outlet for this line should be different from the 117-V ac outlets to prevent confusion. A station which runs more than 500 watts input to the transmitter should have this higher voltage line to prevent lights from "blinking" with keying or modulation. It also provides better regulation. A single switch, either on the wall of the shack or at the operating position, should control all of the 117- and 234-volt outlets, except for lights and the line to which the clock is connected. This makes it a simple matter to turn the station to "standby" condition. In case of an emergency, a family member has one switch to shut off power but not the lights. The station equipment normally should be shut off with their own power switches before the main switch is turned off. With equipment left on, turning on the power with the main switch could cause a great surge on the line, which could trip a fuse or circuit breaker.

All power supplies should be fused. Pilot lights or other types of indicators always should be used to tell the operator when the unit is on. All switches for these power supplies should be clearly marked. Even though *you* may know the different functions of the control panel or power supply, a family member may not, and it is important that this vital information be available in case of trouble. In high voltage power supplies, it is recommended that an autotransformer be used in the primary circuit, aside from the power switch, to maintain better control of the high voltage. It also reduces the initial surge of current in the line caused by charging filter capacitors.

SWITCHES AND RELAYS

It is dangerous to use an overloaded switch in power circuits. After it has been used for some time, it may fail, leaving the power turned on even after the switch is set to the "OFF" position. For this reason, large switches or relays with adequate ratings should be used to control the plate power supply. Relays are rated by coil voltage (for control circuits) and by contact current and voltage. Any switch or relay for the power-control circuits of an amateur station should be conservatively rated; overloading a switch or relay is very poor economy. Switches rated at 20 amperes at 125 volts will handle the switching of circuits at the kilowatt level, but small toggle switches rated for 3 amperes at 125 volts should be used only in circuits up to about 150 watts. When relays are used, the coil voltage can be controlled by a switch of low-current rating. The relay contacts then, in turn, handle the higher current demands of the power supply.

Any remote-control circuitry should be powered from low voltage. It is dangerous to have 117-V ac controlling remote antenna relays mounted atop a tower. It is recommended that low dc voltages be used for all control systems. One 12-V dc power supply of suitable current rating could be used to handle all control circuitry. As a back-up power source, an automobile battery could be tied in parallel with this supply in case of a power failure. Relay contacts used for antenna switching or rf switching should be rated at least 10 amperes, which will handle two kilowatts. A basic diagram of a remote antenna switching system is shown in Fig. 23-1. The coaxial cable is used to carry the control voltage. The two diodes provide proper operation of either relay.

The nature of the send-receive control circuitry depends almost entirely on the particular station equipment. It is impossible to list here anything but the broadest principles to follow. Commercially manufactured equipment usually has a section of the instruction book devoted to this point. In many cases the antenna-transfer relay is included in the transmitter so that the antenna is directly connected to the transmitter and a separate cable is connected from the transmitter to the receiver. When the transmitter is "on" the relay transfers the antenna to the transmitter output circuit. Lacking an antenna transfer relay, many amateurs have used a short separate wire for the receiving antenna. While this is acceptable in many instances, it is seldom as effective for receiving as using the same antenna for both transmitting and receiving.

EQUIPMENT INTERFACE

As the station grows in complexity, it is important to maintain a unique cabling system. The use of standard cable connectors makes the station components flexible. For low power rf or af, phono plugs and jacks are adequate. High power