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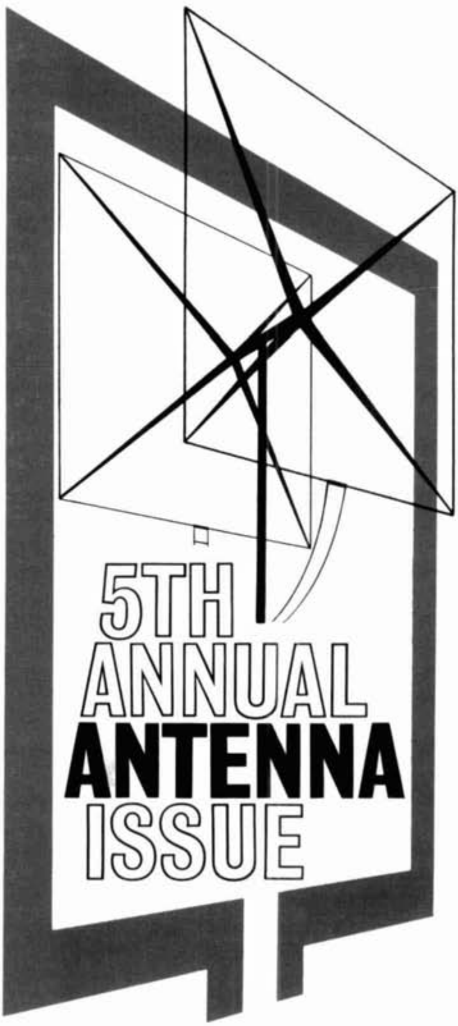

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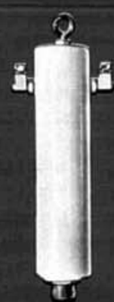

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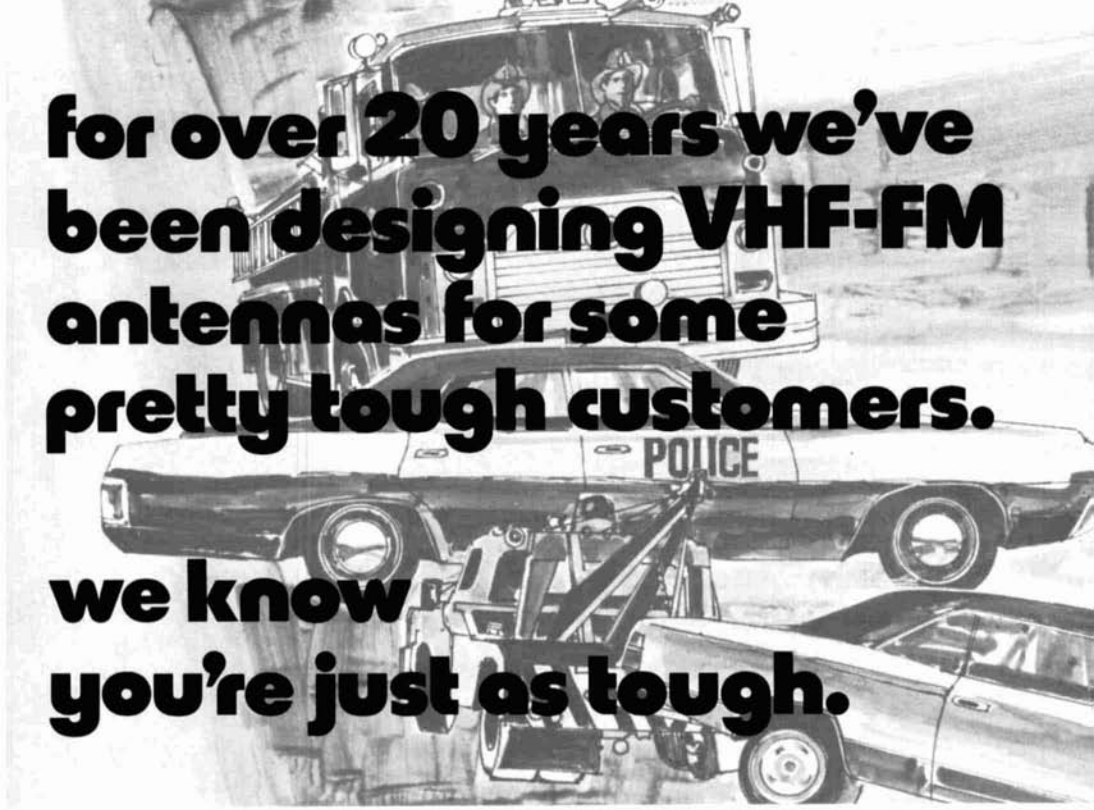

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contents

a second look

by jim fisk

Ever since the military services first started using wireless back around the turn of the century their engineers and radio officers have been trying to find a way to use trees and other natural objects as antennas. Many methods were tried, including the simple expedient of pounding nails into trees and connecting the transmission line to them. Nothing worked. It was found, in fact, that trees actually absorbed most radio waves and that thick forests made radio communications all but impossible over any but short ranges.

It wasn't until relatively recently, in 1969, that any real progress was made. At that time an intensive research program was begun at the Army Electronics Command's research laboratory. In the four years since the program began a team of scientists under the direction of Dr. Kurt Ikrath have developed a system for making effective use of trees and other natural objects as antennas. The key, of course, is the coupling of rf energy into and out of the object. The Army Command accomplished this through a flexible, toroid-shaped hybrid electromagnetic antenna coupler called a *Hemac* which is formed in a circle around the tree as shown in the photograph.

This tree is radiating a signal on 10.8 MHz. The transmitter is coupled to the tree through a matching network (in the box on the tree) and the toroidal Hemac. (U.S. Army photo.)

The Hemac operates as the primary of a leaky rf transformer; the tree or other core object acts as a single-turn secondary. A variable tuning and impedance-matching circuit is used with the Hemac to provide a good match to 50-ohm transmission lines. Dr. Ikrath reports that the Hemac-tree antenna requires less skill to tune than the short whip on the Army's PRC-74 radio set. Nor is the Hemac's use limited to trees – it has been used successfully with such man-made objects as light standards, window frames and helicopters. In one case two Hemac coils were used with trees, four meters apart, as a high-frequency phased array. By changing the phase difference between the 4.65-MHz signals driving the two trees, engineers were able to vary the radiation pattern.

As might be expected, frequency is very important to the operation of the system. In a forest environment the dense underbrush scatters or absorbs short wavelengths. Long wavelengths seem to work best as absorption is much less. The optimum operating frequency also depends upon the object used as the antenna. A 100-foot tree, for example, works best in the 80-meter range. Who will be the first to put this idea to work on Field Day?

Jim Fisk, W1DTY
editor-in-chief

More Details? CHECK—OFF Page 110

fixed log-periodic beam for 15 and 20 meters

A simple, low-cost wire beam that provides lots of gain per dollar

G.E. Smith, W4AEO, 1816 Brevard Place, Camden, South Carolina 29020

Since retiring from business in 1970 I have been designing, building and testing fixed, high-frequency, log-periodic beam antennas. I had long wondered why amateurs had made so little use of these very excellent beams which are used extensively by commercial, military and government communicators.

To date, over fifteen log periodics have been erected and thoroughly tested here. Most of these have been horizontal doublet log periodics for the 20-, 15- and 10-meter bands, as shown in plan form in **fig. 1**. Some have been for 40, 20 and 15. Two vertical monopole log periodics (with ground plane) were tested on 40 and 80, giving 10-dB gain with the low angle of radiation best suited for DX.

Since most of these log periodics cover a 2:1 or one-octave bandwidth, e.g., 7-14 or 14-28 MHz, they are rather long for the average amateur antenna farm. Two of the log periodics tested here for 14-30 MHz were one with a 40-foot (12.2-meter) boom length, having 8-dB gain, and one with a 70-foot (21.35 meters) boom, giving 10-dB gain as compared with a doublet at the same height. My longest log periodic is 100-feet (30.5 meters) long, has 17 elements, and gives 12- to 13-dB gain. The swr for these antennas is relatively low over the 20-, 15- and 10-meter bands, generally not exceeding 2:1 with 1.1:1 to 1.4:1 typical.

Since these log periodics are wire beams, they are quite inexpensive considering their gain. They are also quite easy to build. The material cost usually runs from $15 to $25 each, less feedline and masts or other supports.

As a result of on-the-air discussions while testing and comparing these antennas, and from several previous articles on log periodics, I receive many requests for information on the smallest possible log periodic to cover at least 14 through 21.5 MHz. The inquirers generally want gain equal to or better than the average ham beam.

two-band log periodic

A log periodic having 8-dB gain and meeting these requirements, erected in a space 40 by 40 feet (12.2 x 12.2 meters), will be described here. This antenna, which is beamed south, has been in use for three years. It gives excellent performance. Also included is a list of materials, approximate total price and brief assembly information.

Fig. 2 shows the layout for this simple 7-element log periodic for 20 and 15 meters. Its bandwidth or frequency coverage is 14 to 21.5 MHz. Theoretically it provides 8-dB gain in the forward direction. However, when compared with a dipole at the same height, reports in the direction of its beam generally show a 10-dB increase over the doublet. When an

S-9 report is received while using the doublet, a "20 over 9" is often received after switching to the log periodic. An equivalent S-meter increase at this end usually confirms the reports received.

At any rate, the reports received during three years of use give this log periodic a conservative 10-dB gain in its forward direction. It is mounted approximately 40 feet (12.2 meters) above ground. The measured swr over the two bands is:

14.0 MHz	1.1:1	21.0 MHz	1.01:1
14.1 MHz	1.1:1	21.1 MHz	1.01:1
14.2 MHz	1.02:1	21.2 MHz	1.05:1
14.3 MHz	1.02:1	21.3 MHz	1.15:1
14.35 MHz	1.01:1	21.4 MHz	1.25:1
		21.45 MHz	1.3:1

If even greater gain is desired and the space is available, a 9-element log periodic having a boom length of 57.3 feet (17.48 meters) can be used (**fig. 3**). This is actually the 20-15-10 log periodic of **fig. 1** with several of the short (10-meter) elements deleted, which reduces its bandwidth to 14 to 21.5 MHz for operation on 20 and 15 meters. This log periodic should give 10- to 11-dB gain on 20 and 15 if its height is at least a half wavelength above ground for 20, about 33 feet (10 meters).

If space is available for an even longer antenna, **fig. 4** illustrates another log periodic which should give 11- to 12-dB gain. The latter two antennas (**fig. 3** and 4) have not actually been tested here, but the gain figures were taken from the 3-band equivalents for 20-15 and 10. Deleting the 10-meter section should have little effect on performance for 20 and 15.

The front-to-back ratio of these log periodics will be approximately 10 to 12 dB, not as good as a Yagi, but with its other advantages over a Yagi the log periodic is well worth consideration.

Fig. 5 shows the **fig. 2** log periodic as it would look suspended from four 40-foot (12.2 meter) masts. These can be inexpensive telescoping TV masts, available at any TV shop, or 45-foot (13.7 meter) wooden poles. Used poles are available from power companies in some areas at a very reasonable price. The TV masts will, of course, require guying, but wooden poles can usually be unguyed for the smaller log periodics. The log periodic of **fig. 2** as used here has its rear end supported by the roof and the short forward end by two cedar trees. This tree-roof configuration just happened to be perfect for suspending this log periodic 40 feet (12.2 meters) above ground, beamed due south.

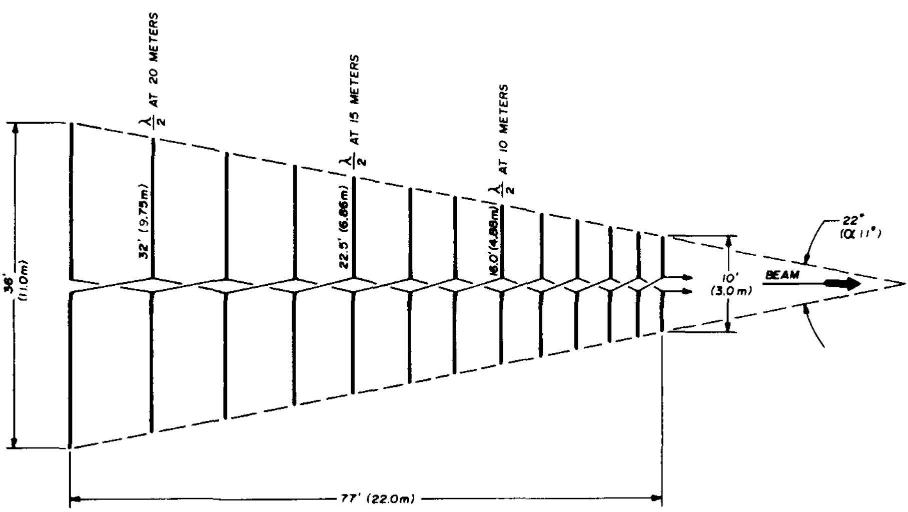

fig. 1. Plan view of a typical log periodic beam for 14-30 MHz. With 13 elements and a boom length of 72 feet (22 meters) this antenna provides 10-dB gain over a reference half-wave dipole for 10, 15 and 20 meters. Note the feedpoint transposition of alternate elements — if this is not done, the antenna will not work.

If any of these two-band log periodics can be suspended at least a full wavelength above ground (approximately 66 feet on 20 meters) they will no doubt provide a lower angle of radiation. This is better for DX and, in effect, will show greater gain, especially on 20. The highest I have been able to use here has been 60 feet (18.3 meters), and considerable improvement was noted on that particular antenna compared to the others installed approximately 40 feet (12.2 meters) above ground.

The beam width of a log periodic is generally about 90 degrees, which is good for a fixed beam required to cover a particular continent or a certain part of the U.S. From this location, the antenna beamed west covers the entire west coast and also Australia.

construction

Fig. 6 illustrates the physical layout of the 7-element antenna showing location of the home-made Lucite insulators and the suspension of the seven elements between the two nylon sidelines or catenaries. Note the transposition of the feedline to alternate elements, a must for a log periodic.

Fig. 7 is a drawing of the insulators, which are made from 1/4-inch (6-mm) Lucite. The end insulators have only the two end holes, while four holes are drilled in the center insulators. The two end holes are for fastening the center of the elements, while the two toward the center, spaced 1½ inches (3.8 cm), are for the two-wire center feeder. The center insulators serve two functions: First, they separate and space the two-wire open feeder, and second, being secured to the feeder at the points specified in **fig. 2,** they space the elements at the required distances so the antenna will function as a log periodic.

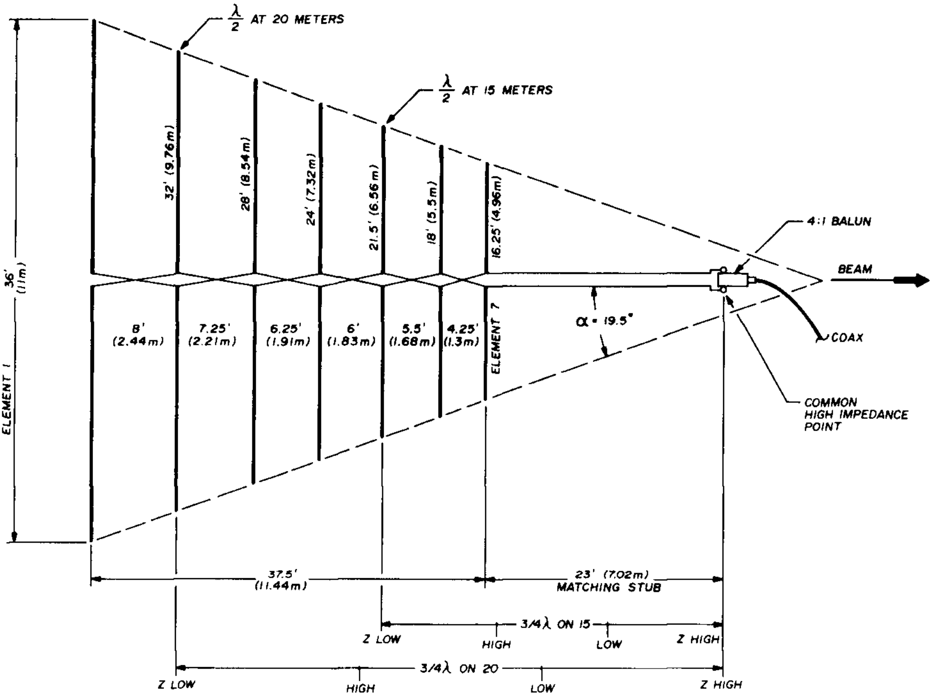

fig. 2. Dimensional drawing of a practical log periodic for 15- and 20-meter operation that requires only a 40- by 40-foot (12- by 12-meter) space for installation. Though its theoretical gain is 8 dB, the author's version of this antenna has consistently shown 10 dB or better gain over a reference dipole at the same height. Note feedpoint transposition of alternate elements.

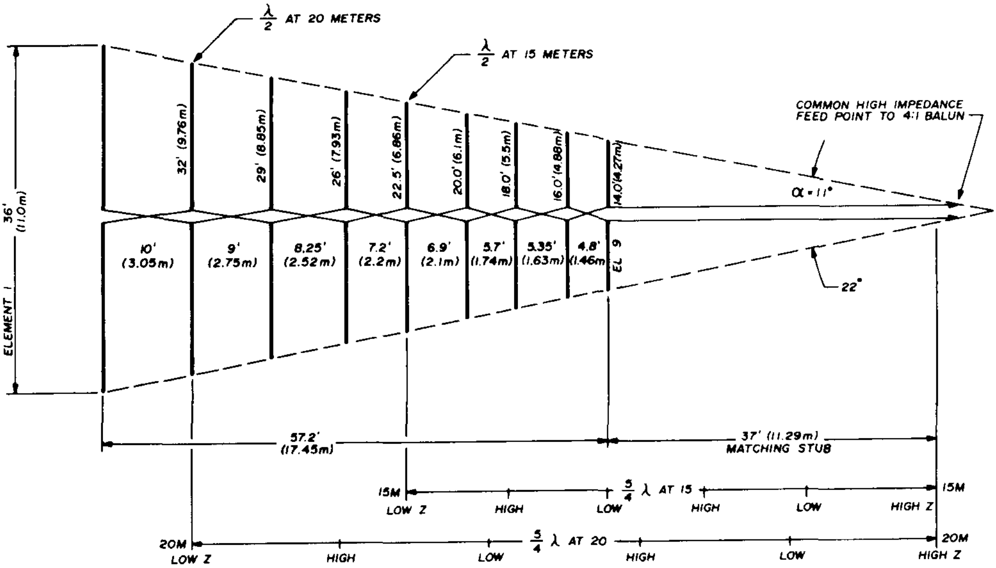

fig. 3. Dimensional drawing of the log periodic of fig. 1 with the 10 meter elements omitted. Though its 57.2-foot (17.45-meter) boom length may be prohibitive in some installations, those who have the room for it should find a 2- to 3-dB improvement compared to the smaller antenna of fig. 2.

Note that six egg-type ceramic insulators are used in place of Lucite for the long rear element, 1, and for the short forward element, 7. This is recommended due to the additional strain on these two elements, which must support the remaining five elements and the weight of the center feeder.

Note that the two-wire center feeder is extended 23 feet (7.0 meters) beyond the short forward element, 7. This provides a common impedance match on both 20 and 15 meters. A 4:1 balun is used to provide a match between the coax transmission line and the antenna. This 23-foot stub would not be necessary if a

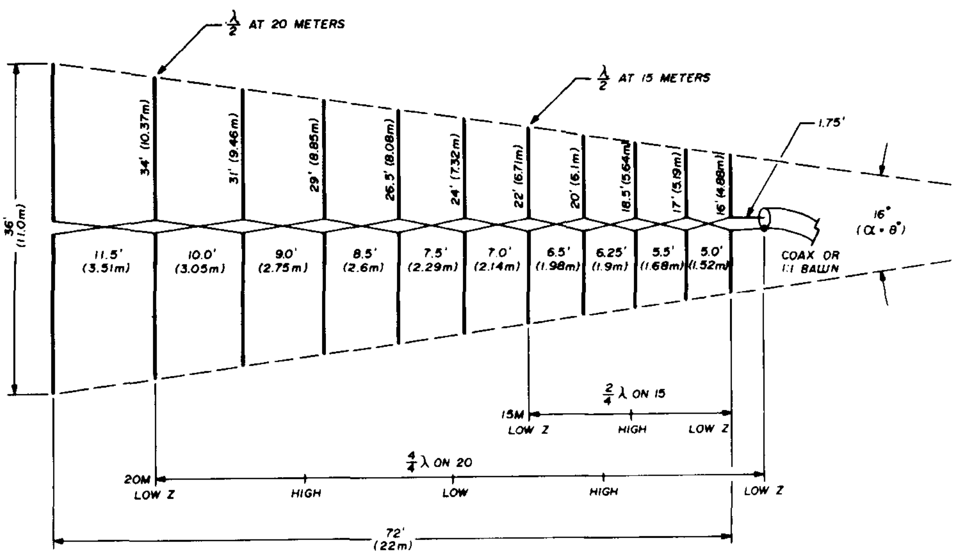

fig. 4. Dimensional drawing of an even longer two-band log periodic. This 11-element array should provide at least 12-dB gain over a reference dipole.

tuned line was used between the shack and the log periodic. However, this would require a tuner or *Match Box* at the equipment end. The use of the stub plus the 4:1 balun eliminates the need for the antenna tuner.

It may be of interest that the above feed method has a very desirable feature. Element 2, which is the driven or active radiator element on 20 meters, is spaced approximately 3/4 wavelength from the common feedpoint. Element 5, the driven or active element on 15 meters, is also

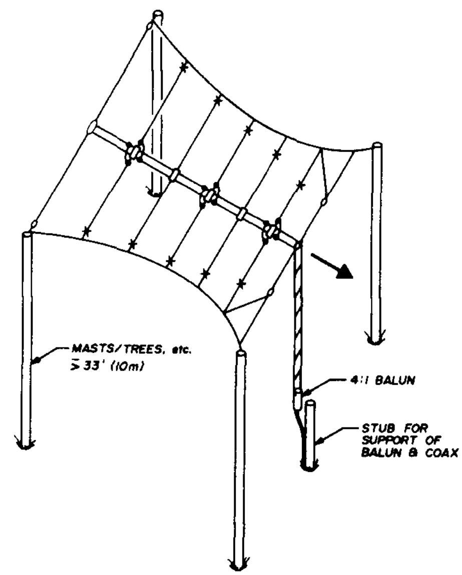

fig. 5. TV masting or used utility poles provide an easy means for putting up a wire log periodic antenna such as the seven-element array of fig. 2.

3/4 wavelength from the balun. Since the active element for a discrete frequency within the bandwidth of the antenna is 3/4 wavelength from the common feedpoint, the center feeder plus the 23-foot (7.0-meter) stub act as an impedance matching line and the impedance at the common feetpoint is relatively constant on either 20 or 15 meters.

The stub can hang down from the antenna as shown in **fig. 5.** A short stub mast can be used to support the balun and the coax, relieving the strain on the short-element end. Several additional

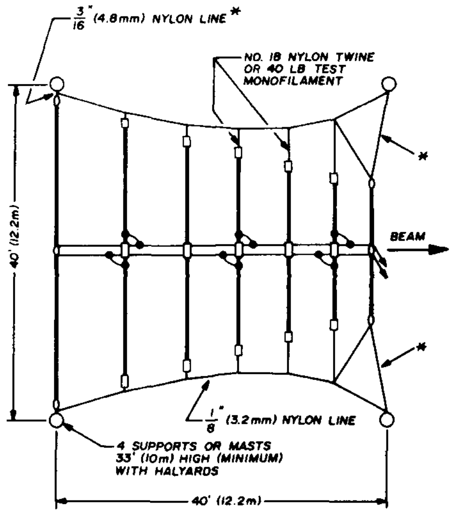

fig. 6. Mechanical layout showing suspension of log periodic of fig. 2. Egg insulators are used on the first and last elements, while the Lucite insulators detailed in fig. 7 are used elsewhere.

Lucite spacers should be used along the stub to keep the two wires separated and parallel. Spacers about every five feet (1.5 meters) are suggested.

log-periodic theory

The log-periodic beam can be considered as a multi-element, broadband, uni-

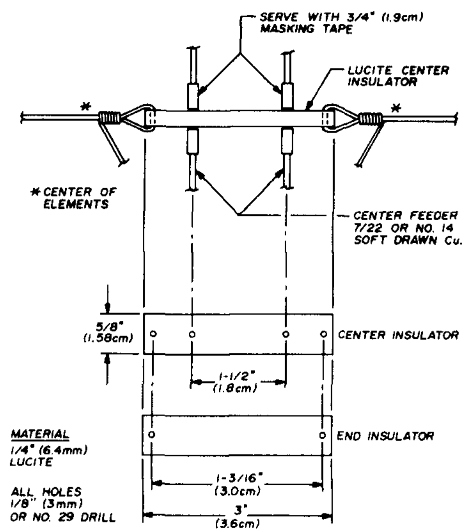

***fig. 7.* Dimensional drawings of Lucite insulators used at centers and ends of center elements. Dimensions and material are not critical.**

table 1. List of materials needed for building the log-periodic antennas described here (not including masts or coax).

item	7 elements (figs. 6 & 2)	9 elements (fig. 3)	11 elements (fig. 4)
Antenna wire (elements)[2]	190 feet (58 meters)	225 feet (69 meters)	290 feet (89 meters)
Antenna wire (center feeder)[1,2]	125 feet (38 meters)	196 feet (60 meters)	160 feet (49 meters)
Ceramic egg insulators	6 each	6 each	6 each
End insulators (Lucite)	10 each	14 each	18 each
Center insulators (Lucite)	5 each	7 each	9 each
Nylon line, 1/8 inch (3 mm)	100 feet (30.5 meters)	170 feet (52 meters)	235 feet (72 meters)
Nylon line, 3/16 inch (5 mm)	25 feet (7.6 meters)	25 feet (7.6 meters)	25 feet (7.6 meters)
Nylon twine, no. 18[3]	1 roll	1 roll	1 roll
Total cost	$17.00	$22.00	$26.00

notes

1. The center feeder should be 7/24 copper (not copper-clad — too stiff) or other stranded wire so the two wires will remain parallel and not kink.

2. The author used number-15 aluminum electric fence wire on many of his log periodics to reduce weight and cost. Caution must be used when working aluminum, and care must be taken to avoid contact between dissimilar metals which can cause electrolysis. Aluminum is not recommended for use near sea coast or in a polluted environment.

3. 40 lb. test monofilament fish line can also be used, eliminating need for end insulators.

directional, end-fire array. The design formulas have appeared before in an amateur publication,[4] which although it covered only vhf log periodics, also applies to high-frequency log periodics. The design formulas are quite complex, so unless a computer is available it is suggested that the dimensions given in this article be followed.

Table 1 is a list of materials for the short 20-15 meter log periodic, **fig. 2**, as well as the two longer models of **fig. 3** and **4.**

summary

Anyone who has the space to put up one of these excellent log periodic antennas for 20 and 15 will be pleased with the results. Considering its moderate cost, its gain in the forward direction is about equivalent to adding a big linear. It is equally helpful in reception in the desired direction, giving the same gain in receiving. It also has a very pronounced diversity effect, especially important during bad signal fading. Of all the various beam antennas tried here during the past three years, the two-band log periodic for 20 and 15 has been the simplest and easiest to construct. I believe it gives more "miles per dollar" than almost any other amateur beam.

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ham radio

parabolic reflector antennas

Complete construction details for a large parabolic reflector for uhf — Australian style

T.R. Naughton, VK3ATN

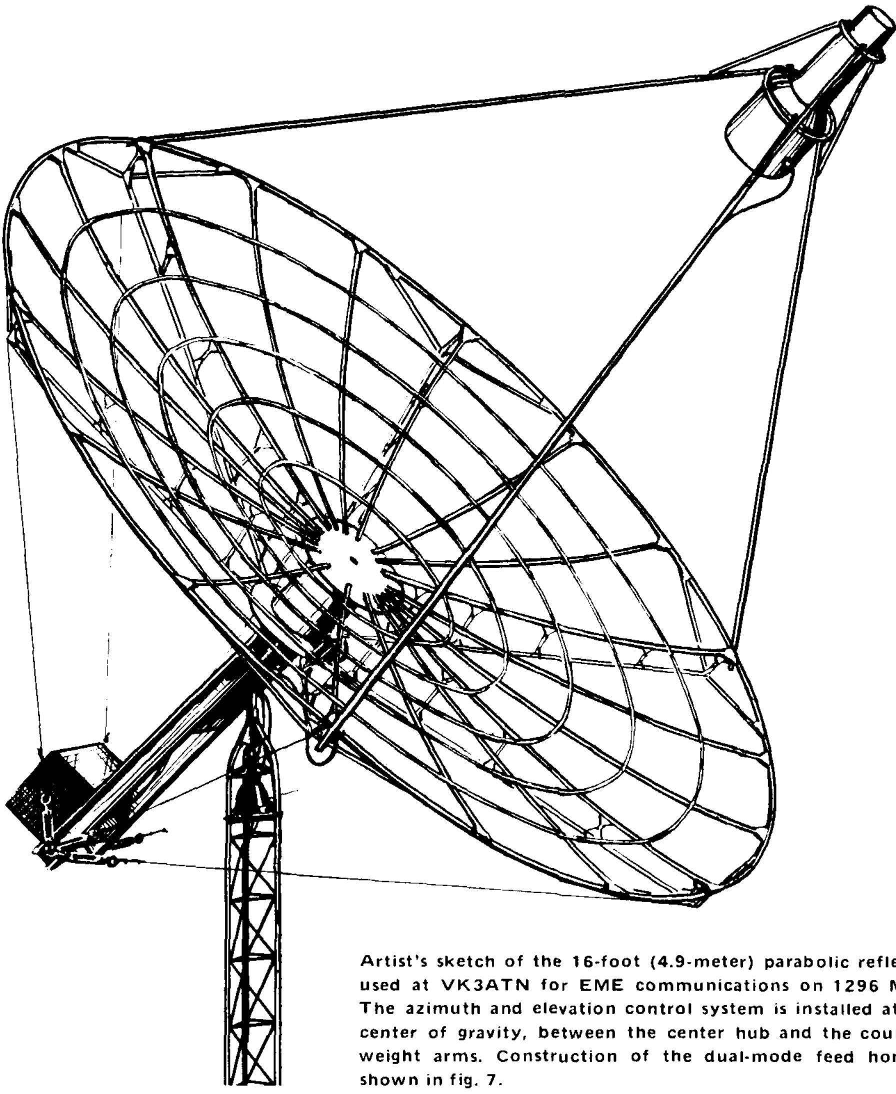
There should be little doubt in the minds of avid uhf experimenters that the antenna is a most important part of his station. This is especially so for long-path DX and EME amateur communications where the most important characteristic of the antenna is its ability to efficiently direct all of the available transmitter power in a preferred direction — its effective gain. Since antennas are passive reciprocal devices they perform the same unique high-gain function in the receiving mode as well. There should also be little doubt that, in the uhf range and higher frequencies, the parabolic reflector is the most efficient, high-gain antenna. Those experts in antenna technology may debate this last statement; however, for home construction without critical measurement and adjustment, the parabolic reflector antenna has no equal.

This article describes fabrication techniques using readily available materials which can be used in the construction of relatively large parabolic reflectors with exceptional rigidity, strength and moderate weight. Construction is mainly of round aluminum tubing with gusset plates and pop rivet fasteners. The conductive reflector surface is aluminum screen or galvanized iron mesh, also readily available.

Although much detail will be described, this article is not intended to give a *cook-book* design. Using the same general construction techniques described here the size of the reflector can range from 10- to 30-feet (3 to 9 meters) in diameter. The design is not unlike many commercial reflectors. However, unlike commercial construction, no aluminum welding is required and weight is kept to a minimum.

feed systems

The efficiency of a parabolic dish antenna is highly dependent on the feed antenna and on the surface accuracy of the reflector. A very efficient feed is the dual-mode, small-aperture antenna whose radiation characteristics determine a focal-length-to-aperture-diameter ratio of 0.6 for the reflector.[1] However, this particular feed antenna, because of its physical size, is not practical for frequencies below about 1000 MHz. A suitable feed for 432 MHz is the NBS gain



Artist's sketch of the 16-foot (4.9-meter) parabolic reflector used at VK3ATN for EME communications on 1296 MHz. The azimuth and elevation control system is installed at the center of gravity, between the center hub and the counter-weight arms. Construction of the dual-mode feed horn is shown in fig. 7.

standard whose radiation characteristics are very similar to the dual-mode aperture antenna. Both feed systems are described at the end of this article. Although these feeds are shown as linearly polarized, they may be adapted for circular polarization. This is recommended to eliminate Faraday fading for moonbounce communications.[2]

surface accuracy

Surface accuracy of a reflector antenna affects the phase of the aperture wave. Variations from an exact paraboloid surface cause scattering of energy in directions away from the main beam and, thus, lower the gain. The reflector design presented here, together with the dual-mode feed system, will produce an effective gain of

$$G_{eff} = 0.65 \left(\frac{\pi D}{\lambda}\right)^2$$

where D is the reflector physical diameter, λ is the operating wavelength in the same length units as D, and the surface accuracy, everywhere on the surface, is within 0.025λ of a true paraboloid.

construction details

Construction of the reflector consists of four parts: one, a central hub from which construction begins and which is also used to mount the antenna; two, an array of identically trussed ribs which are

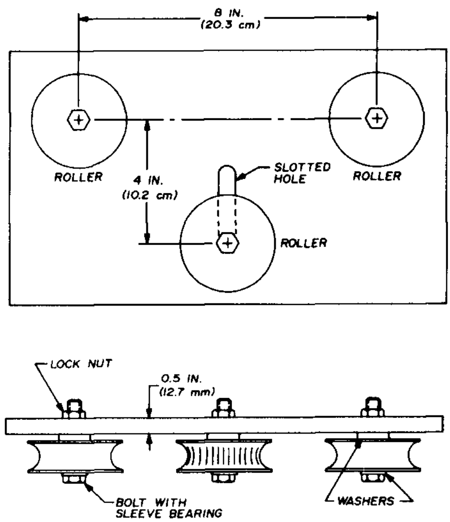


fig. 1. Rolling mill construction. Curved grooves in the rollers should be slightly larger in radius than the tubing to be bent. Middle roller should be knurled or roughened if this roller is driven. Slot for the middle roller mounting bolt is to permit changing bending radius.

attached to the hub and form the parabolic shape; three, a series of circumferential rings which join the ribs and provide support for the conductive surface material, and four, the conductive surface. Mounting of the feed, although important to the use of the reflector, will be considered separately from construction of the paraboloid.

The aluminum tubing used in this construction is a half-hard or 6100 alloy which can be easily bent. Bending can be done several ways. Two methods suggested here are by a rolling mill, which must be constructed, or by a special tool called a *hickey* which is used by electricians for bending conduit. These may be bought from most electrical supply houses for about $5.

The rolling mill produces a smooth arc bend and is very desirable for bending the circular rings which support the reflector surface material. The rolling mill used in the construction described here is shown in **fig. 1.** With this mill it is important that the groove in each roller is a bit larger than the tubing which is to be bent. Also, it is necessary to have a secure and resettable position for the middle roller to set the bend radius. A hand crank or other drive mechanism attached to the middle roller will ease the required rolling effort. Even though it will take some time to construct the rolling mill, its use will greatly shorten total construction time and produce very uniform and repeatable bends. Since the extreme ends of tubing bent in the rolling mill will not conform to the curvature of the central portion, a few inches should be cut off at each end. Some care should be taken in rolling as the tubing may have a tendency to twist.

The *hickey* is used to kink the tubing in small incremental sections producing an arc composed of short straight sections between kinks. This method of bending is entirely acceptable for the rib and hub construction. Note that the actual reflector surface material is not supported by the ribs but by the rings which are spaced about one foot apart along the ribs.

Virtually all the fastening of tubing is done with aluminum or steel pop rivets. These are readily available in hardware stores along with a manually operated tool which properly sets the rivets. This method of fastening is quick and provides a long-lasting permanent fastener. A unique feature of pop rivets is that they may be used in blind holes as shown by **fig. 2.** Either 1/16- or 5/32-inch (1.6- or 4-mm) diameter rivets may be used for most fastening, but larger rivets may be used where heavy pieces or thick pieces are to be joined.

The center hub which I used consists of two circular rolled rings of 7/8-inch (22.2-mm) tubing about 24 inches (61 cm) in diameter and spaced 18 inches

(45.7 cm) apart. A number of cross braces are used to hold the rings together rigidly. While this construction method used only tubing and rivets, an improved hub construction would be a spool or reel design made of 1/8-inch (3.2-mm) aluminum plate and a 16-inch (40.6-cm) section of large diameter aluminum tubing. This hub design is shown in **fig. 3.**

The end discs of the hub are secured to the large tubing by means of many small aluminum angle brackets with rivets. If a large diameter tube is not available a suitable substitute would be a hexagonal section composed of flat 1/8-inch (3.2-mm) plates. Additional stiffening of this hexagonal tube at its center is required and may consist of a single band of aluminum bent to conform to the outside of the hexagon and fastened near the plate seams with rivets.

A very important part of the hub is the holes cut in the center of each end plate. The size of the holes is made to be a snug fit with a standard aluminum or steel tube available, 1½ to 2 inches (3.8 to 5.1 cm) in diameter. These holes and the tube form the axis of symmetry of the paraboloid and will be used to align the ribs and surface material as described later. The hub length should be about one-twelfth the reflector diameter; the end discs need not be larger than 24 inches (61 cm) for any size reflector.

Sets of two or three rivet holes can be drilled in the hub end plates at the radial locations of the ribs. Additionally, similar sets of holes can be drilled to mount the gusset plates used to attach the back member of the rib to the hub.

trussed-rib construction

To maintain uniformity of the ribs and accuracy of the parabolic shape it is essential that a jig be built to hold the rib pieces in position while fastening. For the 16-foot (4.9-meter) diameter reflector, an 8-foot (2.45-meter) piece of half-inch (13-mm) plywood may be used with wooden blocks to serve for alignment and holding. Alternatively, the jig may be made of angle iron, welded together. If the plywood jig is used, one edge of the plywood sheet is used as the axis of symmetry and the parabolic curve may be carefully laid out and drawn using the coordinates given in **table 1.** Draw in the remaining truss members as shown in **fig. 3**. The height of the rib at the hub end must be equal to the hub end plate

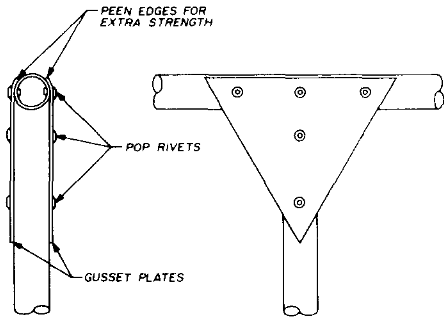


fig. 2. Gussett plate detail. Gusset plates are not necessarily all the same shape.

spacing so that the rib may be fastened to the hub with a minimum of strain.

Blocks of wood about ½ inch (13 mm) in height may now be securely attached to the plywood jig so that the truss members are held in their appropriate positions. It should be noted that the parabolic member is actually bent into a circular arc which will require a minimum of distortion to form the parabolic arc. The radius of curvature which fits this requirement is very nearly twice the focal length. Prebending of the parabolic members is done in the rolling mill or by the multiple kink method. If the latter method is employed, the kinks should occur between the locations of the circular rings. In this way the points of ring attachment will conform to the parabolic arc in the jig. These points should be marked on the rib members for ease in indexing the rings later.

The cross braces in the ribs are short pieces of the same diameter tubing as the ribs and spaced about 18 inches (45.7 cm) apart. The cross braces should be notched to fit the main members. The notching operation may be done with a table 1. Parabolic curve coordinates for reflector diameters of 16 feet (4.9 meters), 20 feet (6.1 meters) and 24 feet (7.3 meters). *Coordinates are given for only one-half of the parabola since the other half is identical.*

reflector diameter		16 feet (4.88 meters)		20 feet (6.10 meters)		24 feet (7.30 meters)	
focal length (f)		9.6 feet (2.93 meters)		12 feet (3.66 meters)		14.4 feet (4.39 meters)	
inches	cm	inches	cm	inches	cm	inches	cm
0	0	0	0	0	0	0	0
3.94	10	0.034	0.085	0.027	0.68	0.022	0.057
7.87	20	0.13	0.34	0.11	0.27	0.09	0.23
11.81	30	0.30	0.77	0.24	0.62	0.20	0.51
15.75	40	0.54	1.37	0.43	1.09	0.36	0.91
19.69	50	0.84	2.14	0.67	1.71	0.56	1.42
23.62	60	1.21	3.08	0.97	2.46	0.81	2.05
27.55	70	1.65	4.19	1.32	3.35	1.10	2.79
31.50	80	2.16	5.47	1.72	4.37	1.44	3.65
35.43	90	2.72	6.92	2.18	5.54	1.82	4.61
39.37	100	3.36	8.54	2.69	6.84	2.24	5.70
43.31	110	4.07	10.34	3.26	8.27	2.71	6.89
47.24	120	4.84	12.30	3.88	9.84	3.23	8.20
51.18	130	5.68	14.44	4.55	11.55	3.79	9.63
55.12	140	6.59	16.75	5.27	13.40	4.40	11.16
59.06	150	7.57	19.22	6.05	15.38	5.05	12.81
62.99	160	8.61	21.87	6.89	17.50	5.74	14.58
66.93	170	9.72	24.69	7.78	19.75	6.48	16.46
70.87	180	10.90	27.68	8.72	22.15	7.27	18.45
74.80	190	12.14	30.84	9.71	24.67	8.10	20.56
78.74	200	13.45	34.18	10.76	27.34	8.97	22.78
82.68	210	14.83	37.68	11.87	30.14	9.89	25.12
86.61	220	16.28	41.35	13.02	33.08	10.85	27.57
90.55	230	17.80	45.20	14.24	36.16	11.86	30.13
94.49	240	19.38	49.20	15.50	39.37	12.92	32.81
96.00	243.8	20.00	50.80	16.00	40.64	13.33	33.86
98.43	250			16.82	42.72	14.02	35.60
102.36	260			18.19	46.21	15.16	38.50
106.30	270			19.62	49.83	16.35	41.52
110.24	280			21.10	53.59	17.58	44.66
114.17	290			22.63	57.48	18.86	47.90
118.11	300			24.22	61.52	20.18	51.26
120.0	302.8			25.00	63.50	20.83	52.91
122.05	310					21.55	54.74
125.98	320					22.96	58.33
129.92	330					24.42	62.03
133.86	340					25.92	65.84
137.80	350					27.47	69.77
141.73	360					29.06	73.82
144.00	365.8					30.00	76.20

rotary rasp of the same diameter as the tubing or with a notching tool used by welding fabricators. A wooden jig can be built to hold the tube at the appropriate angle if the rotary rasp method is used. A less pretentious but adequate notch may be vee-shaped and made by hand with a file or saw.

With all the rib members in the jig, gusset plate fastening of the butt joints is accomplished as shown by the detail drawing of **fig. 2.** The gusset plates may be predrilled and used as a guide for drilling the tubing through a single wall thickness. One hole drilled and pop riveted at a time will eliminate hole misalignment. When all gusset plates are secured on one side of the rib, the rib is removed from the jig and turned over for fastening the second set of gusset plates. The gusset plates are cut from half-hard sheet, 22 gauge or about 1/32-inch (0.8-mm) thick. The reverse rib alignment template may be built in a similar way on the same plywood sheet.

The alignment template and support tube must be constructed accurately because they determine the ultimate accuracy of the reflector surface. This consideration is important since the reflector can be used at higher frequencies

ameter tubing as the rim for my 16-foot (4.9-meter) reflector, it is recommended that 1½-inch (38-mm) tubing be used if possible for additional strength. The rim may be rolled to the prescribed radius bend in the rolling mill by starting with a larger radius and rolling the pieces through several times, each time decreasing the bend radius until the final value is achieved. A large circular arc may be chalk-marked on a convenient surface (garage floor, driveway, patio, etc.) for checking the sections as they are rolled.

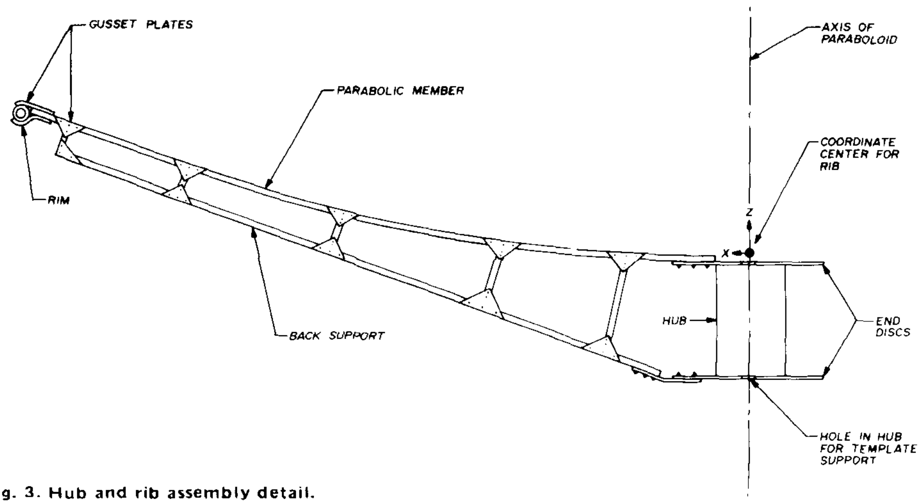


fig. 3. Hub and rib assembly detail.

if the surface accuracy is good. The alignment template support tube must fit snugly into the holes at the center of the hub.

For larger reflector diameters it may not be possible to obtain tubing of sufficient length and splices will be required. The method I used consists of taking a short length (4 to 6 inches or 10 to 15 cm) of the same tubing to be spliced (see **fig. 4**). Cut a single slot lengthwise about ¼-inch (6.5-mm) wide. Then squeeze the piece until it fits inside the splice pieces, forming a butt joint. Finally, pop rivets are used to form a permanent joint as shown by **fig. 4**.

surface support rings

Although I used 1-inch (25-mm) di-

Assemble the arc sections into a circle at the final construction site using the butt splice technique except for the final splice. Leave this last splice open with some overlap so that exact adjustment of the last splice will give a good fit to the ends of the ribs.

The circular rings of 3/8-inch (9.5-mm) tubing may be rolled after the hub, ribs and rim have been assembled. These rings should be spaced concentrically with the rim starting at the rim. Approximately one-foot (30.5-cm) spacing between rings will be adequate to support the screening. At the rim a surface registration problem will occur because of the way the rim is attached to the rib ends. This problem can be resolved by either attaching a 3/8-inch

(9.5-mm) ring directly at the rim or by deliberately bending the last one foot (30.5 cm) of the parabolic member so that the rim tube will be in correct surface registration. This bend correction must be included in the rib jig before the ribs are assembled and must also include the extra kink in the parabolic member.

Since the rings will require a long section of 3/8-inch (9.5-mm) tubing, it may be necessary to splice pieces. For this small-size tubing it will be adequate to use a simple short overlapping splice riveted together. Splicing may be done after rolling, and some pre-squashing of the tubing is desirable before drilling and riveting.

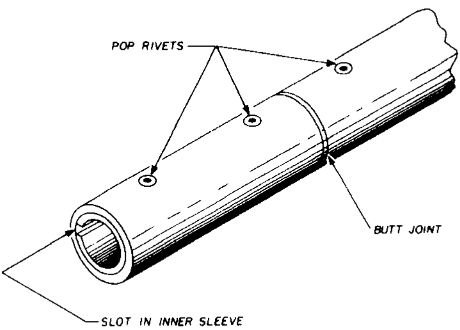


fig. 4. Method of joining sections of tubing. Use eight rivets in diametrically opposite pairs for extra strength.

assembly

Assembly starts by riveting the hub gusset plates on at the locations of the back rib members. These gusset plates should be of 1/16-inch (1.6-mm) material for extra strength. The parabolic member of the rib may now be riveted to the top of the hub and the back member temporarily clamped. Alignment of the rib is now accomplished by inserting the reverse rib template support tube into the hole at the center of the hub. The rib should be adjusted by loosening the back member clamp and allowing the parabolic member of the rib to conform exactly to the edge of the template. Now the back member may be riveted in place. Repeat this procedure for all ribs.

As the structure grows, it will be necessary to provide temporary trusses between ribs to prevent strains and lateral bending. Diametric wire or heavy cord guys between rib ends will also aid in maintaining the ribs in alingment. The reflector will be constructed with the parabolic surface initially upward.

When all the ribs are attached a survey check of rib alignment should be made with the template before the rim is attached. The rim is attached to the upper and lower surfaces of the parabolic members by means of gusset plates and rivets. Additional support for the rim may be added in the form of diagonal members from a point about 18 inches (45.7 cm) from the rib on the rim to a point near the end of the back member of each rib.

At this point in construction a number of additional single member parabolic ribs should be carefully bent, formed into parabolic shape, checked against the template or jig and then fastened to the rim and hub so that at the rim there will be a rib spacing of about 2 to 3 feet (61 to 91 cm), no more. For the 16-foot (4.9-meter) diameter dish I built, two additional single-member ribs are added between the six trussed ribs. Check these additional ribs for alignment with the template.

When forming these single-member ribs they should be marked so that the correct end is attached to the rim. The curvature is so slight that it is quite easy to reverse the rib end-for-end by mistake. The locations of the rings may now be

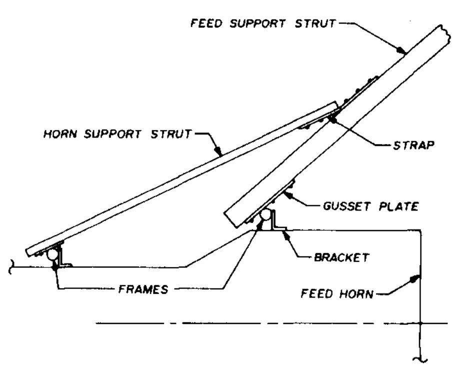


fig. 5. Partial view of the feed support detail.

marked on each rib member by first marking the locations on the template along the parabolic edge and transferring these marks to each rib.

Finally, the 3/8-inch (9.5-mm) surface-support rings are formed and riveted to the ribs. The rings must be squashed to a thickness of 5/16 inch (7.9 mm) at rivet points in order to use 5/32 x ½-inch (4 x 12.7-mm) long rivets. The rings may be temporarily clamped to the ribs to aid the assembly. After all of the rings are riveted in place a final check should be made with the template for accuracy. If errors greater than ¼-inch (6.4-mm) are found they should be corrected, even if rivets must be extracted and parts altered. If you have come this far you are to be congratulated, the rest is easy.

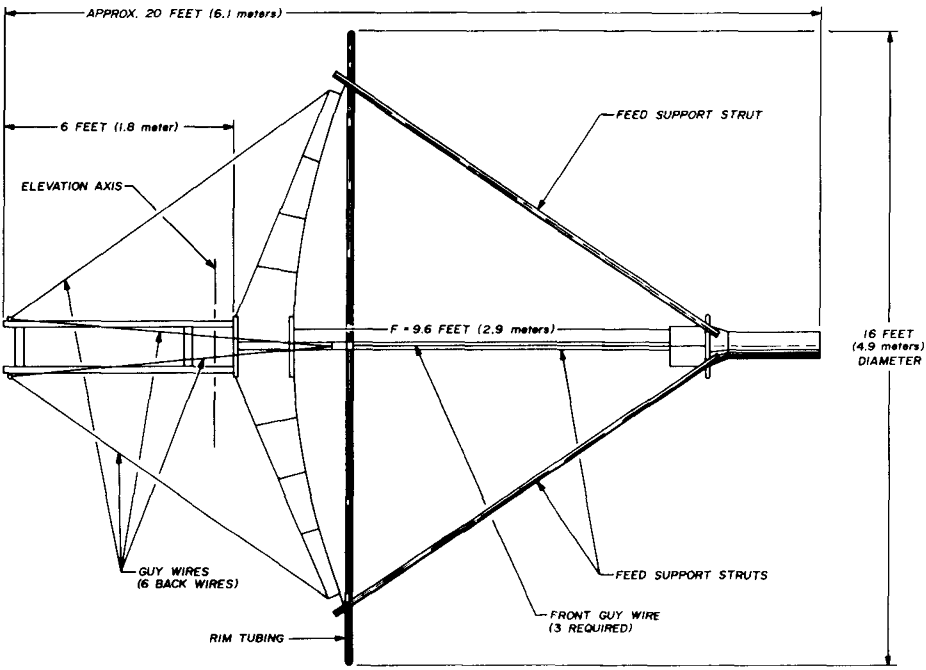


fig. 6. Skeleton plane view showing rigging and overall dimensions for the 16-foot (4.9-meter) diameter parabolic reflector.

surface construction

Surfacing consists of cutting radial length strips of screening diagonally. These triangular sections are then carefully laid over the rings between pairs of ribs in pie section fashion and fastened to the rings with wire ties. The ties should be spaced a maximum of 4 to 6 inches (10 to 15 cm) apart. Start along a ring at the middle of the pie section and work towards the rim and hub. Try to keep the screening taut with as little bowing as possible. Trim off any excess at the center to permit the template support tube to be inserted at the center of the hub. The smallest 3/8-inch (9.5-mm) support ring should be no less than about 6 inches (15 cm) in diameter. It will be more convenient to rivet the screening down where ties cannot be used. A thin washer above the screening will prevent damage if aluminum window screening is used.

At the rim, the screening should be long enough to be wrapped around the outside of the rim and secured by a spiral wrap of wire which passes through the screen near the point of tangential contact. As each section of surface material is added, the edge overlap should be a minimum of 2 inches (5 cm) and held together by wire ties to prevent gaps. A last check of screening surface accuracy should be made with the template and the screening trimmed up if necessary. Pinching the mesh can be used to take up slack areas. Every effort should be made to maintain a surface accuracy of ±¼-inch (±6.4-mm) over the entire surface to assure satisfactory performance at 1296 MHz.

If galvanized iron mesh (hardware cloth) is used, the mesh size will permit inserting the tip of a pair of long-nose pliers and twisting the mesh wire to draw up specific areas where sags appear. This procedure, though tedious, can result in a very taut surface.

In the event of damage to a small surface area, an overlay of screen may be added on, provided the patch size is not less than one wavelength in its smallest dimension. Larger area damage may require replacement of an entire pie section of screening.

Another useful suggestion is to use epoxy cement to tighten up rivets which may become loosened.

feed support

The feed support is a tripod of 1½-inch (3.8-cm) diameter thin-wall aluminum tubing. For extra stiffness, and to damp wind vibrations, these tubes may be filled with foam-in-place urethane foam or billets of cylindrically-cut rigid foam. This procedure prevents diametric deformation of the thin wall and can add much to the tubing stiffness with little added weight. The foam-in-place urethane is a two-part mixture which is mixed and quickly poured down the tube with the tube in a vertical position. A wad is forced into the tubing near the middle before foaming and the foam poured in from each end.

The tripod legs are attached to the outside of the rim with short pieces of aluminum angle and bolts or, alternatively, with heavy gusset plates. The preferred locations of the legs are one near top center when the reflector is in its normal zero-degree elevation position and the other two legs spaced equally to either side of bottom center.

A frame assembly to support a 1296-MHz feed horn or higher-frequency feed systems is placed at the apex of the tripod. This is shown in part in **fig. 5.** This partial drawing shows details for one leg. The other two legs are similar but spaced around the frame in the same manner that the legs are spaced around the rim of the reflector. The ends of each leg are fastened to the frame by heavy gusset plates and rivets. These gusset plates are approximately diamond shaped. Additional strength can be provided for the thin-wall legs at their ends by a similar technique used in splicing. In this case the split sleeve inside the leg tubing serves as additional wall thickness.

The feed holding frame may be a circular ring rolled from heavy-wall, soft-alloy aluminum conduit or a square of rigid tubing assembled with corner gusset plates. To support the rather long circu-

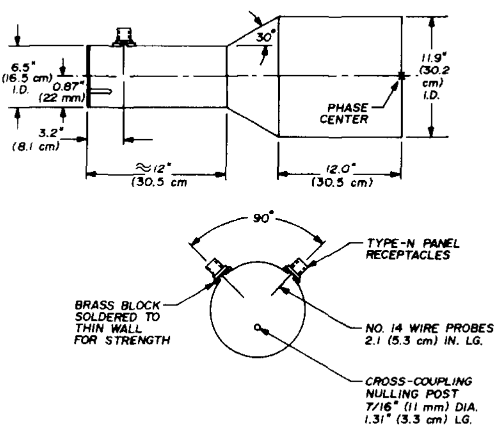


fig. 7. Dual-mode feed antenna for 1296 MHz. Material for the round sections is 1/32-inch (0.8-mm) brass, rolled and butt joint seamed. The conical section is soldered on with many small angle tabs. Probes are provided at right angles to facilitate circular polarization. Adjust probe lengths for best swr on 50-ohm feedline. The nulling post should be mounted in a radially slotted hole to permit radial adjustment of position for minimum cross coupling between probes.

larly polarized feed for 1296 MHz it is necessary to have an additional frame smaller in size and about 24 inches (61 cm) behind the first frame. Support members for this small frame are added between frames and side struts attached to the tripod legs with riveted straps for lateral support. If axial twisting of the feed support assembly is objectionable, it can be minimized by the addition of a rolled ring approximately 48 inches (1.2 meters) in diameter and fastened to the tripod legs in front of the feed support frame.

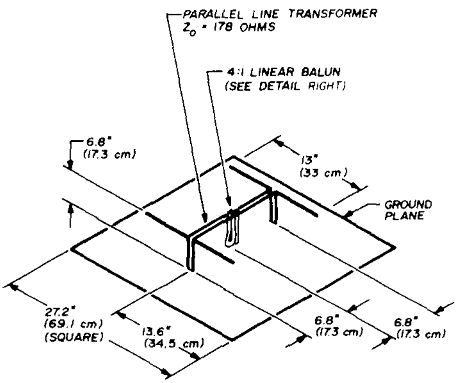
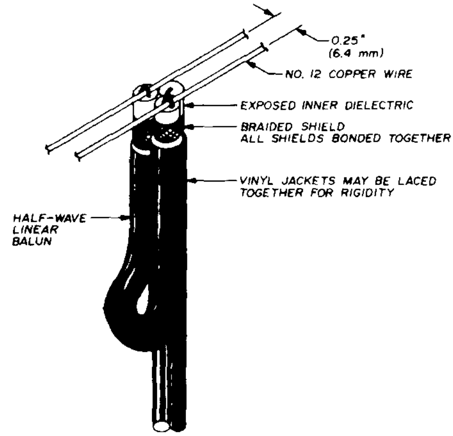


fig. 8. Double-dipole feed system for 432 MHz.

For 432 MHz the feed system shown in **fig. 7** may be mounted on long studs in front of the first frame so that the ground plane is located at the focal point of the reflector. This can be done with the 1296-MHz feed horn in place, but not in use, by mounting the ground plane just far enough in front of the horn to permit the coaxial feed cables to clear. The dual-mode horn is mounted inside the frames by means of short studs or brackets. It is important that screws used to fasten the horn should always be arranged with their heads on the inside of the horn wall.

counter weight

If the complete antenna is to be placed on an elevation-over-azimuth mount, the following construction will provide for counter balancing and extra stiffness. The counterweight arms are made of channel steel or aluminum beams spaced about 18-inches (46-cm) apart and cross braced in the manner shown in **fig. 6.** Attachment to the reflector hub is by means of two angle brackets which are bolted to the back of the hub. It is most helpful to place the elevation axis in the plane of one side of the support tower and as close to the hub as the support tower will permit. In this way the counter weight arms will lie parallel with the tower when the antenna is in the stowed position, beam aimed straight up. This is the position of least wind resistance and, by securing the counterweight arms to the tower, the reflector antenna and tower can survive severe weather conditions. It is also the best symmetrically balanced position for ice and snow loading.



final rigging

The final rigging involves turn-buckled guy wires from the end of each main rib back to the ends of the counterweight arms on their respective sides. The registration or positioning of the main ribs in the reflector with respect to the tower mount should be such that the bottom two ribs straddle the tower. In this way all rib ends may be guyed to the counterweight arms. If the bottom rib were aligned vertically it would not be possible to guy it due to interference from the tower. All guys should be carefully trimmed since they essentially hold the reflector and counterweight arms in rigid assembly. Three additional guys may be added from the rib ends between the tripod feed support legs to the feed-support frame.

The counterweights are simply large, heavy bars U-bolted to the inside of the counterweight arms so that they may be slid along the arms for adjusting balance. Alternatively, the bars may be replaced by iron pipe sections which have heavy concrete weights permanently attached at one end.

summary

Construction techniques for relatively large paraboloidal reflector antennas have been given with the hope that those amateurs who are interested in high gain antennas for uhf will find comfort and encouragement in their endeavors.

Since feedline losses are significant at uhf, it is recommended that the preamplifier and mixer be located at the feed with only i-f and dc cables dressed down a leg of the tripod and around to the mount axis where a slack loop will permit rotation without cable joints. For strictly moonbounce communications, the support tower for the reflector need be no higher than the reflector radius, provided that the foreground clearance (trees, buildings, etc.) is good in the azimuthal angular directions of the rising and setting Moon.

It is also suggested that the final power amplifier and driver be mounted in a suitable weatherproof enclosure on the counterweight arms so that a minimum of large low-loss coaxial cable can be used to connect the output to the feed. This arrangement has special merit because no rotating joints or flexing cable are required in the high power line but only in the low power line to the driver input where lossy flexible cable can be tolerated in a slack loop.

A note of caution for those who live in extreme cold areas where icing and high winds occur: It is not known how this antenna construction will survive these extremes of weather. It is advisable in areas where freezing temperatures occur to drill small (1/8-inch or 3-mm) diameter holes in all tubing where water may collect.

The 16-foot (4.9-meter) reflector antenna described here was a first prototype and has proven adequate in receiving the first EME signals in Australia on 1296 MHz from W2NFA. Actually, the first signal ever heard on this antenna was W2NFA via EME!

acknowledgement

A project of this magnitude must require enthusiasm, help and encouragement and I am happy to acknowledge the assistance of the following people. Mike Hooper, VK3CCX, for his help in designing and building the jigs and trusses and for installing the cables; Les Jenkins, VK3ZBJ, for his contribution with the feed and adjustment, the loan of a converter and for numerous tests of equipment; Noel Walker, VK2ZNS, for helping with the design and building of the mount and digging holes for tower foundations at 1:30 AM (the weather was too hot during the day); Roger Hord, VK2ZRH, Ray Beevers, VK3BRB, and many others for various efforts related to the fabrication of the reflector and its final installation. I am particularly indebted to Dick Turrin, W2IMU, for his boundless encouragement and technical advice and lastly to my wife, Margaret, and my family for their patience and cooperation.

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ham radio

More Details? CHECK—OFF Page 110

simple antennas for satellite communications

How to adapt ground-plane antennas for practical communications through OSCAR 6

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If the most consistent communication via amateur satellites is desired, then beam antennas which constantly track satellite passes over the ground station are clearly in order. On the other hand, the current OSCAR series of satellites present dramatic proof that many contacts through the on-board repeater can be generated by stations using relatively low gain, stationary antennas. Granted some freedom from complicated antennas and tracking mechanisms, it becomes worthwhile to investigate design modifications of simple fixed antennas which maximize the operating time during an arbitrary pass. The following comments suggest a design change for ground-plane antennas that makes them attractive for modestly equipped stations involved in satellite communications.

The basic concept is quite simple. Slightly tilting the vertical radiator tends to optimize the transfer of energy between a satellite in a circular orbit and a ground-plane antenna for any point locating the satellite in the visible sky. The design objectives and the theoretical basis underlying the modification are reviewed below. Practical tips on matching and constructing the modified antenna are also discussed.

design objectives

The following four characteristics provide a useful (but not exhaustive) set of design objectives for fixed antennas used for satellite work:

1. A vertical plane pattern which remains constant along any azimuthal bearing in the horizontal plane.

2. A vertical plane pattern which provides a smooth increase in radiation as the vertical angle of elevation, measured between the horizon and the satellite, decreases. An increase of 11 dB between the overhead and horizontal field strengths is appropriate for OSCAR satellites at an altitude of approximately 910 miles.[1]

3. Relative independence from ground effects. This permits installation of the antenna in the clear where nearby trees, buildings, etc., exert minimum screening when the satellite nears the horizon.

4. Simplicity in mechanical construction and electrical matching.

The selection of the first two items involves certain simplifying assumptions: the satellite is in a nonsynchronous-circular orbit, signal perturbations caused by interactions between the radiated wave and the ionosphere are negligible, and the satellite antenna is always favorably oriented with respect to the fixed antenna at the ground station.

theoretical basis

Which of the design objectives are met by a quarter-wavelength vertical erected adjacent to the ground? No serious problems concerning point 4 are encountered by this antenna, and the theoretical pattern of the isolated vertical completely satisfies point 1. Over perfect ground the radiation is maximum along the horizon which is convenient for DX work through the satellite. However, a depressing null develops in the vertical plane pattern for elevation angles near the zenith. Thus signals will be degraded during the overhead portions of satellite passes. The antenna fails on point 3. Two simple alterations remove these drawbacks.

It has been shown elsewhere that tilting the vertical element away from the normal fills in the overhead null without materially changing the other pattern characteristics.[2] A vertical plane pattern for a tilt of 45 degrees is drawn in **fig. 1A**. The depression at the zenith deepens and field strengths become less dependent upon the azimuthal bearing as the tilt

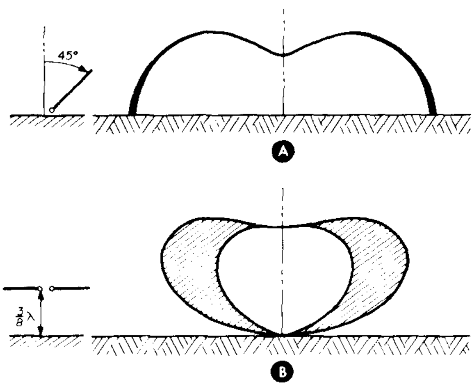
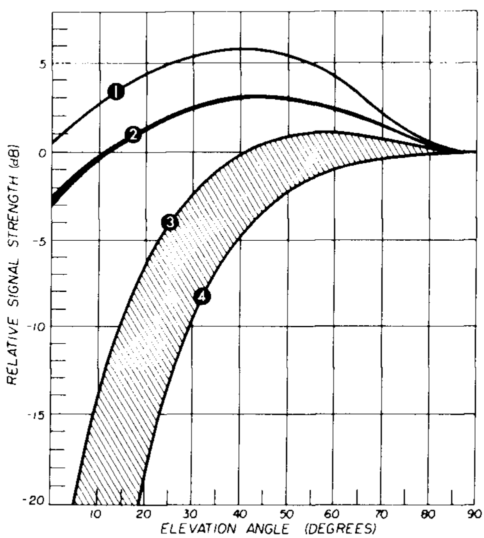


fig. 1. Vertical plane patterns for quarter-wave vertical tilted away from the normal by an angle of 45 degrees (A) and horizontal dipole at a height of 3/8 wavelength (B). The patterns for an arbitrary azimuth bearing fall within the width of the solid curve for the tilted vertical (A) and within the shaded region for the horizontal dipole (B). Perfect ground is assumed for both cases.

angle decreases. The width of the curve in **fig. 1A** reflects the extremes in vertical plane patterns as one circles a vertical tilted at 45 degrees. Since the variation is less than 0.5 dB, this trade-off is easily accommodated. Another trade-off involves the lower input impedances of the tilted vertical. As shown below, it is an easy matter to resolve this problem with a quarter-wavelength coaxial transformer.

The second change is to simulate actual ground with a plane of quarter-wavelength radials. This frees the antenna from the earlier criticism regarding point 3. Naturally the limited size of the elevated ground plane will slightly alter the pattern of **fig. 1A**. Basically, somewhat more radiation occurs at higher angles and somewhat less energy is radiated along the horizontal direction. The net result of these alterations is a tilted, vertical, ground-plane antenna which adequately meets each of the four design goals listed above.

The advantages of this antenna can be brought into sharper focus by briefly examining the characteristics of horizontal half-wave dipoles using the same performance criteria. **Fig. 1B** gives the vertical plane pattern for a horizontal antenna at a height of 3/8 wavelength. This height is close to optimum because it offers the greatest freedom from the undesirable lobe effects in the vertical-plane pattern associated with higher antennas while still maintaining a greater percentage of radiation nearer the horizon than can be supplied by lower antennas.



Curve 1 Vertical tilted 30 degrees from normal
Curve 2 Vertical tilted 45 degrees from normal
Curve 3 Horizontal dipole broadside to satellite
Curve 4 Horizontal dipole endfire to satellite

fig. 2. Relative signal strength versus angle of elevation between the satellite and the horizon. The curves can be used to estimate the effectiveness of a given antenna as the elevation angle changes during a satellite pass. A reference level of 0 dB was arbitrarily selected at the zenith point for each antenna. In curves 3 and 4 the dipole is assumed to be 3/8-wavelength above ground. The satellite is in a circular orbit at an altitude of 910 miles.

The outer and inner boundaries of the dipole pattern in **fig. 1B** define the broadside and endfire conditions, respectively. It is immediately obvious that the radiation from the dipole is sensitive to azimuthal bearing. Moreover, horizontal antennas at any height always show poor radiation along the horizontal plane. In practical terms at 10 meters, the average city-dweller will find that the effects of real earth and screening likely to be present for an antenna located only 12-feet above ground combine to further reduce antenna performance at low elevation angles. Thus, the single horizontal dipole fails to satisfy the first three points of the design criteria. Azimuthal omnidirectionality can be improved by connecting a second dipole at right angles to the first in a turnstile configuration.[3] Points 2 and 3 still remain inadequately satisfied, however.

A graphical summary of the theoretical performance of a tilted vertical and horizontal dipole is presented in **fig. 2.** The curves of relative signal strength incorporate not only the variation in radiated field strength of the ground station antennas shown in **fig. 1** but also the varying distance separating the antenna and the satellite as elevation angle changes during a pass. It is convenient to arbitrarily normalize all curves to zero dB at an elevation angle of 90 degrees. Therefore, comparisons between different antennas should be restricted to relative changes in signal strength for corresponding changes in elevation angle. **Fig. 2** indicates that a vertical tilted 30 to 45 degrees provides a response which varies less than 6.0 dB, even for an overhead pass. Tilt angles which fall outside this range cause antenna performance to deteriorate.

The curve widths provide a measure of the departure from azimuthal omnidirectional behavior for tilt angles of 30 and 45 degrees. A much larger variation in signal strength is observed for a satellite passing over a horizontal dipole located

3/8 wavelength above ground. The marked disparity between the broadside and endfire curves at low elevation angles illustrates the value of installing a rotator to keep the dipole broadside to the satellite when it is near the horizon.

While simple treatments of ideal antennas are helpful in formulating an overall design philosophy, the real antenna usually provides some deviation from the predicted behavior. For example, real

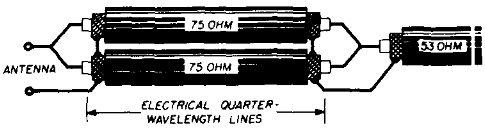


fig. 3. Quarter-wave matching transformer which matches antenna radiation resistances of the order of 25 ohms to the 50-ohm impedance level of popular coaxial lines.

ground, non-sinusoidal current flow, satellite spin and ionospheric polarization distortion can modify conclusions based on models which ignore there features. Low gain antennas aggravate matters because a host of conducting and insulating objects are illuminated in the immediate vicinity of the antenna. Precise pattern and impedance descriptions under such conditions are very elusive. The influence of these complications is usually not overwhelming, however, and practical antennas can be expected to approach the theoretical behavior deduced from ideal models.

matching transformer

As a vertical antenna is tilted away from the normal, the radiation resistance decreases from the theoretical value of 36.5 ohms computed for the perpendicular orientation. King's results for thin-wire, V-shaped antennas reveal that vertical tilts of 30 to 45 degrees yield radiation resistances of 29 to 21 ohms, respectively.[4] Although low-impedance coaxial cable (50-ohm class) can directly feed an antenna having a radiation resistance on the order of 25 ohms, a much better match is obtained by inserting a quarter-wavelength section of transmission line having an impedance equal to the geometric mean of the load and feedline impedances. This suggests a transformer impedance of about 36 ohms in the present application:

$$Z_T = \sqrt{Z_R \times Z_O} = \sqrt{25 \times 50} = 35.36 \text{ ohms}$$

Such a line is approximated by connecting two lengths of 75-ohm line in parallel as shown in **fig. 3.** The lines are an *electrical* quarter-wavelength long. Because the interior dielectric of conventional coaxial lines reduces the velocity of waves on the line, the *physical* length of the transformer section will be less than a quarter-wavelength in free space.

construction tips

Tilting the vertical radiator offers little complication of the detailed plans for building ground-plane antennas which abound in amateur periodicals and handbooks. Therefore, the following tips are simply offered to recall some well-known construction ideas using readily available parts.

table 1. Lengths of elements and matching transformers for tilted vertical ground-plane antennas where f is the frequency in MHz. Remember velocity factor, V, when computing the length of the coaxial quarter-wavelength transformer (0.66 for polyethylene cables, 0.79 for foam dielectric).

	dimensions	
component	high-frequency length (feet)	vhf length (inches)
central radiator	$\frac{235}{f}$	$\frac{2800}{f}$
ground radials	$\frac{240}{f}$	$\frac{2860}{f}$
quarter-wave coaxial transformer	$\frac{246\ V}{f}$	$\frac{2950\ V}{f}$

Fig. 4 shows the details of a mounting assembly suitable for 10-meter ground-plane antennas. The four ground radials are cut from 10-foot sections of half-inch aluminum conduit using the lengths given in **table 1.** The remaining threaded end of

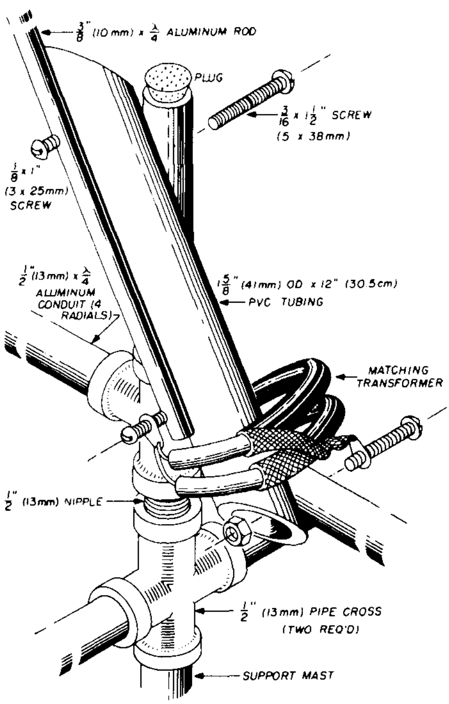


fig. 4. Isometric view of a partially assembled 10-meter ground-plane antenna. The whip and PVC tube are tilted with respect to the short upright section of conduit by an angle of approximately 30 degrees. While the antenna could be fed with a single-line of low-impedance coax, a better match is obtained by inserting a matching transformer constructed from two lengths of 75-ohm coax connected in parallel (see fig. 3). Table 1 lists the lengths of the tilted radiator and the ground-plane radials.

each radial is screwed into a half-inch pipe cross. A short upright section of conduit serves to anchor one end of the PVC water pipe used as an insulator for the center element. The opposite end of the PVC tube is fastened to one of the radials. As indicated in **fig. 4**, the PVC tube is cut at an angle to permit easy access to the nuts and washers securing the bolts which fasten the PVC tube to the mount and the whip to the PVC tube. The whip is formed from 3/8-inch aluminum rod. The rod, PVC tube and pipe fittings are stock items in most hardware stores. Aluminum conduit can be obtained from local electrical suppliers or contractors.

Lengths for the various elements and the matching transformer are listed in **table 1.** Exact whip and radial lengths for resonance depend upon the tilt angle and the relative element diameter with respect to the operating wavelength. The frequency response of these antennas is broad enough (3 percent bandwidth for vswr less than 1.5:1) that precise adjustment of the element lengths should not be necessary, however.

Since the pipe joints are painted with a metal primer to retard galvanic action, positive electrical contact is insured by installing wire straps near the threaded end of each radial. In the interest of clarity, these straps and the sheet metal screws which hold the straps in place are not shown in **fig. 4.** All electrical connections are sealed from the weather with silicon caulking compound.

The tilted vertical ground plane can also be used to advantage on the vhf links of OSCAR satellites. One of the simplest ways to construct these antennas is to use stiff wire or 1/8-inch welding rod for the elements and standard coaxial chassis receptacles (SO-239) for the base mounts. Lengths appropriate for vhf designs are also given in **table 1.**

observations

To some extent theoretical concepts and drawing board creations present an aura of make-believe. There is one central question at this stage that needs an answer. Does the modified ground plane deliver real performance during actual satellite passes?

The 10-meter downlink signals of numerous OSCAR 6 passes were monitored on a tilted vertical ground plane (35-degree tilt, height of 3/4 wavelength) and a half-wave dipole (height, 3/8 wavelength). Both antennas were well matched with vswr below 1.5:1 in the downlink passband. For elevation angles below 30 degrees, the modified ground plane was clearly superior.

Switching to the ground plane would often provide Q5 copy of signals that were only Q2 to Q3 on the dipole. This improvement is particularly significant since most of the operating time available for OSCAR satellites occurs for elevation angles below 30 degrees. The dipole came on strongly at elevation angles near 90 degrees. Although signals remained good on the ground plane, the results of these tests indicated that the signals on the dipole were stronger by roughly 4 dB when the satellite was directly overhead. The most consistent copy throughout any pass was always obtained on the ground plane.

Using the projected capabilities of AMSAT-OSCAR-B satellites, a few remarks are in order concerning applications for modified ground planes over the vhf links. Mechanical tracking schemes can be eliminated with these antennas if a transmitter power of approximately 200 watts is available on the 432-MHz uplink or 80 watts on the 145-MHz uplink. The additional gain from beam antennas will be useful for downlink reception in these two bands, but under optimum conditions signals should be copied with low-gain antennas such as dipoles and ground planes.

summary

This pretty well wraps up the case for adapting ground-plane antennas to satellite communications. Slightly tilting the vertical radiator yields a stationary antenna that is useful for any satellite pass. The modified ground plane is a simple way of getting the job done, but you don't have the extra performance of a tracking beam. You also don't have to pay for multi-elements, two rotators, tracking charts, a mini-computer or extra arms.

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ham radio

vertical antenna ground systems

How to design practical, efficient radial ground systems for vertical antennas

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This is the third article of a series about vertical antennas. The objective is to learn about the characteristics of such antennas so that you can intelligently select an antenna height for your own station. The first article[1] showed that for a short antenna (h = 0.1λ), bandwidth was small (50 kHz at 3.8 MHz), and matching-network coil losses were high (about 100 watts). The second article[2] showed that the radiation pattern is affected very little by height (in the range from h = 0.1 to 0.25λ).

In this article I will show the effects of earth losses and the radial system upon the ability of a vertical antenna to radiate efficiently. The radial system consists of a number of radials, of a certain length, using a given wire size, and buried in earth having a finite conductivity. The radiating efficiency of the antenna depends upon the radial system, earth conductivity and antenna height.

ground systems

My analysis of earth losses and the effectiveness of radial systems uses two approaches, one using a theoretical model for earth losses, and one using actual experimental data. The experimental results give field strength at 3 MHz at one mile from the antenna for various radial conditions. While the theoretical model does not allow calculation of exact values of earth losses in watts, it does provide insight into important situations not covered by experimental data, such as losses for poor earth and the distribution of earth losses near the antenna for various conditions.

Both of these methods are from Brown's 1937 article,[3] and they are applied to the amateur situation used in my previous articles for a 30- to 60-foot (9.1- to 18.3-meter) vertical antenna at 3.8 MHz. The results, however, are given in terms of antenna electrical height and radial electrical length to allow you to design vertical antennas and radial systems for other amateur bands as well.

Since an antenna and a radial system form a closed electrical circuit, there are return currents flowing in the radial wires and in the earth itself near the antenna. Since there are so many variables involved I wrote a computer program to calculate these currents for a variety of factors, listed in **table 1.** For each antenna height the correct antenna base resistance and matching-coil rf resistance was included. This was done for a transmitter power of 600 watts output at 3.8 MHz.

The 600 watts is divided between radiated power from the antenna, and losses in the earth, matching coil and radial wires. Ideally, of course, we would like the *radiated* power to be 600 watts and the losses to be zero. Interestingly enough, there *are* combinations when this *almost* happens.

To simplify the analysis I tried to eliminate unimportant factors, and the most likely one was wire size. My analysis showed that wire size is important only when a few radials (eight or less) are used, when the antenna is short (less than 0.15λ), and for poor earth (σ = .00002 mhos/cm^3). For this case, going from number-18 wire (1-mm diameter) to number-8 wire (3.3-mm diameter) will increase the radiated power up to as much as 125%. However, by using 15 or more radials, wire size becomes relatively unimportant and the improvement then, by going from number-18 to number-8, never exceeds 8%. On this basis I eliminated wire size as a factor in the remaining analysis.

The power lost in the radials is insignificant. Wire conductivity is so huge compared to earth conductivity that you can use copper or iron wire. Number-18 iron electric fence wire (1-mm diameter) costs only $7.10 for 2640 feet, but number-16 copper wire (1.3-mm diameter) would be better for a permanent installation as it would not corrode and disintegrate as quickly as iron wire.

radial system design

To design the radial system you need to know how many radials to use and how long they should be. A look at how the radial currents drop off as you go further from the antenna provides the necessary information. This is illustrated in **fig. 1**, which shows radial current (I_W amperes) versus distance from the antenna in fractions of a wavelength (x/λ), and also versus the number of radials for both poor and good earth. When the radial current drops to a low value the radials are no longer effective. At this distance from the antenna base most of the current has already entered the earth, and longer radials are unnecessary.

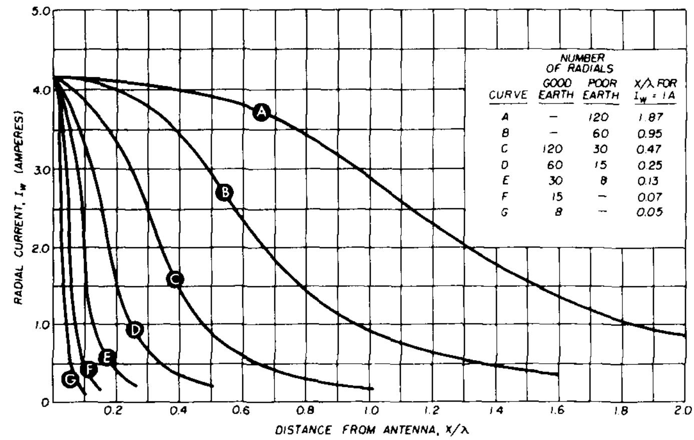

fig. 1. Radial current vs distance from antenna for different numbers of radials in poor and good earth.

You can see from **fig. 1** that long radials should be used with a large number of radials, and vice versa. Therefore, this situation for vertical antenna radiation is somewhat different from that of obtaining a low ground resistance where you can trade-off number of radials for length of radials. The proper radial length depends upon the number used, local earth conductivity, how low you want the radial current to be at the end of the radials, and how much real estate you can use. These results are summarized in **table 2** for a radial current at the ends of the radial wires of 1 ampere.

Table 2 shows that, if you have poor earth, the radials should be two to four times longer than for conditions of good earth. There is, of course, no harm in using longer radials, and you can use **fig. 1** as a guide for your own location.

There are several criteria for deciding how long radials should be. The one used in **table 2** is for radial current, I_W, to drop to 1 ampere. Other criteria are given later in the discussion about **figs. 2** and **3**.

The question of how deep to bury radials often comes up. Here the earth losses are calculated down to the skin depth, which at 3.8 MHz is several feet (about 1 meter). Both the theoretical model and the experimental data show that it doesn't matter if the radials are buried a few inches. This is better than tripping over a maze of wires strung out on top of the ground (your wife will be happier, too).

I next calculated earth losses for various radial conditions, for both poor and good earth. The losses are in watts/meter of distance, down to the skin depth, at various distances from the antenna base, and are shown in **fig. 2**. Study of this figure shows:

table 2. Radial length to reduce radial current to 1 ampere (assuming 600 watts at 3.8 MHz).

number of radials	distance from antenna, poor earth (wavelength)	distance from antenna, good earth (wavelength)
8	0.13	0.05
15	0.25	0.07
30	0.47	0.13
60	0.95	0.25
120	1.87	0.47

1. Maximum values for earth losses are high when only a few radials are used.

2. When only a few radials are used the losses peak close to the antenna base (within 0.1λ for eight radials).

table 1. System design factors considered for calculating return currents for a vertical antenna and radial ground system.

Antenna heights, feet	30, 40, 50, 60 (9.1, 12.2, 15.2, 18.3 meters)
Number of radials	8, 15, 30, 60, 120
Radial wire size	no. 8, no. 18
Radial lengths	0.05 to 2.0 wavelength
Earth conductivity	0.00002 mhos/cm^3 (poor earth)
	0.0004 mhos/cm^3 (good earth)

3. The total amount of power lost in the earth is related to the area under each curve. It shows that, for the same number of radials and antenna height, considerably greater earth losses occur in poor earth than in good earth.

4. Higher values of losses occur closer to the antenna base for good earth as compared to poor earth, other conditions being the same.

5. When many radials are used the losses are not greatly different for 30- or 60-foot (9.1- or 18.3-meter) antennas. When only eight radials are used, then losses are greatly reduced by using a 60-foot (18.3-meter) antenna instead of a 30-foot (9.1-meter) one.

Coil losses were similar to those given in the previous article.[1] These losses, and some other previous data, are summarized in **table 3**. The coil losses are somewhat less when earth losses are considered than they were when earth losses were not considered. Part of the 600-watt transmitter output power now contributes to earth losses, so that coil losses and radiated power are lower than they would be otherwise.

Some of the experimental results from reference 3 that apply to our situation are shown in **fig. 3**. This shows radiated power as indicated by field strength, E, at ground level at one mile in millivolts/-meter, versus number and length of radials and antenna height. These results appear to be for conditions of good earth conductivity, where coil losses were not included. Comparison curves for the theoretical maximum possible values for E are included, and these were probably derived from measurements of antenna base current. A study of **fig. 3** reveals several interesting facts:

1. When using a 30-foot (9.1-meter) antenna and two radials 0.137λ long, the distant field strength is only about 50% of theoretical maximum. This is for good earth and does not take coil losses into account. They will be considered later.

2. Using a 60-foot (18.3-meter) antenna and 113 radials, 0.41λ long, gives results nearly as good as the theoretical maximum.

3. When only two radials are used they need be only 0.1λ long.

4. When 15 to 30 radials are used with a 30-foot (9.1-meter) antenna 0.274λ is long enough for the radials.

5. Other situations may be deduced from **fig. 3**, and from methods of design discussed later.

local earth conditions

We need to define what poor and good earth is. I have used a conductivity of σ = .00002 mhos/cm^3 for poor earth, and σ = .0004 mhos/cm^3 for good earth. You should be curious by now to know what the conductivity is for your local area. This can be found in Jordan,[4] page 638, or in reference 5.

It is beyond the scope of this article to relate radiated power to the field strength at radiation angles above the horizontal. My recent article[2] gave the pattern for radiation angles of DX interest for the case of no ground losses. When *ground* losses are considered, as must be done in the *real* case, the low-angle radiation will depend on the earth conductivity. See Jordan,[4] page 641, for more information on this. Hovever, whatever the earth conductivity, the less your losses are by use of a good radial system, the more power you will radiate.

choosing antenna height

Now we should go back and think about our original objective: Choosing an antenna height. The yardsticks that should influence the decision are first,

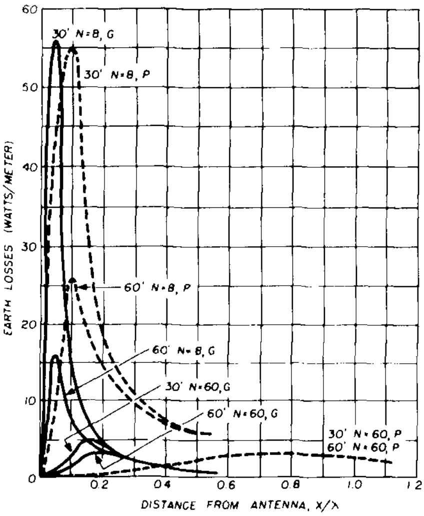

fig. 2. Earth losses vs distance from antenna for different numbers of radials in poor (P) and good (G) earth, 30- and 60-foot vertical antennas.

performance, and next, cost and size of the antenna and radial system, These, in turn, will depend, as we have seen, on the number of radials used, the length of the radials, and the local earth conductivity. Most of the results have been summarized in **table 3.** Earth losses and radial systems were not included in **table 3** because there are so many possible combinations. However, I'll work out some examples which will show you how to design for your own situation.

example 1. Antenna height, HA = 60 feet (18.3 meters) good earth, number of radials, n = 113, radial length, φ = 0.41λ. **Fig. 3** shows that the distant field strength, E, is about 99% of theoretical. In all of these examples you can relate E to the radiated power, P, since E is proportional to $\sqrt{P}$. Therefore:

$$\frac{E}{E_{TH}} = \sqrt{\frac{P}{600}}$$

Where E_{TH} is the theoretical maximum, or 100%. In this case,

$$\frac{E}{E_{TH}} = \frac{99\%}{100\%} = 0.99 = \sqrt{\frac{P}{600}}$$

so P = 594 watts. Since coil losses are not yet included, the earth losses are 600 − P = 600 − 594 = 6 watts, and are low due to the good radial system. Total losses = coil losses + earth losses = 1 + 6 = 7 watts. The field strength, E, using this total loss is still about 99% of theoretical.

example 2. Antenna height, HA = 30 feet (9.1 meters), poor earth, n = 60, φ = 0.25λ. **Fig. 3** is for good earth only. **Fig. 1** provides information on how to relate poor and good earth radial systems. To get the same results in poor earth that you would in good earth you should make the radials from 2 to 4 times longer for the poor earth case. If you limit the length as we have in this example, then the results will be inferior for the poor earth case. Refer to **fig. 1.**

For 60 radials and x/λ of 0.25, for poor earth (curve B), I_W = 3.95 amps (which also indicates a poor radial system). For this same value of radial current, I_W, and for good earth (curve D), x/λ = 0.1. Therefore, use x/λ = 0.1 in **fig. 3** which shows that E, before coil losses, is 70% of maximum. The corresponding earth loss, calculated as in **example 1,** is 306 watts. Therefore, the total loss is earth loss plus coil loss, or 306 plus 80 watts, for a total of 386 watts. The resulting field strength, E, is 60% of maximum.

An example that you can practice on is to verify that E is only 22% of maximum for a 30-foot (9.1-meter) antenna, with two radials, each 0.1λ long in good earth.

As a final example, consider the difference in performance for two antenna heights for the same radial system and for good earth. Use n = 30, x/λ = 0.25, good earth, and for a 30- and 60-foot (9.1- and 18.3-meter) antenna. **Fig. 3** shows that before coil losses, an E of 82% for the 30-foot (9.1-meter) antenna, and an E of 84% for the 60-foot (18.3-meter) anten-

table 3. Vertical antenna coil losses and bandwidths for various antenna heights. Earth and radial losses are not included because of the many possible variations.

antenna height (feet)	antenna height (wavelength)[1]	coil losses (watts) good earth	coil losses (watts) poor earth	bandwidth (kHz)[2]
30 (9.1 m)	0.12	120	80	50
40 (12.2m)	0.16	45	35	100
50 (15.2m)	0.20	20	12	180
60 (18.3m)	0.24	1	1	320

1. Electrical height at 3.8 MHz.
2. No earth losses and 3.8-MHz matching network.

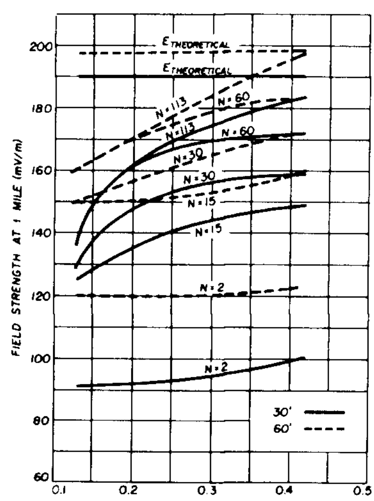

fig. 3. Experimental data from reference 3 showing field strength at one mile vs length of radials at 3 MHz for 30- and 60-foot antennas. This data assumes good earth and no coil losses.

na. When coil losses are included, the E for the 30-foot (9.1-meter) antenna is 68% of maximum, and the E for a 60-foot (18.3-meter) antenna is still 84% of maximum. Results for a 40- or 50-foot (12.2- or 15.2-meter) antenna fall between these.

conclusion

It is obvious that there is no simple answer to the question of what height antenna and what radial system to use. I began all of this work not knowing exactly what to expect. I had expected that short antennas (say 0.1λ high) would have shown up better than they have. It appears to me that a vertical antenna 0.2λ to 0.25λ high offers some significant advantages over one 0.1λ high: Essentially no coil losses, reasonable bandwidth (200 to 300 kHz at 3.8 MHz) and distant field strengths of 85% to 95% of theoretical with a reasonable radial system. There does not appear to be any advantage in going to a height of over 0.25λ for use at DX sky-wave radiation angles and, in fact, there may be some disadvantages when you consider the radiation pattern (see reference 2).

An important lesson from these studies is that earth conductivity is a very important factor, so that for poor earth long radials should be used. We have also seen that wire size is not generally important, and that it is permissable to bury the radials.

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measurement techniques

for antennas and transmission lines

How to use homebrew test equipment to measure impedance and resonance characteristics of antennas and transmission lines

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Two basic instruments for the measurement of antenna and transmission line parameters that can be profitably used by the radio amateur are the radio-frequency impedance bridge and the spectrum analyzer. The radio-frequency impedance bridge is a most useful and informative piece of equipment with which both resistive and reactive components of impedance can be determined as separate values. The spectrum analyzer will display the resonant frequency of an antenna or a section of transmission line.

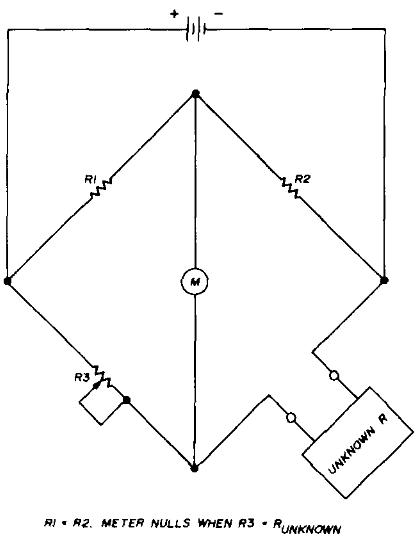
the rf impedance bridge

The standard circuit for a bridge is shown in **fig. 1A**. In this form, only resistive measurements can be made. But this bridge, while not useful for rf measurements, illustrates the basic bridge principle. Note that the excitation voltage is injected into two opposite arms of the bridge. When the bridge is balanced (R3 = $R_{unknown}$), there will be no voltage across the detector.

The bridge circuit shown in **fig. 1B** is equipped with provisions for ac excitation and the arms are arranged so that the resistive component is indicated separately from the reactive component. An excellent design for use on the amateur high-frequency bands was described in a recent issue of *QST.*[1] For use in the radio-frequency spectrum, the source generator may be any signal generator having a frequency range that meets the required range. The detector can be any frequency-selective voltmeter such as a radio receiver's S-meter. When the bridge is balanced the voltage at the detector arms will then approach zero and a null will be detected. At this point the readings of the two variable arms will be representative of the unknown's internal impedance. Practical uses for this instrument include, but are not limited to, measurements of antenna impedance, tuned-circuit impedance, matching-transformer impedance, as well as the characteristic impedance of a transmission line.

If the signal generator and detector are set to 7.00 MHz and the X dial indicates 210 when the bridge is balanced, the actual reactive ohms will be (210/7.00) = 30 ohms. Since the resistive dial is not frequency selective, the resistance dial indicator will not require such conversion.

If the indicated reactive component is inductive the result is written +j30. Con-



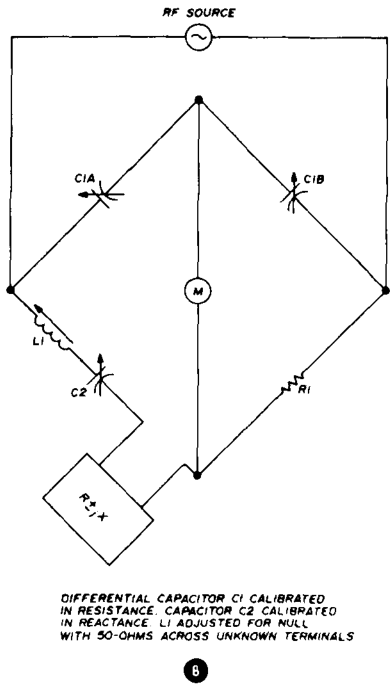


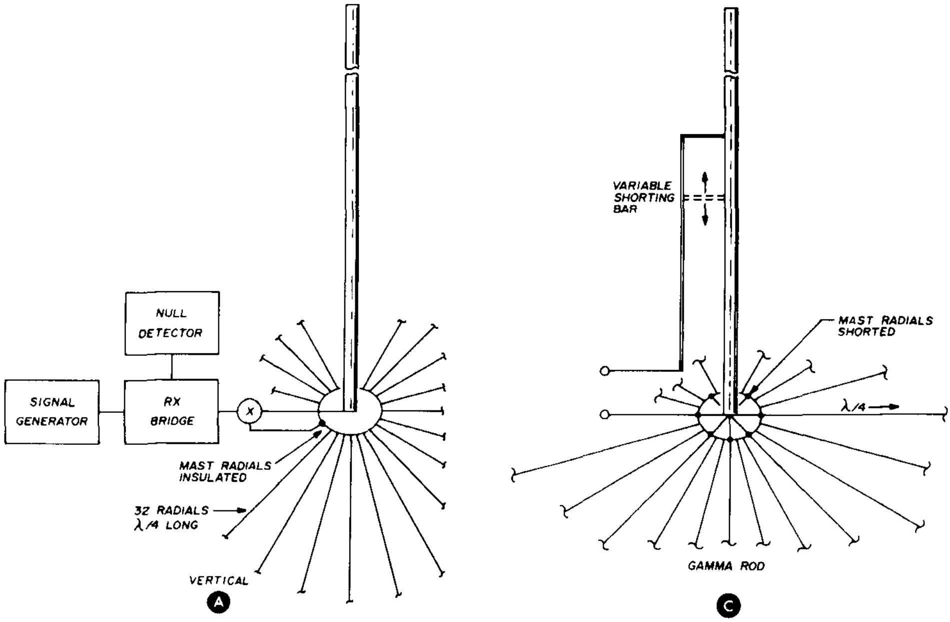
fig. 1. Basic balanced resistance bridge shown in (A) is not suitable for rf measurements. The RX impedance bridge shown in (B) indicates the resistive and reactive components of a complex impedance.

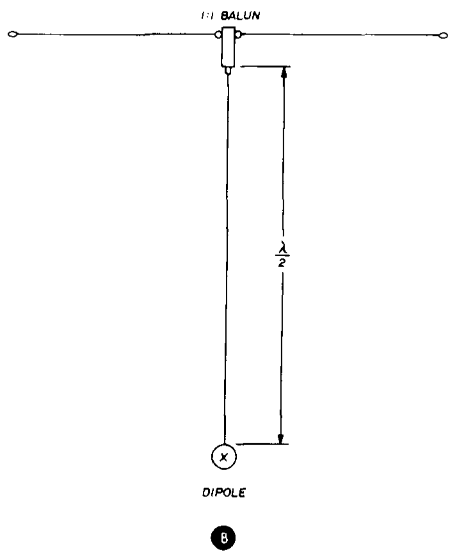
Setting up the instrument for measurement of an unbalanced system such as a vertical radiator is shown in **fig. 2.** Since most bridges are asymmetrical (unbalanced) instruments, they lend themselves to such measurement with ease. Readings on the X (reactance) dial must always be related to the frequency of calibration. For example, if the bridge was calibrated at 1 MHz, all indicated readings of the X dial must be divided by the frequency of measurement expressed in megahertz. An example will serve to clear up this point:

versely, if the reactive component is capacitive the result is written −j30. The physical representation of these values can be shown on rectangular coordinate graph paper (the +j30 value is plotted as 30 units *above* the zero axis (horizontal)— a −j30 value is plotted at 30 units *below* the zero axis. The resistive readings will be plotted to the right of the vertical axis in resistive units, as shown in **fig. 3.** An excellent article on the use of graphic solutions to impedance-matching problems may be found in reference 2.

balanced impedance measurements

The impedance of a dipole can be measured quite accurately by placing a 1:1 balun between the bridge and the





symmetrical radiator. This device converts the balanced impedance of the dipole to an unbalanced condition for measurement by the asymmetrical rf impedance bridge. The impedance can even be measured remotely, with good accuracy, by the use of an electrical half-wavelength transmission line (or multiple) and a balun, since the impedance seen at

fig. 2. Using the RX bridge for impedance measurement of a vertical antenna (A), dipole antenna (B) and gamma-rod matching section (C).

the far end of a half-wavelength line is the same as that seen at the near end.

Odd wavelengths of line can also be used for remote impedance measurement, but the use of a device such as a Smith chart will be required to properly rotate an impedance value measured the correct number of electrical degrees, to obtain meaningful data. While this is a useful and practical method, the use of the Smith chart will not be covered in this article since several practical articles on its principles and use have appeared in recent amateur magazines.[3,4] How to measure electrical length of a transmission line will be covered in a later paragraph.

using the rf bridge

In practice, the use of the rf impedance bridge is quite simple. When connected to an unknown impedance as shown in **fig. 4**, The frequency of the signal generator is set to the desired frequency. The frequency of the detector is set to produce maximum indication of signal input. A "standard" is placed across the unknown terminals (in some rf bridges the terminals are shorted). When balanced, the bridge is ready for measurement of the unknown impedance. If the detector has no visual indicator (such as an S-meter), a pair of headphones can be effectively used to detect the null when the bridge arms are in balance. A little practice with this method can produce greater accuracy than a visual indicator, because the human ear can detect a deepter null than can a visual indicator.

When measuring the impedance of a tuned circuit, the bridge will indicate the correct operating parameters only if its normal voltages and current are present under certain circumstances. In many cases this power could damage the mea-

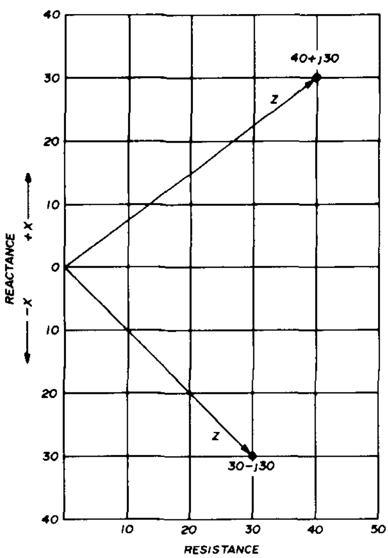


fig. 3. Plotting complex impedance values.

suring instruments so static substitution of such dynamic parameters must be made. One practical method is to substitute a resistor of the proper value for the dynamic value of resistance. First, determine the required resistance value by dividing the required operating voltage by the current, and put that value of resistance across the circuit to be measured

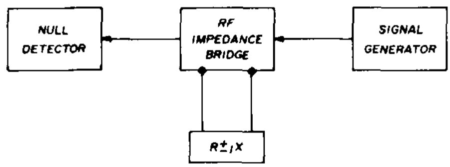


fig. 4. Typical rf impedance bridge setup.

without operating voltages and current. For example, assume you want to measure the input circuitry of a grounded-grid linear amplifier with a bifilar-wound filament-grid isolation choke plus tube and stray capacitances. From available data it may be determined that 400 mA of total dc filament current is required at 100 volts. Therefore, a 250-ohm resistor (100 volts/400 mA - 250 ohms) from filament to ground will simulate the dynamic desired operating condition and the bridge will indicate the proper load impedance shown by such circuitry (see **fig. 5**). Similar dynamic substitution can be made to the output circuit for proper plate-load design.

spectrum analysis

To some readers this may sound like a very sophisticated term. It is really very simple when its operation and technique is explained in basic terms. The equipment setup shown in **fig. 6** is capable of spectrum analysis, although I prefer to call it the *sweep-null* technique as applied to the relationship of frequency vs electrical length measurement. It has many other applications, but for the purposes of this article I will stick to this basic use.

The sweep-frequency generator is simply an fm signal generator that is swept through a predetermined range of frequencies. Suppose a sweep of 4 to 5 MHz is desired. The sweep range is set to about 1 MHz and the center frequency is set to 4.5 MHz. This signal is then applied to the unknown through a detector and a sample of the resultant is brought out to an oscilloscope for analysis. If the unknown impedance is frequency sensitive it will change impedance at various frequencies and thus load the detector accordingly. This will be evident as a varying voltage on the scope trace. To determine the exact frequency at which some parameter of the unknown impedance has a low or high value, a frequency marker which will appear on the scope trace at the appropriate point is injected into the detector.

If the unknown is a pure resistance, the horizontal trace of the scope will be a straight line with a vertical beat note pattern appearing on the trace which is

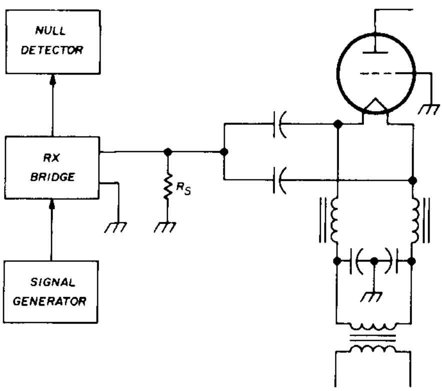


fig. 5. Method of substituting resistor Rs for dynamic resistance at the input of a grounded-grid cathode circuit.

dependent upon the frequency of the marker generator. However, if the load is a complex impedance somewhere within the sweep-frequency range, at this point the load will be frequency sensitive and will have a lower or higher ratio of voltage current. When this occurs, there will be a null or hump in the horizontal scope trace. If a wide frequency range is swept, there may be several repetitive nulls and humps in the trace which will coincide with lower or higher impedance points. If you want to determine the exact frequency of a hump or null, the marker is adjusted until the vertical mark is symmetrically centered.

By increasing the gain of the horizon-

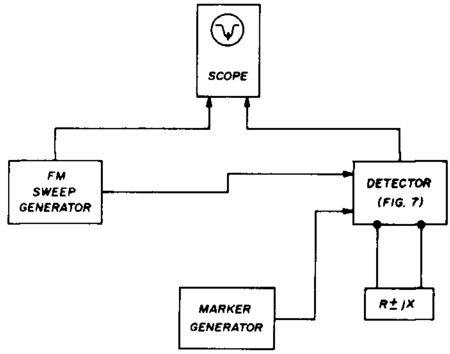


fig. 6. Sweep-null method of measuring resonance of complex loads.

tal and vertical scope amplifiers, a W-shaped trace for a null (or an M for a hump) similar to that shown in **fig. 8** will be formed and further symmetry can be achieved. The use of a horizontal graticule is often useful in judging symmetry. When the marker frequency is read it can be converted to electrical length by the use of standard formulas for propagation velocities in the various types of transmission line.

To illustrate a specific use of the sweep-null technique refer to **fig. 9.** This is a typical amateur setup using readily available equipment to solve a very practical problem: The measurement of a quarter- or half-wavelength (or multiple) of coaxial line.

To digress a moment, coaxial cable using solid polyethelene dielectric has a velocity constant of approximately 0.66. This means that this cable will propagate a signal at approximately two-thirds the

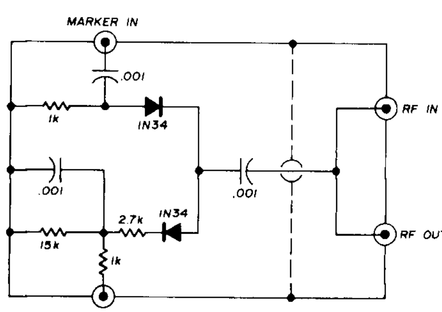


fig. 7. Circuit for the sweep-null detector used in the setup shown in fig. 6.

velocity that a signal will be propagated in free space. Another way of saying this is that it will take the same time for an rf signal to traverse 66-feet (20.1-meters) of that cable as would be required for the same signal to propagate 100-feet (30.5-meters) in free space. Foamed polyethelene dielectric has a velocity constant of about 0.80 so it will take about 80 feet (24.4 meters) of this cable to be electrically equal to 66-feet (20.1-meters) of solid dielectric polyethelene cable. The

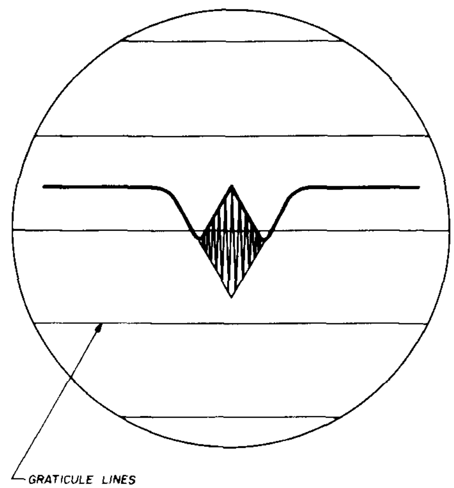


fig. 8. Oscilloscope pattern showing the W-shaped null pattern. Marker generator may be used to accurately determine the null frequency.

relationship between wavelength in free space and frequency in megahertz is given by:

$$\text{wavelength (feet)} = \frac{980}{f_{MHz}}$$

$$\text{wavelength (meters)} = \frac{300}{f_{MHz}}$$

Returning to the instrumentation shown in **fig. 9**, a 66-foot (20.1-meter) length of solid-dielectric coaxial cable, shorted at the far end, is connected to the detector. When swept over the frequency range from 3 to over 10 MHz, a null will be seen at 4.90 MHz (length = ½ wavelength). A hump will also appear at 7.35 MHz (3/4 wavelength) and another null at 9.80 MHz marks the full-wavelength

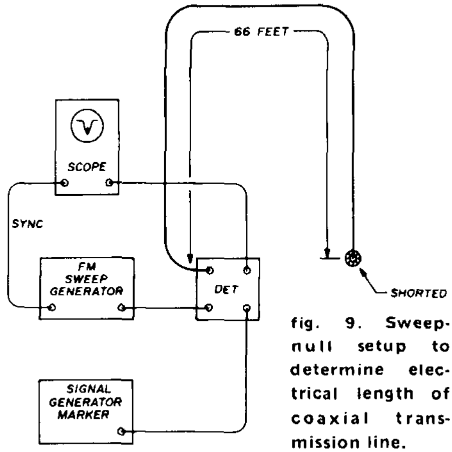


fig. 9. Sweep-null setup to determine electrical length of coaxial transmission line.

point. A practical note: The peaks on the scope trace are much less sharply defined than the nulls, since the *ratio* of change of voltage to current is more sharply defined at the low-impedance points (half-wavelength points). In practice this means that more accurate frequency determination can be made at the nulls than at the peaks.

As can be seen in **fig. 10** the detector's inner conductor is connected to the

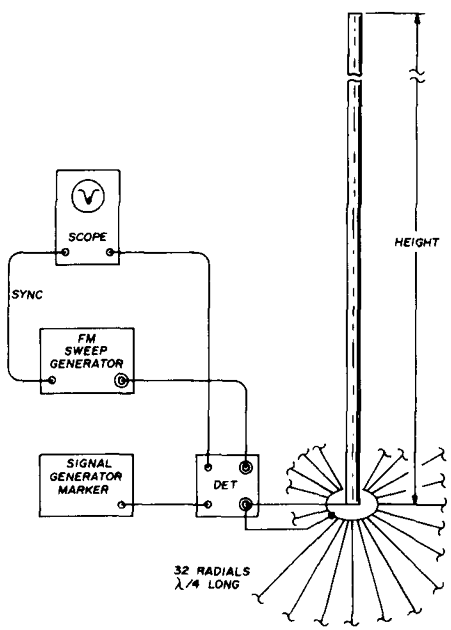


fig. 10. Sweep-null setup to determine electrical height of vertical radiators.

bottom of the vertical radiator (insulated from ground for this measurement) and the outer conductor is connected to the ground plane (*not* ground). As the sweep frequency goes through the quarter-wavelength resonant frequency of the vertical, the impedance will decrease to a minimum, indicating a null in the horizontal scope trace. When the frequency marker is accurately centered in the null as shown in **fig. 8** the quarter-wave resonant frequency is indicated.

The height of a quarter-wavelength vertical antenna operating against a good ground is given by

$$\text{height (feet)} = \frac{234}{f_{MHz}}$$

$$\text{height (meters)} = \frac{71.6}{f_{MHz}}$$

Vertical antennas made of small diameter materials will have a 1:1 relationship of physical length to electrical height when compared to this formula, but thick vertical elements, such as a metal pole one-inch (2.54 cm) or more in diameter will show a slightly higher (by a few percent) electrical height for a given physical length. When a capacitive top hat or a Yagi or quad beam is mounted on top of the vertical, the electrical height will be increased considerably.

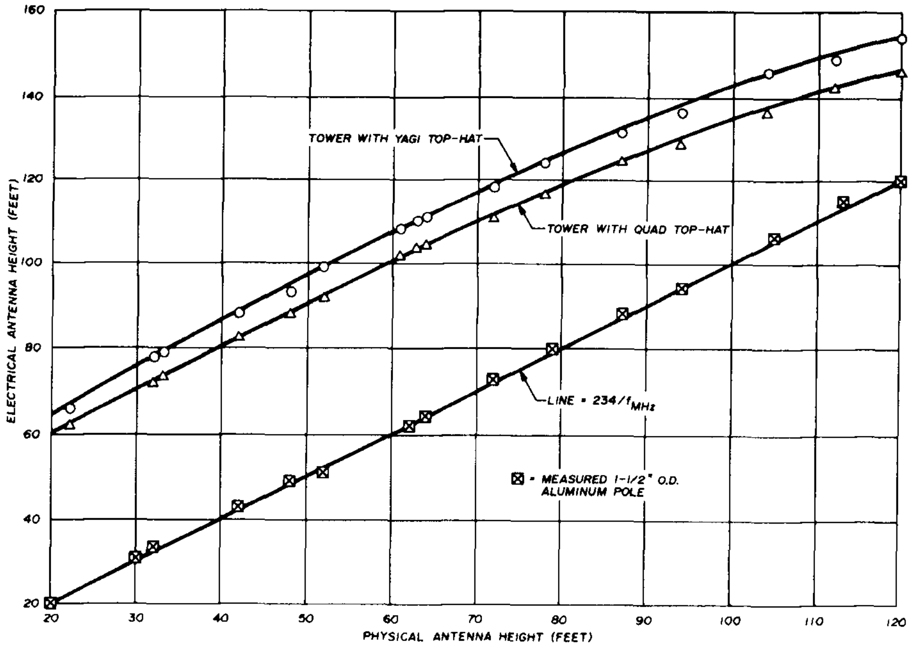


fig. 11. Physical vertical antenna height versus electrical height. Capacitive top-hat loading, as provided by a Yagi or quad, increases electrical height considerably.

The curves plotted in **fig. 11** show that a 1½-inch (3.8-cm) diameter metal pole is electrically slightly longer than a thin wire of the same length. This chart also shows the lengthening effect that Yagi and quad beams have on the electrical height of towers.

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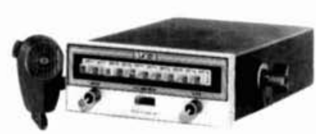

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More Details? CHECK–OFF Page 110

three-band vertical DX antenna

Here's the result of some scrap materials and amateur ingenuity — a low-angle radiator for 40, 20 and 15 meters

Frank Lallak, W9BQE, 4061 North Drive, Fort Wayne, Indiana 46805

DX can be worked without a beam antenna. I've used a vertical antenna for the past seventeen years. Although I don't operate as many hours as most DXers, nevertheless I've worked my share of DX stations. The antenna described here is the result of some experimentation over the years. It will give a good account of itself.

Years ago I purchased parts for a 20-meter Yagi. Before I obtained the appropriate tower, TV became popular, and my neighbors decided they would rather view sub-fringe TV stations than the black-and-white interference bars caused by my rig. Scratch one Yagi antenna.

early attempts

My first vertical consisted of a 34-foot (10.4 meter) length of 3-inch (7.6-cm) diameter aluminum tubing, which was made from the boom for my Yagi. This arrangement blew down, but the only damage was a slight bend to the tubing. The next attempt was a supporting member for the tubing consisting of a 4 x 4-inch (10.2 x 10.2-cm) post, but unfortunately the post had a large knot at ground level. The 4 x 4 was replaced with two 2 x 6-inch (5.1 x 15.2-cm) wood members bolted together. I attached the aluminum tubing to the wooden mast and added a 13-foot (4.0-meter) length of

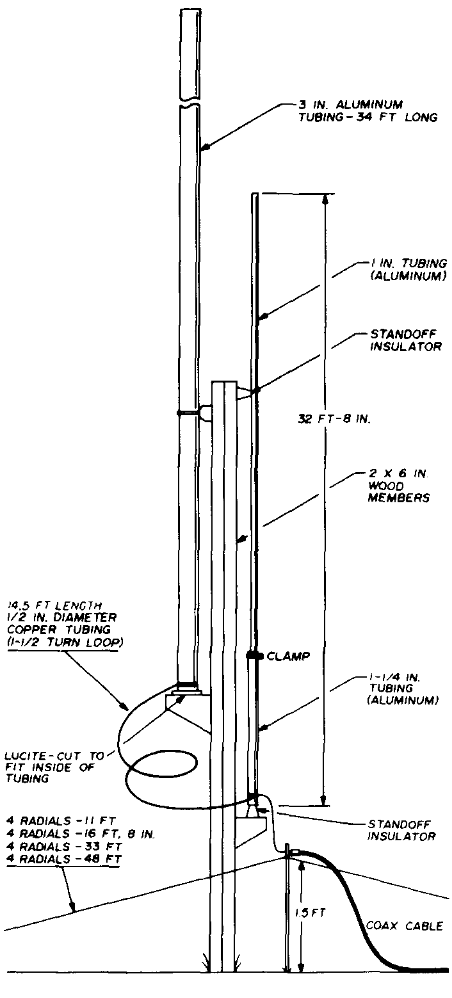

fig. 1. The three-band DX vertical. Additional radials will improve performance; the more radials, the better.

½-inch (13-mm) diameter copper tubing, formed into a 1½-turn loop at the bottom end, which was about six feet (1.8 meters) above ground. Two 32-foot (9.8 meter) radials completed the system. The copper tubing extended the antenna length to 3/4 wavelength on 20 meters, which produces a low vertical radiation angle.

This antenna worked fine on 20. To work the 40-meter band, I made a clamp and a double coax fitting, which I fastened at the 32-foot point on the 3-inch (7.6 cm) aluminum tubing. To change bands, I simply changed the coax cable from the 20-meter to the 40-meter spot on the tubing and connected the radials to the other side of the coax fitting. This arrangement produced a 1:1 swr on 40 meters; however, I wasn't able to work anything on 20 meters until I changed the coax to the 20-meter point. I used this two-band combination for several years but finally became tired of changing the coax on cold winter nights.

final design

The two-element vertical antenna I am now using is shown in **fig. 1.** The antenna on the right-hand side of the wooden mast consists of two pieces of tubing that were originally intended for elements on a Yagi antenna. The top section, of 1-inch 25.4 mm) aluminum tubing, telescopes into the bottom section, which is 1¼-inch (37.5 mm) tubing. Both sections are held together with a clamp. The bottom portion of the 20-meter antenna, which is the 1½-turn loop of copper tubing, is connected to the bottom end of the tubing on the other side of the mast. Radial wires, as shown in the figure, should be used for best results.

performance

The swr on 40 meters is 1.1:1. On 20, it is 1.1:1, and on 15 it is 1.25:1. I tried the antenna on 80 meters this last winter, but the swr was extremely high on the low end of the band. On the phone portion of 80, the swr is 3:1. I have had good reports, coast-to-coast, on 80 but haven't worked any DX. On the higher-frequency bands, the antenna has performed well. I've used the antenna for two years and am pleased with the results.

ham radio

160-meter loop
for receiving

Construction of a simple 160-meter loop antenna for receiving that reduces noise and strong-signal interference

Charles G. Bird, K6HTM, 875 Lindo Lane, Chico, California 95926

Reception on 160 meters can be greatly improved by using a loop antenna. Its primary virtue, reducing noise pick-up, is due to its small relative size and directional characteristics when properly located. A loop antenna is easy to build and doesn't have to be nearly as complicated as some loops that have been described.[1]

construction

A two-turn loop, 23 inches (58.4 cm) in diameter was fashioned out of a length of semi-flexible aluminum-sheathed coaxial cable. Braided cable would have been fine. The vinyl jacket acts as a dielectric, and the two turns are securely taped, the ends being brought close together and bridged with sufficient capacitance to resonate at 1.835 MHz. The center conductor is ignored. A voltage divider across the ends permits coupling to a low-impedance transmission line.

The 23-inch (58.4 cm) dimension resulted from a random length of cable and was used as a starting point. To obtain a rough idea of the inductance of this loop I used the following formula:

$$L = \frac{R^2\ N^2}{9R + 10S}$$

Where L is the inductance of the coil in microhenries, R is the radius of the coil in inches, S is the length of the coil in inches and N is the number of turns. For the two-turn, 23-inch loop I built out of coax,

$$L = \frac{(11.5)^2\ (2)^2}{(9 \times 11.5) + (10.1)} = \frac{529}{113.6} = 4.66 \mu H$$

Although this value may not be particularly accurate, it is quite helpful in determining an experimental value of capacitance at C1 to resonate the loop to 1.835 MHz. From the resonance table in he *Radio Amateur's Handbook*[2] this works out to be about 1600 pF.

By adjusting capacitor C1 it is possible to peak the response over a narrow portion of the 160-meter band. Tuning your receiver across the noise hump provides the surest indication of the resonance point. In **fig. 1** the resonating capacitance includes the parallel capacitance of the input voltage divider. Using the equivalent parallel capacitance as a basis (approximately 1424 pF), the actual inductance of the loop, at 5.28 μH, is slightly higher than that given by the formula.

At 1.835 MHz a 1735-pF capacitor exhibits 50-ohms reactance. I used the closest value I had available, 1670 ohms. A 100-pF capacitor provided satisfactory coupling for the 50-ohm transmission line.

performance

Compared to receiving on a half-wave dipole, the loop is like turning on a light. Both the noise and strong signals are reduced by 20-dB or more, but more important, unreadable signals become clearly readable. This result was enough. The directional characteristics which were noted at the test bench disappeared when

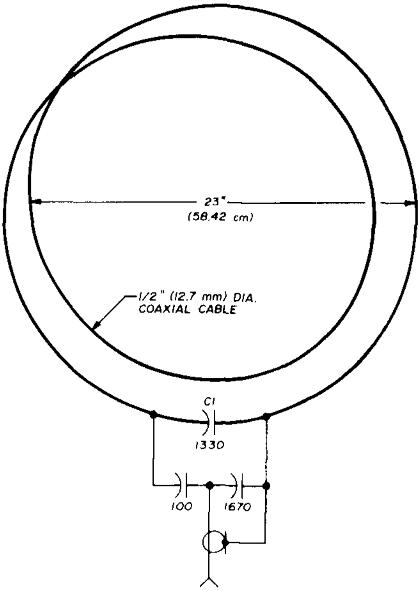

fig. 1. Simple 160-meter loop antenna for receiving.

the loop was suspended from the boom of a quad at eighty feet (24.4 meters). Those operators who are bothered by noise from a specific location or QRM from a certain direction would do better to mount the loop away from any reflecting objects and rotate it accordingly.

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ham radio

the truth about 5/8-wavelength vertical antennas

This practical discussion of 5/8-wavelength vertical antennas adds perspective to the varied gain claims seen in the amateur magazines

Paul Meyer, KØDOK, 9921 Crestwick Drive, St. Louis, Missouri 63128

The recent growth in popularity of the 5/8-wavelength vertical radiator, particularly for use at vhf, has given rise to many varied claims as to its performance. Several local amateurs have been unable to detect improved performance after changing from quarter-wave to 5/8-wavelength antennas. Because of my vocation as an antenna engineer, I was prevailed upon to examine the problem. A theoretical analysis was considered and several actual measurements were performed.

theory

A monopole antenna mounted on a ground plane may be considered equivalent to a free-space vertical dipole having each dipole arm equal to the length of the monopole. The lower arm of the dipole corresponds to the image of the monopole reflected in the ground plane. Equivalent radiation patterns may be expected as shown in **fig. 1**. A ground plane of infinite size is assumed.

Actually, with any finite ground plane size and where the field strength is measured at a point some distance beyond the edge of the ground plane, the pattern is altered considerably by reflection from the discontinuity at the edge of the ground plane. The resulting pattern has multiple lobes caused by phase interference of the direct and edge reflected waves. **Fig. 2** shows the results of an actual measurement made with a large but finitely-sized ground plane. Notice that the signal maximum is at an angle considerably above the horizon where it is not useful for ground-wave communications.

If an infinite ground plane is assumed and the monopole is analyzed as its equivalent dipole, we must formulate a mathematical expression for the field strength as a function of angle from the antenna. This angle, commonly called θ, is measured from the zenith (straight up) and equals 90 degrees at the horizon. The field strength at any θ angle may be calculated by summing the radiation from an infinite number of short current elements spaced evenly along the length of the dipole. This type of summation is performed mathematically by a calculus technique known as integration.

Phase must be considered in this summation since the radiation from some current elements may cancel that from others by being out of phase. The amplitude of the currents in the short elements are not equal but each is a function of its position along the antenna. A very close approximation is to assume the current to be sinusoidal starting from zero at the top end because the end is an open circuit and no current can exist there.[1]

Assuming a sinusoidal current distribution along the dipole and performing the mathematical integration yields the formula for field strength of a dipole:[2]

$$E = \frac{60}{r} \times I_o \times \frac{\cos(\pi L \cos\theta) - \cos \pi L}{\sin\theta}$$

Where

E = field strength in volts per meter

I_o = current maximum in rms amperes

L = overall length expressed in wavelengths

r = distance from the antenna in meters

The mathematically inclined reader will recognize that for a given current maximum, wavelength and distance this formula yields a maximum horizon (θ=90°) field strength when the dipole is one wavelength long. If you intend to use an impedance-matching network to match any arbitrary length dipole to the transmission line, and if it is assumed that the network is lossless, the transmitter will be able to deliver the same power to the antenna regardless of its length. However, when a constant radiated power is maintained, the antenna current (also the unmatched impedance) depends upon the length of the antenna. The optimum dipole length for maximum horizon field strength will, therefore, not be one wavelength but will be somewhat longer.

Since the formula is in terms of a constant rms current maximum, the problem of determining optimum length for maximum gain becomes complicated.

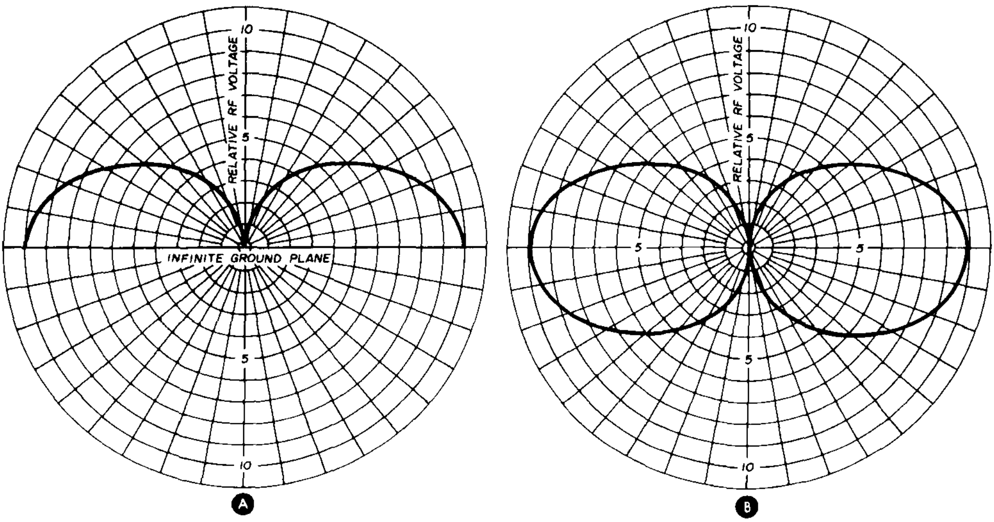

fig. 1. Theoretical radiation pattern of a quarter-wave vertical monopole on an infinite ground plane is shown in (A). Theoretical pattern of a half-wave dipole in free space is shown in (B).

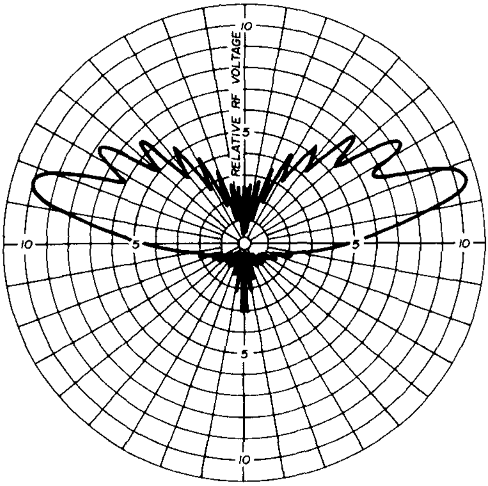

fig. 2. Radiation pattern of a quarter-wave vertical mounted in the center of a ground plane 16 wavelengths in diameter. (Antenna range test at 8 GHz, quarter-wave stub = 0.37", ground plane, 24.4" diameter.)

One approach to the problem is to construct the three-dimensional antenna radiation pattern from the formula and then calculate the total power contained within the radiated field. You may then adjust current I_0 as necessary to hold the power constant as the antenna length is varied. The horizon field strength may thus be calculated under these conditions for various lengths until the optimum length is determined.

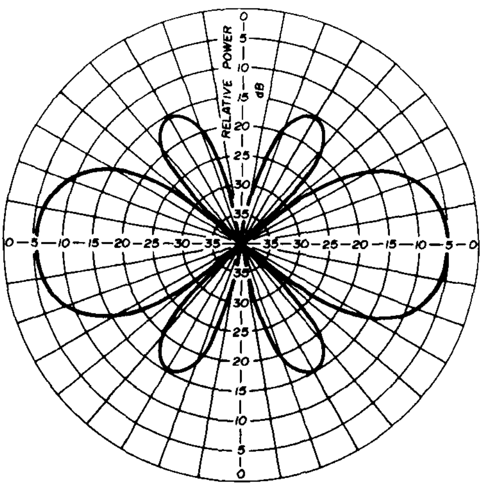

fig. 3. Theoretical radiation pattern of a 1.27-wavelength dipole in free space.

In order to do this, you must have a method to calculate the power contained in the radiated field. Such a method exists if you can use the calculus technique of integration.[3] Considering that the entire sphere of all directions from the antenna can be made up of an infinite number of small segments of solid angle and that the power contained in each segment is proportional to the square of the field strength (voltage) in that particular direction, a mathematical summation (integration) may be performed to calculate the total power.

The result of this calculation may be obtained as an isotropic value. The isotropic is the field strength which would result in all directions from the antenna if the radiated power were spread evenly over the entire sphere about the antenna rather than being concentrated in certain directions as is the actual case.

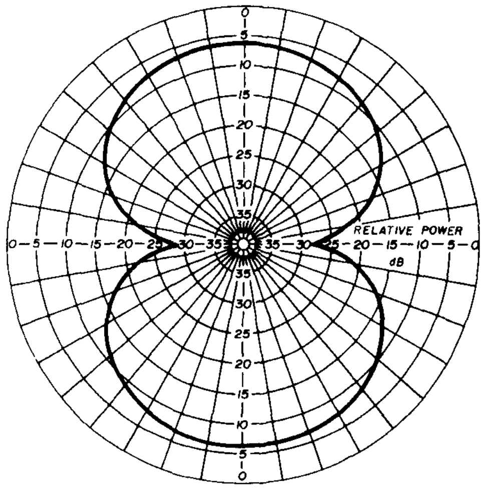

fig. 5. Radiation pattern of the balun-fed and matched half-wave dipole shown in fig. 4A.

Details of the calculus procedures are beyond the scope of this article. However, I have calculated the results shown in **table 1**, assuming the same current regardless of the dipole length. The results show that the half-wave dipole itself has directional properties and exhibits *2.15-dB gain over an isotropic (non-directional)* radiator. This is an important fact since the gain of any antenna may be

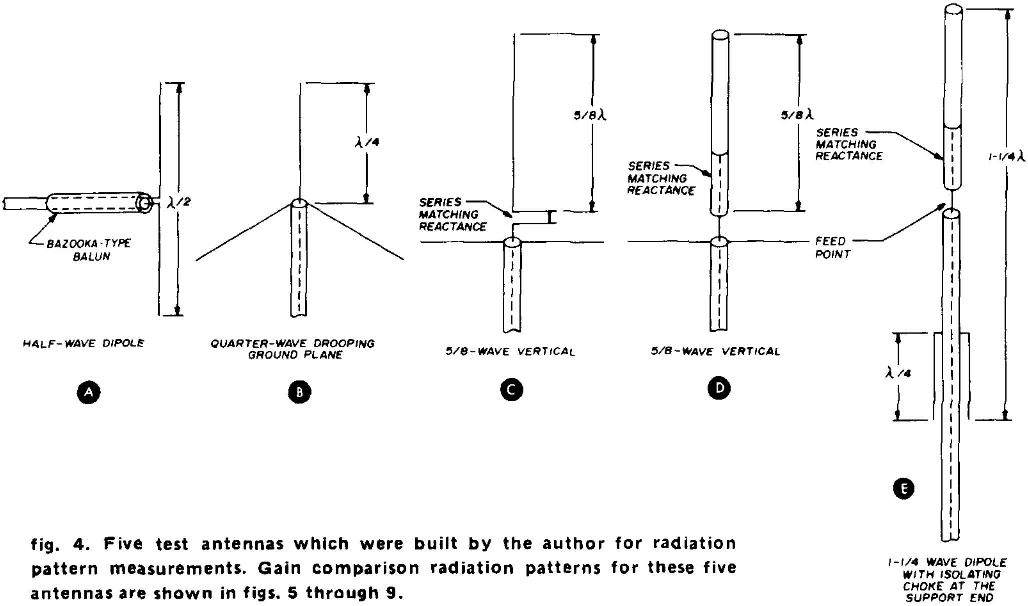

fig. 4. Five test antennas which were built by the author for radiation pattern measurements. Gain comparison radiation patterns for these five antennas are shown in figs. 5 through 9.

expressed in dB above a dipole, or isotropic, or some other standard. Using the isotropic as reference will, of course, make the gain figure 2.15-dB higher than if a dipole is used, and larger numbers look better in the advertising. When you read a manufacturers claim be sure that the gain reference is specified, otherwise the claim is meaningless.

The results also show that the dipole reaches its maximum gain when its length is 1.270 wavelengths, and that the gain decreases as it is further lengthened. That maximum of 5.18 dBi (dB over an isotropic) is equal to 3.03 dBd (dB over a dipole).

Thus, we have verified the basis upon which the 1-1/4-wave dipole or equivalent 5/8-wavelength monopole radiator is commonly considered to be a 3-dB gain antenna. Bear in mind that this is the theoretical maximum gain for the ideal situation of a matched dipole in free space or an equivalent matched monopole on an infinite ground plane. If the ground plane is less than infinite, the gain will be reduced from this maximum value. A plot of the theoretical radiation from a 1.27-wavelength dipole appears in **fig. 3.**

actual measurements

In an attempt to determine just how much gain reduction results from using ground planes of practical dimension, I built a number of antennas and carefully measured their radiation patterns. The antennas were measured on a test range at 1000 MHz where signal reflections from the ground and surroundings could be controlled to at least 40-dB below the incident signal. The antennas were rotated while signal strength was auto-

table 1. Field strength and gain of various length horizontal dipoles.

Dipole (wavelengths)	Field (volts/meter)	Isotropic (volts/meter)	Gain Ratio (over isotropic)	Ratio (dB)
0.500	1.00	0.78065	1.2815	2.150
1.265	1.6730	0.92165	1.8152	5.179
1.270	1.6613	0.91511	1.8154	5.180
1.275	1.6495	0.90878	1.8150	5.178

matically plotted on a polar graph recorder.

Five antennas were constructed and their radiation patterns measured. The antennas were a half-wave dipole (**fig. 4A**), a quarter-wave vertical with a drooping four rod ground plane, (**fig. 4B**), a 5/8-wavelength vertical above a plane of four 1/4-wavelength rods and using a shorted section of open-wire line in series with the feed to cancel reactance (**fig. 4C**), a similar 5/8-wavelength vertical except with a shorted coaxial section for

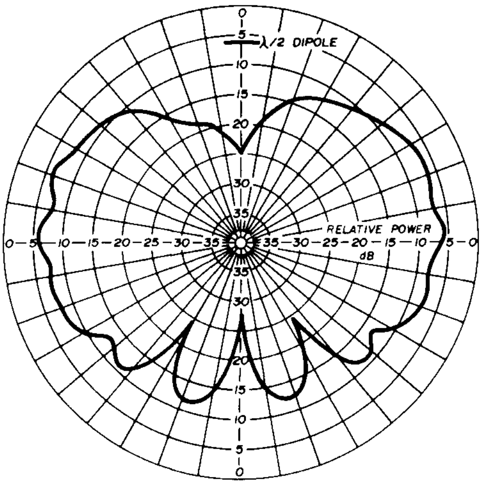

fig. 6. Radiation pattern of the quarter-wave drooping ground plane antenna shown in fig. 4B.

the series matching reactance (**fig. 4D**), and a 1-1/4-wavelength vertical dipole with a coaxial series matching reactance and end support isolated by a quarter wave choke (**fig. 4E**). All antennas were matched to less than 1.2:1 vswr so that no mismatch losses had to be considered when making gain measurements by substituting one antenna for another. The radiation patterns are shown in **figs. 5** through **9**.

As expected, the half-wave dipole and the quarter-wave drooping ground plane exhibited nearly the same gain. Although the 5/8-wavelength verticals produced somewhat smoother patterns, they failed to yield significant gain over the dipole or quarter-wave vertical. The two schemes

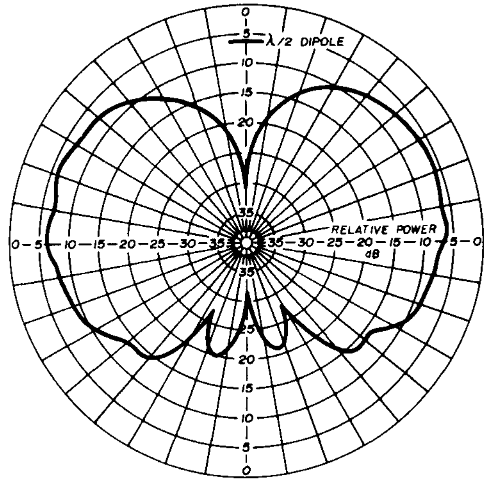

fig. 7. Radiation pattern of the 5/8-wave-length vertical on a 4-rod quarter-wave ground plane with a hairpin matching loop shown in fig. 4C.

for matching the 5/8-wavelength rods appear to be equivalent. The 1-1/4-wavelength vertical dipole antenna supplied nearly the theoretical 3-dB gain and exhibited a pattern shape similar to that predicted from the formula.

My only conclusion from this testing is that the usual image plane analysis of vertical monopoles is valid only for infinite ground planes and is greatly in error

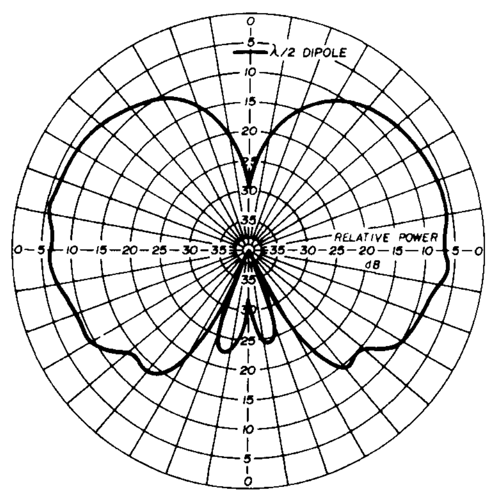

fig. 8. Radiation pattern of the 5/8-wavelength vertical on a 4-rod quarter-wave ground plane with a series coaxial matching reactance shown in fig. 4D.

for very small ground planes. As you can see from **fig. 1**, even a ground plane many wavelengths in size is a poor approximation of the infinite image plane. Therefore, it is not surprising that despite many gain claims, the 5/8-wavelength vertical ground plane frequently disappoints those expecting performance exceeding that of a quarter-wave ground plane. The mobile antenna situation is somewhat better due to the larger ground plane that a rooftop provides, but it is doubtful that even this advantage can add up to the 3-dB gain theoretically achieved on an infinite ground plane.

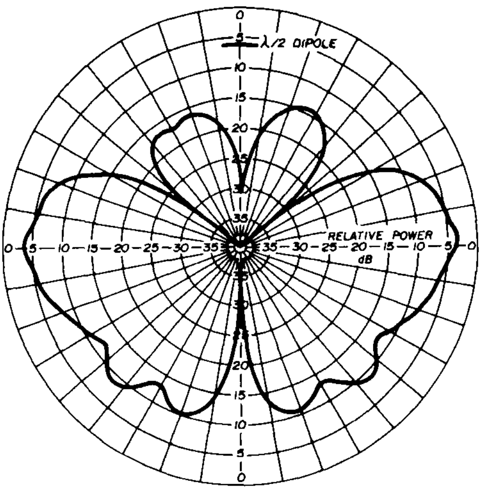

fig. 9. Radiation pattern of the matched 1-1/4-wavelength sleeve dipole with a decoupling choke shown in fig. 4E.

It is noted that the FCC is now requesting certified gain and pattern measurements from the manufacturers of antennas intended for use in amateur repeater stations.[4] The results of those measurements should indeed be very interesting.

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ham radio

five-to-one transmatch

Harry R. Hyder, W7IV, 9842 N. 57th Street, Scottsdale, Arizona 85253

Transmatches always seem more complicated than they have to be, particularly if you recall that *any* transmission line impedance, real or complex, at *any* vswr, can be made to look like a 50-ohm resistive load by the use of only one inductance and one capacitance in the familiar L-network shown in **fig. 1.**

What complicates the design of most transmatches is the desire to match almost any impedance with reasonable and practical values of L and C. Examples of extreme mismatch problems are matching a "random length" long-wire antenna, using a center-fed dipole on half or twice its resonant frequency or using an antenna fed with open-wire transmission line on several bands.

These are extreme cases. More common problems are the need to match a beam antenna that has been carefully pruned for the phone band in the CW portion, or the need to use a single coax-fed antenna over the entire 3.5- to 4.0-MHz band. The mismatch in these cases is usually more than the transmitter's output network can handle, but in general the vswr is not more than 5:1.

If you were to design a transmatch to handle a maximum vswr of 5:1 on a 50-ohm line, it could be made quite simple, and would not require more than one inductance and one capacitance, both of quite practical size.

As amateurs should all know by now, vswr for *practical* lines on bands below 30 MHz is independent of line length. The resistive and reactive components of the mismatch, however, are a strong function of line length. For a vswr of 5:1 on a 50-ohm line of any length, the resistive component will be between 10 and 250 ohms and the reactive component will be between plus and minus 120 ohms. A transmatch that will match these resistances and cancel these reactances on the 3.5- to 30-MHz bands is diagrammed in **fig. 2.**

construction

The rotary inductor could be a Johnson 229-202 or equivalent, having an inductance of 18 μH. The capacitor is a surplus 5-gang unit used in WWII direction-finding receivers. This capacitor has 420 pF per section (2100 pF total with all in parallel). It should be used with a switch (S2), so that only one or all five sections can be used. The minimum capacitance with all five sections in parallel approaches 100 pF, and less than this may be needed. This capacitor is available from Barry Electronics and Fair Radio Sales, and possibly other surplus dealers.

A word about component ratings. The capacitor is a high-grade receiving unit, but for any *legal* power rig, the voltage across it is nearly 1000 volts peak. I have tested my own unit to 1500 volts dc without any arc over. However, you may get a higher voltage than this is you are in the habit of tuning up at full power. If the capacitor does break down, it will impress on you forcibly that this is very bad practice and should be discontinued.

The roller inductor is rated at 5 amperes. Under some conditions the current may be higher than this, but not dangerously so. Here, the problem is heat; excessive heating could loosen the wire on the ceramic form or melt a solder joint. Except for high-power sstv or RTTY, average current will always be less than 5 amperes.

The switches should be heavy-duty rf types. The switches from surplus BC-375 tuning units are good, as are the excellent rf switches made by the James Millen Company.

tune up

The best way to tune up this, or any other transmatch, is with a low-power 50-ohm bridge and a signal source such as the Omega-T Noise Bridge, or the simple resistive bridge described in most editions of the *ARRL Handbook,* using a grid-dip meter as the source.

If all you have is a vswr meter and you don't want to invest in any more test equipment, you should use no more power than is necessary to obtain a reliable vswr reading. Tuning up on full power is ungentlemanly, illegal and hard on components. Of course, when the proper settings have been found for all your mismatch conditions, they should be recorded for future operation under those conditions.

Connect your vswr bridge between the power source and the transmatch. Since I must presume that all you know is your vswr and have no idea of what resistance and reactance it represents, you can flip a coin as to the initial position of S1. Switch S2 should place all sections of the variable capacitor in parallel.

Start with an inductance of zero, then rotate the capacitor through its range. Make small increases in inductance, tuning the capacitor each time until a vswr of 1:1 is obtained. If none is found, throw S1 to its other position and repeat the process. This is far less tedious than it sounds. The tuning is very broad, because the Q never exceeds 2.25. If you think that the Ls and Cs you get for a match don't seem to be proper for the band in use, don't worry. This could be a point where the resistive component is close to 50 ohms, but where the reactance is as high as plus or minus 90 ohms—all perfectly normal.

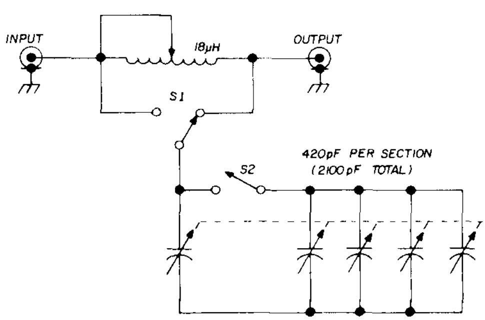

fig. 2. Circuit for the five-to-one transmatch. The rotary inductor is an E.F. Johnson 229-202 or equivalent.

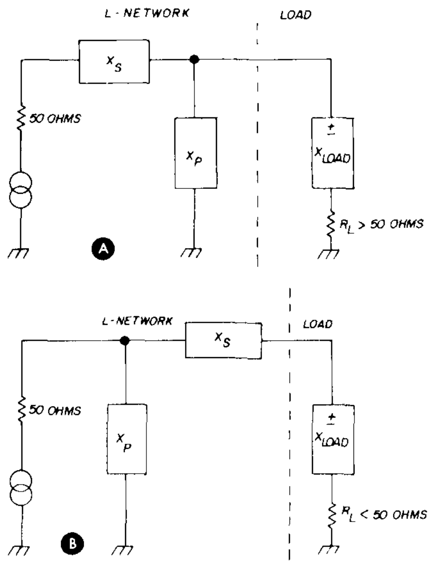

fig. 1. Basic L-network impedance-matching circuits. Circuit in (A) matches loads with resistive component greater than 50 ohms. L-network in (B) matches loads with resistive component less than 50 ohms.

summary

The five-to-one transmatch will actually handle some, but not all, mismatches greatly in excess of 5:1 on the 3.5-MHz band. On the 7-MHz band, the range is far higher, and on higher frequencies it is almost unlimited. However, the components, particularly the variable capacitor, can easily fail at some standing-wave ratios higher than 5:1 when used with a high-power rig. This should be taken into account.

In any event, if your mismatch requirements are moderate, you can easily build this transmatch at a fraction of the cost of a wider-range unit.

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vertical radiation patterns of horizontal antennas

How antenna height affects the vertical radiation angle of horizontally polarized antennas

H. Glenn Bogel, WA9RQY, 4111 Beaverbrook Drive, Fort Wayne, Indiana 46805

There are many sources of information describing the vertical radiation angles of horizontal antennas (the angle above the horizon of the axis of the main lobe of radiation), but most of these references tend to go so deeply into theory that the reader is unable to answer the basic question, "How can I determine the radiation angle of *my* antenna?" The graphs presented in this article will go a long way toward answering that question.

Height above ground, not antenna type, determines the radiation angle of horizontally polarized antennas. Although a parasitic antenna, such as a Yagi, will cause more power to be radiated at a low angle than a dipole, in both cases the vertical radiation angle is the same, assuming both antennas are at the same height. The effects of ground reflection are probably most easily understood by studying the *image antenna* approach found in the *ARRL Antenna Book*[1] and other publications.[2]

Basically, if the antenna were to be suspended in free space, the main lobe of radiation would be directly in line with the aperture of the antenna. When the antenna is located near the earth, however, a conflict occurs between the direct wave from the antenna and the wave that is

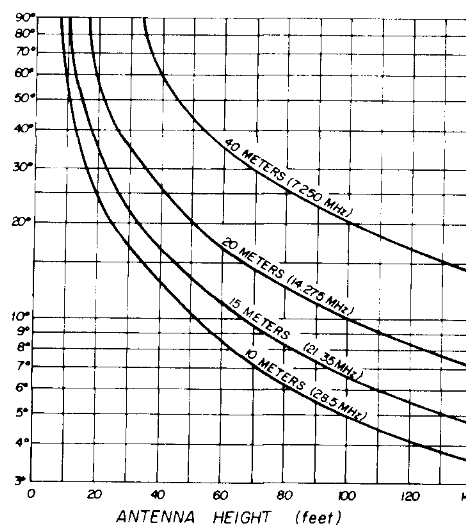

fig. 1. Graph of major vertical radiation lobes for various horizontal antenna heights up to 140 feet.

reflected from ground. The phase difference between these two waves results in cancellation and reinforcement at various angles above the horizontal. Where reinforcement occurs lobes are present, and at points of cancellation nulls appear in the vertical radiation patterns. Varying

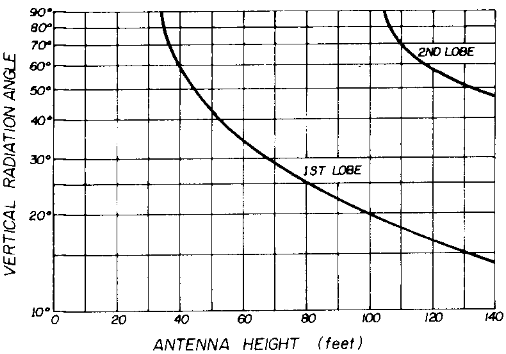

fig. 2. Vertical radiation angle of first and second lobes of a 40-meter (7.250 MHz) horizontal antennas at heights up to 140 feet.

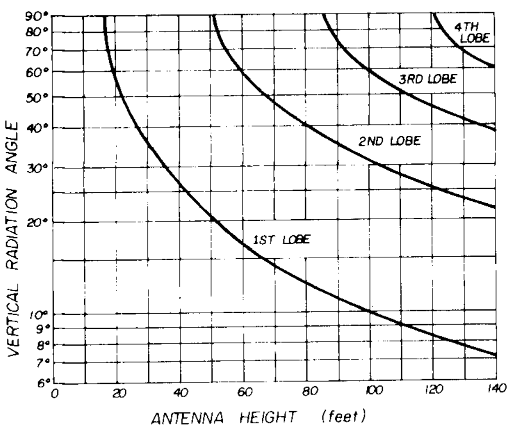

fig. 3. Vertical radiation angle of pattern lobes for 20-meter (14.275 MHz) horizontal antennas at heights up to 140 feet.

the height of the antenna above the reflecting ground changes the vertical angles of cancellation and reflection patterns.

My interest in DXing, contest operating, rag chewing and antennas led me to a very practical magazine article on the subject of vertical radiation patterns.[3] This, in turn, resulted in many days of calculations and graph making, producing the graphs presented here which show angle of radiation vs antenna height above ground for 10, 15, 20 and 40 meters.

The following method was used to plot the graphs. This approach is based on the fact that the incident and reflected waves, when analyzed vectorially, are in phase at 90°, 270°, 450°, 630°, 810°, etc.

1. Calculate the wavelength (in feet) of the frequency being considered:

$$\lambda = \text{wavelength (feet)} = \frac{984}{f_{MHz}}$$

This represents one wavelength or 360 electrical degrees.

2. Determine the antenna height in electrical degrees:

$$h_A = \text{antenna height (degrees)} = 360\frac{h_1}{\lambda}$$

where h_1 is the height of the antenna and λ is one wavelength, both in feet.

3. Compute the vertical angle of radiation for each lobe

$$\sin \alpha = \frac{90}{h_A}\ \frac{270}{h_A}\ \frac{450}{h_A}\ \frac{630}{h_A}\ \frac{810}{h_A}\ \text{etc.}$$

where α is the vertical angle of each lobe.

4. From a table of natural trigonometric functions, find the vertical radiation angle, α, for each value of $\sin \alpha$ up to 90°. Since 90° is straight up ($\sin \alpha$ = 1.00), higher values are not valid.

For example, assume you have a horizontal 20-meter antenna installed on top of a 70-foot tower. What is the vertical angle of radiation at an operating frequency of 14.275 MHz?

1. One wavelength at 14.275 MHz is 68.9 feet:

$$\lambda = \frac{984}{14.275\ \text{MHz}} = 68.9\ \text{feet}$$

2. A 70-foot tower represents 365.6° at 14.275 MHz:

$$h_A = (360^\circ)\frac{70}{68.9} = 365.6^\circ$$

3. To find the vertical angle of the first (primary) lobe,

$$\sin \alpha = \frac{90^\circ}{365.6^\circ} = 0.246,$$

Consulting a table of natural sine functions, the vertical angle is approximately 14.25° (see **fig. 3**). The second lobe is at approximately 47.5°.

$$\sin \alpha = \frac{270^\circ}{365.6^\circ} = 0.739, \alpha = 47.5^\circ$$

Therefore, the first (major) lobe occurs at 14.25° above the horizontal while the vertical angle of radiation for the second lobe is 47.5°.

Fig. 1 is a composite graph of the first, or major lobes, on 10, 15, 20 and 40 meters for antenna heights from 8½ to 140 feet. The curves were all calculated for the center of the American phone bands except for 10 meters. The low end of the American portion of 10 meters was chosen because of the concentrated activity in this area of the band. The angle of radiation will not vary appreciably from one end to the other on any of the bands.

Figs. 2 through **5** show all of the lobes present on each band for any given height. Again, the lines are the lobes of vertical radiation and the null points are approximately midway between lobes. Never pick an antenna height which will present any lobe at 90° – this results in wasted radiated power. One interesting observation I made is that 70 feet is the only antenna height on the graphs that has a null point at 90° on each band!

It should be pointed out that these graphs were based on the assumption that electrical ground (the electrical plane from which the antenna waves are reflected) is at the physical surface of the ground. In actuality, electrical ground varies considerably from one location to another, and may be located from several inches to several feet below the surface.

These graphs, combined with a little operating experience, should be helpful in selecting the proper antenna height for DXing or short-haul propagation, or both, depending on your choice of radiation angle.

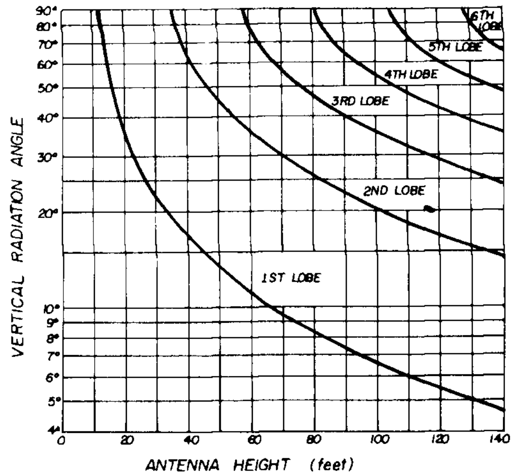

fig. 4. Vertical radiation angle of pattern lobes for 15-meter (21.250 MHz) horizontal antennas installed at heights up to 140 feet.

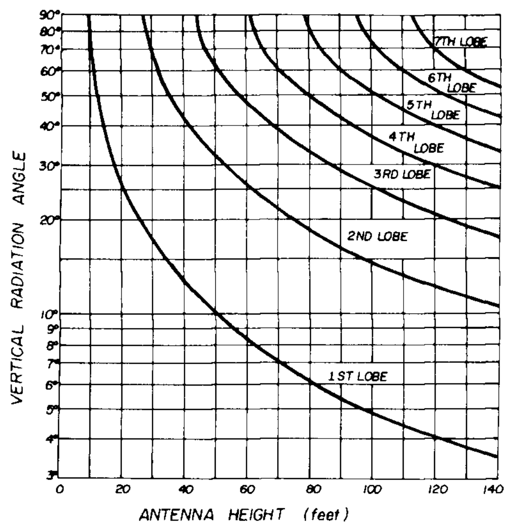

fig. 5. Vertical radiation angles of pattern lobes for 10-meter (28.5 MHz) horizontal antennas installed at heights up to 140 feet.

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pi network design aid

Presenting a set of curves for choosing power amplifier components to provide optimum tank-circuit efficiency

Alf Wilson, W6NIF, 1068 Arden Drive, Encinitas, California 92024

The tank circuits of yesterday, with their beehive insulators and cumbersome copper tubing coils, have all but disappeared from modern transmitters. The main reason is, of course, that today's rigs are designed for use with coax transmission lines. The simplest and most efficient means of transforming the high plate-load impedance of the final amplifier tube to low-impedance coax is with a pi or pi-L network. The pi network is the most often used of the two circuits since it requires fewer parts.

Much design data on pi networks has appeared in the literature over the past 15 years and will not be repeated here. The purpose of this article is to present design data for those who wish to build a pi-network amplifier without wading through a multitude of table lookups and without having to convert component reactance values into equivalent capacitance and inductance.

ground rules

To keep things simple and still provide useful data for most amateur applications, the curves are based on the general case; i.e., a tank circuit Q of 12, tube load impedances between 1000 and 4000 ohms, and an output impedance of 50 ohms. The advantage of using these curves is that no interpolation is required for values that don't appear in published tables of such data. You can pick off exact values of capacitance or inductance directly from the curves.

The curves are based on calculations for tube load impedances used in the Class C mode:

$$R_L = \frac{E_B}{2\,I_B} \qquad (1)$$

where

R_L = tube load impedance (ohms)
E_B = tube plate potential (volts)
I_B = tube plate current (amperes)

using the curves

As mentioned previously, the curves are based on an operating Q of 12, which is optimum in terms of tank-circuit efficiency and harmonic attenuation. Most rigs today cover the bands between 3.5 and 28 MHz with bandswitching coils.

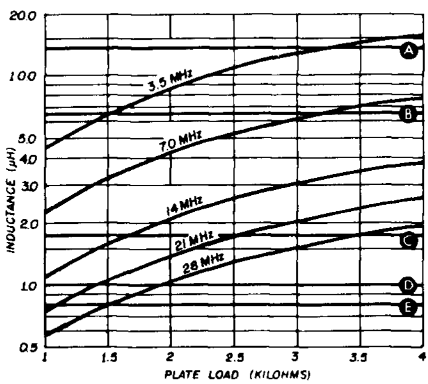


fig. 1. Curves of inductance as a function of tube plate-load impedance for pi networks. Loci of constant inductance for the five amateur hf bands are shown for the B&W 850A tapped inductor example discussed in the text (lines A, B, C, D and E).

One of the problems in such transmitter designs is finding components that will operate satisfactorily over the desired five-band frequency range while still maintaining reasonable circuit Q.

If the Q is to be held at or close to 12 in an amplifier that's switchable over the five high-frequency bands under different operating modes (CW and ssb), then it is difficult if not impossible to find off-the-shelf components for the pi network input capacitor, inductor and output capacitor. Several compromises have been reported for resolving this problem. An example is given in reference 1, which shows one way to deal with the designer's dilemma involving different plate-load impedances in a pi network tank for 1-kW CW and 2-kW pep ssb operation.

In this case, a multi-tapped coil is used, with two taps for each band, one for CW and one for ssb. Lacking a continuously variable inductor, this is one way to obtain the optimum inductance for different plate-load impedances — it requires a little work, but it's less expensive than buying a rotary inductor that will handle the power involved.

design example

An inductor can be designed to provide the correct inductance for most plate load impedances with the aid of the curves in **fig. 1.** Included in **fig. 1** are loci of constant inductance *(straight lines) for* the popular B&W model 850A tapped bandswitching inductor. This inductor is extremely rugged and has been used by many amateurs in multiband amplifiers. However, as with many manufactured components, it is a compromise; the manufacturer tries to put out a product that will be useful for general applications, and to obtain optimum performance for a specific plate load impedance requires further work by the amateur.

For example, suppose you wish to design a five-band rf amplifier around the B&W 850A inductor. Assume that dc power input is to be 1 kW. If plate voltage is, say, 3000 volts and plate current is 0.3 ampere, the plate load impedance, from **eq. 1,** will be R_L = 1800 ohms. From **fig. 1** inductance values for this load impedance would be:

band	L (μH)	B&W 850A L (μH)
3.5	7.6	13.5
7	3.8	6.5
14	1.88	1.75
21	1.25	1.0
28	0.92	0.8

Clearly, the taps on the 850A inductor are not located to provide the optimum inductance for the plate load impedance in the example, especially for the two lower bands. The coil taps are closer to the proper inductance for the three higher-frequency bands, but optimum efficiency and power output cannot be obtained unless the plate load impedance is more accurately matched for all five bands. The remedy is to rework the coil so that the taps are located to provide the inductances shown by the curves.

By consulting **fig. 1** and eyeballing the particular tapped coil under consideration (in this case the B&W 850A), it's fairly easy to judge where the taps should be relocated to provide the proper inductance for the particular plate load impedance involved. Clip leads may be used between the coil and switch points, after disconnecting the existing coil taps, to obtain the proper inductance experimentally. Then new taps can be installed in place of those on the as-built coil.

In my case, using a 4-1000A in grounded grid, I was able to increase transmitter power output substantially on all bands by relocating the taps on the B&W 850A coil in the amplifier pi network. If you'd rather not modify the coil, the clip-lead method can be used instead – a not too elegant way of doing the job, but the coil can easily be returned to its original configuration for trading purposes at the next swap meet.

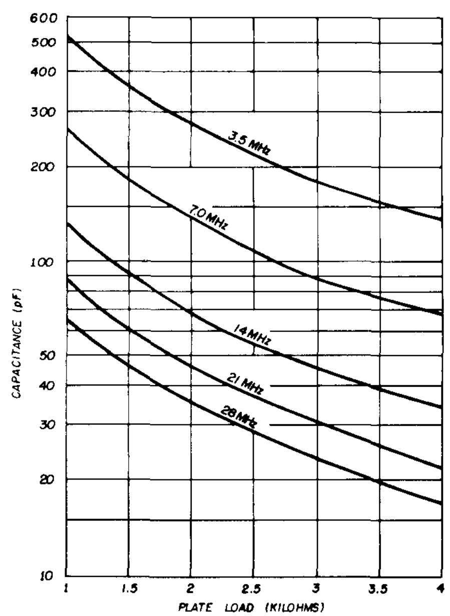


fig. 2. Pi network input capacitance as a function of plate-load impedance.

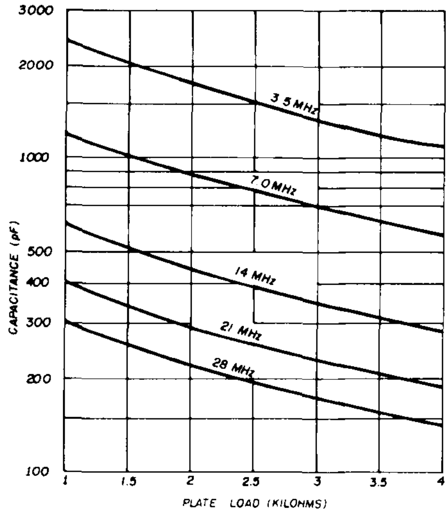


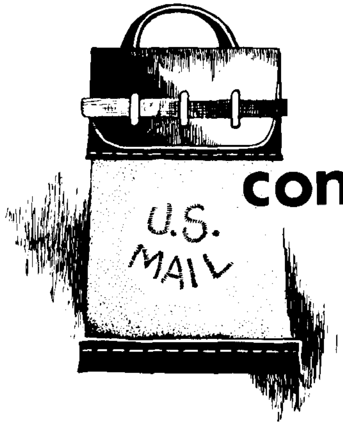
fig. 3. Pi network output capacitance as a function of plate-load impedance.

The curves in **figs. 2** and **3** are included for the remainder of the pi-network design problem. These curves provide values for the input and output capacitors (C1, C2) for plate-load impedances between 1000 and 4000 ohms. The same ground rules apply as for the inductor: operating Q of 12 and 50-ohm output impedance. You'll probably find that another compromise will be necessary in the choice of C2 for specific frequencies. For example, if you wish to use a variable capacitor for C2, it will probably be necessary to use fixed capacitors in parallel with C2 on certain frequencies to obtain optimum transmitter loading.

reference

1. Douglas A. Blakeslee, W1KLK, and Carl E. Smith, W1ETU/4, "Some Notes on the Design and Construction of Grounded-Grid Linear Amplifiers," *QST*, December 1970, page 22.

ham radio



comments

log-periodic antennas

Dear HR:

I am afraid I have not stressed enough the importance of transposing the open center feedline that must be used with log-periodic antennas. It is an absolute *must.* Several amateurs who have written to me about log periodics built from my articles have indicated that the antennas have no gain but appear to have a bi-directional pattern off the sides of the antenna. In practically all cases this is caused by a failure to transpose the center feedline as shown in **fig. 1.** Note

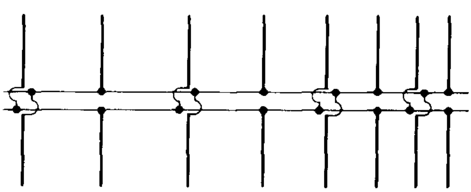


fig. 1. Center feedline connections to every other element of a log-periodic antenna must be transposed for proper operation, as shown here.

that every other element of the log periodic is connected to the opposite side of the center feeder. For more information on this essential part of log periodic construction, refer to my article in the September, 1972, issue of *ham radio* (page 33), or read my article on page 6 of this issue..

George Smith, W4AEO
Camden, South Carolina

Dear HR:

When I first built the five-element vertical 40-meter log periodic described by W4AEO in the September, 1973, issue of *ham radio* (page 46) and put it on the air, it didn't perform at all like it was supposed to. After checking all dimensions and the feedline transposition, WB4JEZ/5 and I sat down and scratched out heads — the antenna still didn't have any directivity. In a fit of desperation I drove a ground rod in at the balun, which is mounted at the front of the vertical array, and grounded the shield. What a difference! The antenna now works as advertised. The problem was a ground loop — without the additional ground rod the shield *at the balun* was not grounded.

Tom Morrison, WB5IZN

noise bridge

Dear HR:

After building the noise bridge that appears in the January, 1973, issue of *ham radio,* the following thoughts came to mind that might be useful for anyone attempting to build the noise bridge.

Although the author does not mention the wire size he used for winding the tri-filar winding on the T-37-10 toroid core, number-26 enameled worked very well. Once the primary side of the coil is connected to the circuit, the problem of finding the proper connections for the secondary with the four remaining wires can be solved as follows: wire this portion of the noise bridge last. With a receiver connected find the two wires that, when joined together and connected to the detector, will give the greatest noise output on the receiver (the remaining two wires must also be connected as per the schematic). Then connect a resistor of known value around 50 ohms to the Z_X

connector and adjust the R_X pot for a pronounced noise null in the receiver output. When this occurs, you know that the coil leads are correctly connected.

I might also mention that the 68-pF mica capacitor and the 140-pF variable capacitor were eliminated from my noise bridge since I am only interested in finding the resonant frequency of antennas, transmission lines, etc., and the resistance at resonance.

Since most amateur antennas have a resistance of less than 100 ohms at resonance a builder might want to substitute a 100-ohm composition pot for the 250-ohm pot used in the article. It was found on my noise bridge that the space between 10-ohm intervals was somewhat small when calibrating the resistance dial.

In comparing the performance of this noise bridge with an Omega TE-7-01 noise bridge that I have been using for three years, the results were very satisfactory. All tests were below 30 MHz.

John Lawson, K5IRK
Amarillo, Texas

standing-wave ratios

Dear HR:

The article in the July, 1973, issue by W2HB on "The Importance of Standing Wave Ratios" was very interesting and informative. Several small points seem, however, to invite some comment and clarification.

Figs. 1 and **2** are stated to depict conditions in a system with a vswr of 2:1. The curve shown in these figures is for a vswr of 3:1. Furthermore, its shape is shown as sinusoidal. When the magnitude of the voltage wave is considered without regard to polarity, which is the case here, the curve has the shape of a full-wave-rectified sinewave.

The first full paragraph at the top of the second column of page 32 regarding reflection at resistive terminations is somewhat misleading. It is certainly true that real power flows in only one direction – from generator to load. However, a reflected wave does exist at any resistive termination which does not match the impedance of the line. The implicit definition of "passive" ("That is, it cannot reflect . . . .") is not standard usage. Reactive elements may also be passive. This paragraph might well have been omitted from this otherwise generally very clear and useful article.

Kenneth H. Beck, W3VDX

Mr. Beck is quite correct in pointing out that the minimum voltage of the curves shown in my **figs. 1** *and* **2** *should be 0.5 instead of 0.3. This error is embarrasing for it resulted from having in mind the 3:1 ratio of the incident wave to the reflected wave that exists when the vswr is 2:1. Also, I have no quarrel with his comments about the shape of the curves. However, I would like to point out that insofar as the article is concerned, only the location of the peak and minimum voltage points is of importance, and the curve shapes shown should not be disturbing to the reader.*

Again I must agree with Mr. Beck that perhaps the choice of the word "passive" in discussing resistive loads was unfortunate because it is not standard usage. However, I was trying to stress the fact that a resistive load by itself does not, and cannot, reflect power in any kind of circuit including rf transmission lines. We consistently hear the statement made that power is reflected by the load. This statement is particularly incorrect when the load is pure resistance. Evidently the difficulties involved in explaining the mechanism of reflection has been avoided to the extent that the load has become credited with a false capability.

The mechanism by which reflection does take place on a transmission line has been described in excellent detail by W2DU in the August, 1973, issue of QST. *In this article the author has made it clear that reflection takes place as a result of the voltage and current conditions at the load, and the effect that these conditions have on the electric and magnetic fields at the load end of the line.*

Earl Whyman, W2HB

More Details? CHECK—OFF Page 110

the ham notebook

programmable calculator simplifies antenna design

Within the past year there has been a whole new series of programmable electronic calculators introduced to the market. These new calculators are a whole new breed of cat and are nothing like the home-variety hunt-and peck units that do a good job of wearing your fingertips down to the first knuckle. One of the programmable calculators currently available is the Compucorp 322G* which sells for slightly under eight bills. That's right, just this side of $800. For this price you get ten memory registers, 80 program steps and memory retention like a bear (unless some idiot turns it off). Furthermore, this unit is completely unbothered by large rf fields – at my station it sits placidly on the operating table, completely ignoring my pair of 813s.

The Compucorp 324G programmable calculator used by the author.

Although the price tag is premium, you have to operate one of these programmable calculators to get the feel. It is all so simple. Just stick a few sample parameters into the memory registers and then load the program and switch the calculator back to *run.* Then you can play games with new items in the memory registers, hit the *start* button, watch it wink its readout light and hang up on the answer.

antenna design

A programmable calculator such as the Compucorp 322G can be used in all kinds of antenna designs, but a simple two-tower directional antenna design will be presented here. However, there's no reason to stop at two verticals – the calculator will also handle four, provided you have the scratch to put up four towers. Nor is the calculator limited to antenna designs – it will handle nearly any sort of design problem you can load into it.

For example, you can load the calculator with a program to tell you which way to point the beam when you're working DX, and it will do the job quicker than your rotator can bring the beam around! I use a Compucorp 324G which stores two 80-step programs – the second to tell the guy on the other end which way to aim his beam.

For the specifics of the two-element directional array design, refer to **fig. 1.**

*Compucorp, manufacturer of the 324G programmable calculator shown in the photograph, is located at 12401 West Olympic Boulevard, *Los Angeles, California* 90064.

Compucorp

Page 1 of 2

PROGRAM	Program No 8806242
	Models 320 Series
DIRECTIONAL ANTENNAS, BASIC TWO TOWERS	Date 21 September 1973
	Author Aylor

DESCRIPTION

This program calculates the radiated field intensity, from a two-tower directional array, at an azimuth angle, ϕ, measured from the reference axis (the line passing thru both towers) and at a vertical angle, θ, measured from the ground plane.

The program includes a stepping increment, allowing evaluation of field intensity for successive values of ϕ.

EXAMPLE:

Find the radiated field intensity from the following information:

- Azimuthal angle ϕ of 15°.
- Vertical angle θ, measured from ground plane of 0°.
- Field phase of second tower, A_2 of 35°.
- Ratio of field which second tower radiates above that radiated by reference element #1, R_2 = 1.15.
- Spacing between towers, S = 150.
- Multiplying Constant, K = 758.287 mv/m.
- Fill Constant, calculated from $(1.0 + R_2^2)/2R_2$, W = 1.00978.

Follow load procedure on reverse side. Steps 1-4, continue by:

ENTER	PRESS	READ	– Description
15	ST, 1		– Azimuth angle ϕ
758.287	ST, 2		– K
1.00978	ST, 3		– W
35	ST, 4		– A_2
150	ST, 5		– S
0	ST, 6		– Vertical angle θ
	S/S	74.997	– Radiated field int. in mv/m

Program No. 8806242
Page 2 of 2

OPERATING INSTRUCTIONS

1. Set switch to LOAD
2. Key in the program steps. (see note below)
3. Set switch to RUN, set DP to 3.
4. Set switch to DEG.
5. Store Registers 1-6 from table below.
6. Press S/S.
7. The radiated field intensity is displayed in millivolts per meter at one mile.
8. For additional increments, continue at Step 6.
9. For next problem, go to Step 5.

DATA STORAGE

Description	Symbol/Register
Azimuthal Angle, measured from ref. axis	ϕ/1
Multiplying Constant, field radiated from tower (2)	K/2
Fill Constant, $(1.0 + R_2^2)/2R_2$	W/3
Phase of field radiated by second tower	A_2/4
Spacing between towers	S/5
Vertical Angle, measured from ground plane	θ/6

NOTES:

1. The stepping increment is entered in the program starting at Step 36. Any desired value can be substituted to generate results for successive values of ϕ.
2. Multiplying Constant is calculated from

REGISTER

0	1	2	3	4	5	6	7	8	9	12
	ϕ	K	W	A_2	S					

PROGRAM STEPS

fig. 1. Compucorp's program for designing a basic two-tower directional antenna.

This is a reproduction of Compucorps's program 8806242 which is based on the design procedure described in Jasik's *Antenna Engineering Handbook*.[1] The program has a number of subtleties such as unequal ratios of rf fields between towers, vertical angle θ, which tells you what's happening at a specific radiation angle, and most important of all, a stepping increment which walks the thing around the azimuth by a specified increment (put in during the load phase) every time you hit the *start/stop* key. For the uninitiated, this is the old routine, "N = n + a," where N is the new value, n is the old value just presented and a is the increment.

The applications for the programmable calculator are limited only by your imagination. For those who are remiss to use their imagination, Compucorp will soak them $19.95 for the entire antenna design package.

reference

1. Henry Jasik, *Antenna Engineering Handbook,* McGraw-Hill, New York, 1961, equation 20-19.

Raymond Aylor, W3DVO

noise bridge

The prospect of tuning a new quad and adjusting a shunt-fed tower for 160 meters led to the construction of the rf bridge described by WB2EGZ (*hr*, December, 1970, page 18). The completed instrument performed perfectly, with very deep calibration nulls. However, once the bridge was connected to an existing 20-meter beam to determine that antenna's resonant frequency, a serious flaw appeared — signals on the ssb segment of the 20-meter band were anywhere from 5 to 30-dB stronger than the noise from the bridge.

W5QJR mentioned the need for high-level amplification of the noise generated by the bridge in the first article on this type of instrument several years ago ("The Antenna Noise Bridge," *QST,* December, 1967, page 39), and I learned quickly that this was the case. A stage-by-stage check revealed that everything was functioning properly, but that gain

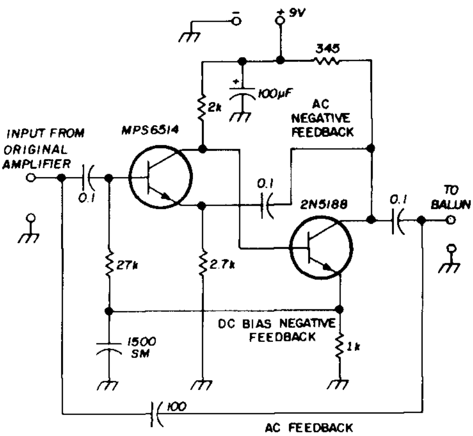


fig. 2. Broadband noise amplifier for use with antenna noise bridges for high-frequency measurements.

through the broadband amplifier was on the order of a mere 15 dB. Not quite enough for normal signal conditions on the high-frequency bands.

The circuit of **fig. 2** was breadboarded and found to provide 35 to 50-dB of additional gain (not entirely constant over 1.8 to 30 MHz). Three strong feedback loops are introduced between the driver and final amplifier. Both devices are high f_T, high beta types, and substitutions of other popular devices (such as the 2N3053, 2N2102, 2N697, 2N706, etc.) will cut overall gain by 10 to 20 dB, so the devices specified should be used. The amplifier was mounted on its own PC board, which in turn was mounted in the Minibox on the opposite side from the first PC board (where the battery is shown in the WB2EGZ instrument).

The battery fits snugly between the ends of the PC board and the bottom of the Minibox. Lead wires were simply run from the output of the WB2EGZ amplifier to the input of the additional amplifier, and the output from the second amplifier was connected to the broadband balun. One slight improvement over the WB2EGZ version involves mounting the potentiometer terminals so that they point directly to the input/output receptacles, rather than as shown in the photos. Zero lead length is thus achieved by mounting each component of the bridge directly to the receptacles and the pot terminals. No reactance arises as a result.

The additional broadband amplifier provides a noise signal that blankets any signal on the high-frequency bands. Further, accuracy of null detection is greatly increased since the noise drops about 40 dB to reach incoming signal levels, and a complete null is down about another 10 to 15 dB. I've found that the bridge now can be tracked down to about a 5-kHz bandwidth.

Ade Weiss, K8EEG

ST-5 keys polar relay

Here is a very simple way to key a polar relay with the ST-5 RTTY demodulator (see **fig. 3**). I use this method to key my transmitter and it works very well. It may also be used to key an AFSK oscillator which feeds a tape recorder. This way you can make a recording on the hf bands and replay it on vhf.

Fred Gilmore, WØLPD

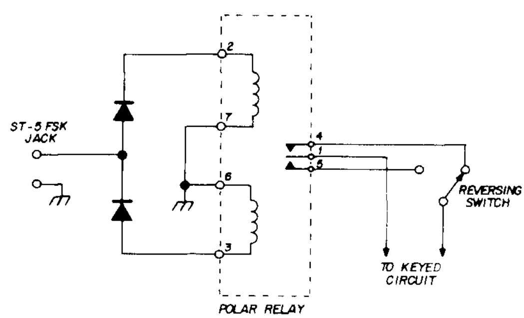


fig. 3. Simple circuit for keying a polar relay with an ST-5 RTTY demodulator.

short circuit

In the article describing the Universal Frequency Standard in the February, 1974, issue, the HEP50 in **fig. 5** (page 44) is missing a 1000-ohm collector resistor; the printed-circuit layout on page 46 is okay. Also, the wiper of PA-12 (switch S2) should be grounded. The output from pin 11 of U5, a 7493 binary-counter IC, is 12.5 kHz, *not* 2.5 kHz.

More Details? CHECK—OFF Page 110

new products

new ham-m rotator

The new Ham II rotator introduced recently by CDE succeeds the popular Ham-M rotator used by amateurs for years. The new Ham II features a new brake release control, separate directional controls and stainless-steel gears and hardware.

The all new, modern design control box is styled to compliment surrounding communications equipment and provides built-in, operator-controlled brake release for improved longevity of the entire antenna/rotator package. The calibration control is now located on the front panel for ease in maintaining directional accuracy. Also included on the front panel is a separate off/on switch which offers continuous direction indication on the illuminated meter, making access to the rear of the control box unnecessary. Individual snap-action switches are used for rotation-direction control.

The new Ham II rotor continues the tradition of the heavy-duty, cast-aluminum bell housing, long the trademark of CDE amateur antenna rotators. The inline construction evenly supports the load on two six-inch bearing races containing 98 ball bearings. An electrically-controlled wedge brake is housed in the base, positively locking the rotor in any of 96 segments (3° 45″ apart). The high torque motor drives the unit through a machined stainless-steel gear and pinion assembly, rotating a full 360 degrees in less than 60 seconds. Designed for antennas of up to 7.0 square feet of wind load area, the rotor accepts masts from 1-3/8 to 2-1/6 inches (3.5 to 5.2 cm). A tower-mounting kit and south-center meter-scale kit are available.

Also new from CDE is the CD44 antenna rotator which succeeds the popular, intermediate range TR44 often used by amateurs for smaller antenna systems. For more information on the new Ham II or CD44, write to Cornell-Dubilier Electronics, Division of Federal Pacific Electric Company, 2070 South Maple Street, Des Plaines, Illinois 60018, or use *check-off* on page 110.

two-meter colinear

The new Hustler two-meter colinear antenna, Model G6-144-A, is expressly designed for repeater or fixed station operation on two meters. FCC accepted for repeater application, the antenna is conservatively rated at 6-dB gain based on EIA Standard RS-329 (gain over a 1/2-wave dipole). Special features built into this 117-inch antenna include high-power capability, shunt feed with dc grounding, easily accessible SO-239 coax connector, four radials, heavy duty construction and double U-bolt mounting. Price is $49.95 amateur net. For additional information, write to Sales Department, New-Tronics Corporation, 15800 Commerce Park Drive, Brookpark, Ohio 44142, or use *check-off* on page 110.

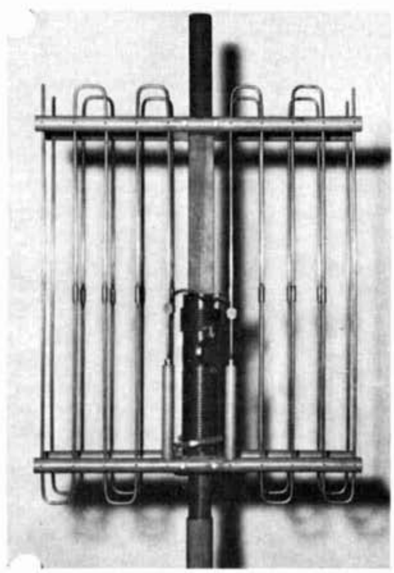
multi-band antenna coupler

The new Gold Line GLC 1079 Multi-Band Antenna Coupler allows you to use your standard car radio antenna to monitor 20–70 MHz, 148–175 MHz and 250–470 MHz as well as your a-m/fm car radio. It can couple up to five bands without a new or special antenna. Two cables are included for easy hook-up. Price is $12.95 from Gold Line Connector, Inc., Muller Avenue, Norwalk, Connecticut 06852. For more information, use *check-off* on page 110.

low-loss uhf coax

The Antenna Specialists Company has introduced what it claims to be the first major development in communications coaxial cable in twenty years, PRO-FLEX$_{tm}$ 450, which offers significantly reduced power loss in the ultra-high-frequency range and higher ambient temperature ratings. The new cable, which is intended primarily for vehicular installations but may also be used effectively in base station installations of moderate power, is rated at 150° F ambient rather than 104° F commonly associated with conventional RG-58/U cable. The cable construction consists of an inner-conductor, an inner-dielectric of foam polypropylene, shield braid and an outer jacket of purest non-migrating vinyl. Antenna Specialists is now converting production of its heavy duty uhf and vhf professional mobile antennas to include the new PRO-FLEX$_{tm}$ 450 cable. It also is available in bulk quantities of 100, 500 and 1,000 feet for the convenience of systems designers and for replacement applications. Complete specifications may be obtained by writing to: Mr. Larry Kline, Professional Products Manager, The Antenna Specialists Company, 12435 Euclid Avenue, Cleveland, Ohio 44106, or by using *check-off* on page 110.

little giant antenna

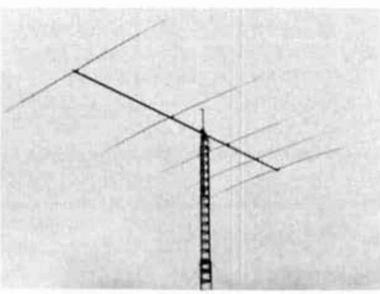


Stan Byquist's "Little Giant" antenna is not exactly new—he received his patent on it back in the 1950s and there was some publicity for it then—but he has recently resurrected the design and its unique character deserves mention in these pages.

More Details? CHECK–OFF Page 110

In brief, the Little Giant is a highly compressed single-band antenna that can be used in situations where conventional antennas are out of the question. The largest model, for 80 meters, is only 27-inches (68.6-cm) high and 32-inches (81.3-cm) wide; even smaller models are available for use on 40 through 10 meters. Bandwidth is necessarily small, as would be expected of such a small and, therefore, high-Q antenna. User reports have been quite favorable considering that any drastically shortened antenna is bound to be a compromise in performance. Amateurs with a space problem should contact Stan at the Little Giant Antenna Labs, Vaughnsville, Ohio 45893, or use *check-off* on page 110.

monobander antenna



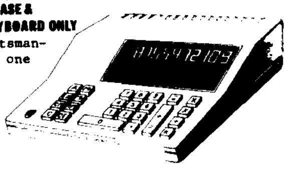
KLM Electronics has introduced a new, 20-meter "big stick" monobander antenna which provides constant gain *and* flat vswr over the complete frequency range from 13.9 to 14.4 MHz. By using very efficient driven elements, the five-element array provides optimum gain of 9.7 ±0.2 dB gain over a dipole with better than 35-dB front-to-side and 30-dB front-to-back ratio. A boom length of 41 feet and turning radius of 28 feet are combined with rugged construction to yield a beam that weighs in at only 65 pounds. Feed impedance is 200 ohms, or 50 ohms with KLM's optional 4-kW PEP balun, priced at $14.95. The 20-meter monobander is priced at $199.95. For more information, use *check-off* on page 110, or write to KLM Electronics, 1600 Decker, San Martin, California 95056. If you're in a hurry, call them at (408) 683-4240.

More Details? CHECK—OFF Page 110

More Details? CHECK—OFF Page 110

More Details? CHECK—OFF Page 110

TABLE TOP CALCULATOR CASE & KEYBOARD ONLY



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This calculator chip has a full four-function memory, which is controlled by four keys, +M (adds entry into memory), -M (subtracts entry from memory), CM (clear memory, without clearing rest of registers), RM (read memory or use as entry).

- 12-Digit display and calculate
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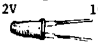


MV5024 red TO-18 — $ .35
high dome — 10 FOR 2.95

MV10B visible red — $ .30
5-7 ma @ 2V — 10 FOR 2.50

Memory IC 74S206

1x256 Bipolar TTL RAM (45 ns). One bit wide by 256 deep random access memory. Three-chip enable lines. Output is complement. Complete data supplied.

$3.95 ea. 10 for $32.00

3-Amp Power Silicon Rectifiers Marked Epoxy Axial Package

PRV	PRICE	PRV	PRICE
100.....	$ .10	800.....	$ .30
200.....	.15	1000....	.40
400.....	.18	1200....	.50
600.....	.23	1500....	.65

CMOS

CD4001	$ .75		
CD4002	.75	74C00	.75
CD4010	1.00	74C20	.75
CD4011	.75	74C160	3.25

7400 Series DIP

7400	$ .25	74L51	$ .30
74H00	.35	74H51	.35
7401	.25	7453	.20
7402	.35	7454	.25
74H01	.35	74L54	.35
7403	.30	74L55	.35
7404	.28	7460	.20
74H04	.35	74L71	.30
7405	.28	7472	.40
7406	.70	74L72	.50
74H05	.35	7473	.60
7408	.35	74L73	.75
74H08	.35	7474	.65
7410	.25	74L74	.80
74L10	.35	74H74	.80
74H11	.35	7475	1.40
7413	1.25	7476	.60
7417	.40	74L78	.80
7420	.25	7480	.65
74L20	.35	7483	1.00
74H20	.35	7489	4.00
74H22	.35	7490	1.20
7430	.25	7491	1.00
74H30	.35	7492	.90
74L30	.40	7493	1.15
7440	.25	7494	1.15
74H40	.35	7495	1.15
7441	1.25	74L95	2.00
7442	1.20	74121	1.25
7446	1.20	74123	1.50
7447	1.20	74154	2.30
		74161	2.00
7450	.25	74163	2.00
74H50	.35	74193	1.50
7451	.25	74195	1.00

RECTIFIERS

VARO FULL-WAVE BRIDGES

V5447	2A	400V	$ .90
V5647	2A	600V	1.10
MR810 Rect.	50V	1A	.10

Special 811: Hex Inverter

TTL DIP Hex Inverter; pin interchangeable with SN 7404. Parts are brand new and are branded Signetics and marked "811."

Data Sheet Supplied

EACH.......$ .30
10 FOR..... 2.50
100 FOR.... 23.00
1000 FOR... 220.00

MAN 3M

0-9 plus letters. Right-hand decimal point. Flat-pack type case. Long operating life. IC voltage requirements. Ideal for pocket calculators!

EACH $1.25
10 OR MORE 1.00
W/O DECIMAL .75

MAN4

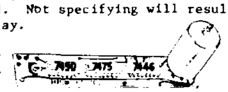
Seven-segment, 0-9 plus letters. Right-hand decimal point. Snaps in 14-pin DIP socket or Molex. IC voltage requirements. Ideal for desk or pocket calculators!

EACH.......$2.75
TEN OR MORE 2.50 EACH

CD-2 Counter Kit

This kit provides a highly sophisticated display section module for clocks, counters, or other numerical display needs. The unit is .8" wide and 4 3/8" long. A single 5-volt power source powers both the ICs and the display tube. It can attain typical count rates of up to 30 MHz and also has a lamp test, causing all 7 segments to light. Kit includes a 2-sided (with plated thru holes) fiberglass printed circuit board, a 7490, a 7475, a 7447, a DR 2010 RCA Numitron display tube, *complete instructions, and* enough Molex pins for the ICs . . NOTE: boards can be supplied in a single panel of up to 10 digits (with all interconnects); therefore, when ordering, please specify whether you want them in single panels or in one multiple digit board. Not specifying will result in shipping delay.

COMPLETE KIT, ONLY $11.95
FULLY-ASSEMBLED UNIT $13.00



Boards can be supplied separately @ $2.00 per digit.

LINEARS

NE540	70-watt power driver amp........	$2.00
NE555	precision timer.................	1.50
NE560	phase lock loop DIP.............	3.25
NE561	phase lock loop DIP.............	3.25
NE565	phase lock loop TO-5............	3.25
NE566	function generator TO-5.........	4.00
NE567	tone decoder....................	4.00
NE5558	dual 741 op amp MINI DIP........	1.00
709	popular op amp DIP..............	.45
710	voltage comparator DIP..........	.75
711	dual comparator DIP.............	.40
723	precision voltage regulator DIP.	1.00
741	op amp TO-5/MINI DIP............	.55
747	dual 741 op amp DIP.............	1.00
748	op amp TO-5.....................	1.00
CA3018	2 isolated transistors and a Darlington-connected transistor pair	1.00
CA3045	5 NPN transistor array..........	1.00
CA3026	dual differential amp...........	1.00
LM100	positive DC regulator TO-5......	1.00
LM105	voltage regulator...............	1.25
LM302	op amp voltage follower TO-5....	1.25
LM308	op amp TO-5.....................	2.00
LM311	comparator TO-5.................	1.75
LM370	AGC amplifier...................	2.00
LM309K	5V-1A power supply module TO-3..	2.00
LM3900	quad op amp.....................	2.00
LM1595	4-quadrant multiplier...........	2.00
8038	sine square triangle function generator..................	4.95

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- Built-in noise blanker
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  CW
  AM
  RTTY
- All essential functions front panel adjustable
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For the cleanest signal on the band, add this versatile accessory to your station today.

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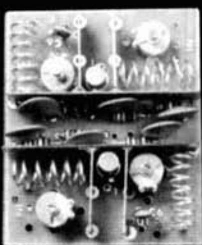

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Complete RTTY System and Accessories

Touch-Tone* to Dial Pulse Converter

Repeater Auto-Patch

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Variable Frequency, Variable Bandwidth CW/Phone Filter

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Is your tone decoder having problems due to input signal variations? If so, eliminate these and other problems caused by weak, strong or varying input signals. The AAGC-1 will take signal levels between 50 mV to 5 Volts and feed a clean rock stable signal to any decoder for perfect operation. Give your decoder a chance to decode properly with our AAGC-1 amplifier.

Shipping Weight 3 oz. $12.95 kit
$17.95 wired

DELUXE RECEIVER PREAMPS

Specially made for both OLD and NEW receivers. The smallest and most powerful single and dual stage preamps available. Bring in the weakest signals with a Data Preamp.

BAND	STAGES	GAIN	NOISE FIGURE	KIT PRICE	WIRED PRICE
10 meter	Single	20 dB	2 dB	$9.50	$12.50
6 meter	Single	20 dB	2 dB	$9.50	$12.50
2 meter	Single	20 dB	2.5 dB	$9.50	$12.50
2 meter	Double	40 dB	2.5 dB	$18.50	$24.50
220 MHz	Single	17 dB	2.5 dB	$9.50	$12.50
220 MHz	Double	35 dB	2.5 dB	$18.50	$24.50
*440 MHz	Single	14 dB	3 dB	$9.50	$12.50
*440 MHz	Double	28 dB	3 dB	$18.50	$24.50

*Available in June

DATA ENGINEERING INC.

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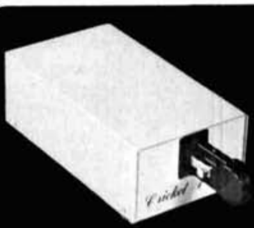

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A popularly-priced IC keyer with more features for your dollar. Cricket I is small in size and designed for the beginner as well as the most advanced operator. It provides fatigue-free sending and its clean, crisp CW allows for easy copying at all speeds. Turned on its side, the Cricket can be used as a straight key for manual keying. Right or left hand operation. AC/DC.

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SPACE-MATIC 21B

The SWITCHABLE Keyer — eight keyers in one! Selectable dot/dash memories, and character/word spacing. The perfectly-timed code sent by the SM-21B is as easy to copy as "Tape Code", and it gives the sender a distinguished "professional fist". When you buy the Space-Matic, you buy a "keyer for keeps". No need to trade next year for another keyer with additional features. They are all here today — in the SPACE-MATIC 21B!

Shipping Weight 4 lbs. $119.50

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ALL-BAND ANTENNA CONNECTOR

HYE-QUE 1 molded connector has eyelets for securing antenna elements, heavy copper leads, coax PL259 connector for feedline, and tie-point for antenna support. Drip-cap protects connector. Reinforced. At your dealer's, or **$3.95 postpd.** Companion insulators, **2 for 99¢ ppd.** Instructions included.

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LARGE INVENTORY OF COMPONENTS

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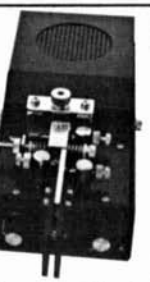

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with built in monitor
$64.95 ppd.

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PREAMP MICROPHONE 26 dB Gain 9 VDC @ 1ma	$3.85
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SWR METER, Stripline, Less 200µa Meter	$3.25
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DRILLS, #54, 56, 58 or 60 (each)	$.50
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EXCEPT AS NOTED ABOVE, ALL KITS ARE NEW, 100% SOLID STATE. AND COME COMPLETE WITH AN UNDRILLED G-10 PCB (PRINTED CIRCUIT BOARD) AND ALL PCB MOUNTED COMPONENTS. KITS ARE LESS POWER SUPPLIES, CHASSIS, AND ENCLOSURE HARDWARE. SEND SELF-ADDRESSED, STAMPED ENVELOPE FOR COMPLETE DATA SHEET AND SCHEMATIC.

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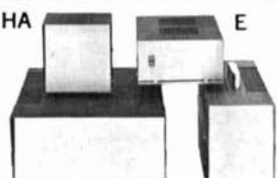
APOLLO PRODUCTS *by "Village Twig"*

1500X-2
Rotary Antenna Switch
Single pole, 3 position Antenna Switch • Low SWR • Use up to 30 MHz. 500 Watt handling capacity. Sloping Front Console Cab.
$12.95

HA E



L K

2100X-2 SWR Bridge
Large Meter - Sloping Panel Cabinet - Rubber Feet - Keep in Antenna Line up to 1 Kilowatt
$29.95

Model	Dimensions	Resale Net
"E"	6½ x 3 15/32 x 7 1/16	8.25
"HA"	5⅛ x 5½ x 4 (Blank Panel)	8.95
"K"	4¾ x 7⅜ x 11 W/Handle	13.50
"L"	11⅛ x 6⅛ x 12¾	20.50

900X-2 Wattmeter
Measurs RF in 2 ranges 25 and 250 watts. 52 Ohm input.
$29.95

450X-S Antenna Switch
3-Position Slide Switch Low Loss - Walnut-grain Finish Chassis - Gold Cover
$5.95

700X-2 KW Wattmeter
Dummy Load Wattmeter for 52 Ohm Input. Measures RF in 4 ranges to 1000 watts. Measures modulation percentage on calibrated scale. Portable.
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Meter O-1 MA
to fit "L" box
ppd. 5.00

"L"
package enclosure "Shadow Box" machined with: 2-SO239, 1 - Pilot Light, 3 - Rocker Switches, and 2 - Knobs
pkg. 29.95

1700X-2 Vertical/Horizontal Antenna Switch
Allows operator to select any one of 3 antennas or dummy load. Two Antennas can be switched in simultaneously. New Sloping Front Console Cab.
12.95

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Vacation or Occasional Miniature Antenna.
Measures 27″ high, 22″ wide, 4″ thick! 7 MHz antenna 40 meters. Ideal for apartment motel, hotel, trailer camper, travel use. 1973 production, if demand warrants.

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Wilson Electronics Presents The Finest 2 Meter Hand Held With the Hottest Rx Front End on The Market.

2 METER FM TRANSCEIVER MODEL 1402SM

FREQUENCY .... 140 - 150 MHZ (2 MHZ SPREAD)
NUMBER OF CHANNELS 6
Supplied with 146.94 Simplex
146.34/94 - 146.16/76
R.F. Output .... 2 Watts minimum
Sensitivity .... better than 0.3 MV/20 DB Q.S.
Audio Output .... 500 mv
Meter .... Monitors battery voltage on Tx, S meter on Rx
Weight .... 1 lb. 4 ounces without battieres
Current drain .... 15 MA Rx
410 MA Tx
Size 8 7/8" x 1 7/8" x 2 7/8"
Includes Adjustable Whip Ant

$239.00 Amateur Net Price

MODEL # ACCESSORIES

1410A 12 Watt Power Amplifier Also Includes Steel Case For 1402SM - Charges 1402 SM When Pluged into Cigarette Lighter **99.00**

LCL LEATHER CASE 12.00
14BC BATTERY CHARGER ... 29.95
SM1 SPEAKER MIKE 24.00

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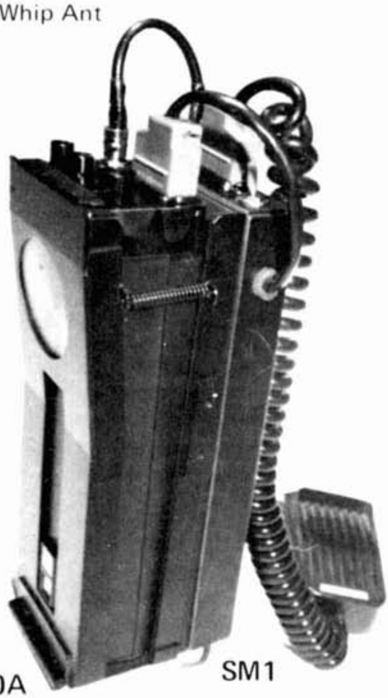
COMMERCIAL VERSION AVAILABLE



1410A SM1

Wilson Electronics

P.O. Box 794 Henderson, Nevada 89015
Telephone (702) 451-5791 451-6650

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MOTOROLA *QUALITY*

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MOTOROLA T43 SERIES MOBILES

- Convertible to 2 meters
- 25 watt ouput
- Trunk or Dash mount avail.
- Mobile accs. included

Normally $75.00 **SPECIAL $55.00**

MFA-22 SYNTHESIZER BY RP

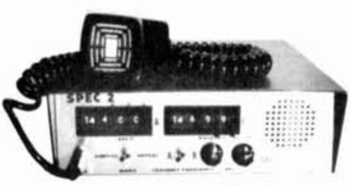
- Full 2mtr band coverage
- Exceptionally clean output
- Both simplex & repeater modes
- Adaptable to any radio
- 1 year warranty

Basic model **$275.00**

SPECIAL PACKAGE

T43 series radio	$ 55.00
MFA-22 Synthesizer	275.00
Interstage tripler for T43	15.00
Normally	345.00
Special Package	$315.00

NOW AVAILABLE FOR IMMEDIATE DELIVERY



SPEC II

- **Completely Synthesized**
- **"Motorola Quality" circuit board**

The SPEC II 2 meter transceiver combines the RP MFA-22 synthesizer with a transceiver circuit board of "Motorola Quality". With the SPEC II's 400 channel capability you are not limited to only 30 kHz channels or 600 kHz spaced repeaters. Write for complete specs on the only radio of its kind made and delivered at this time.

$489.00

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now available

...TPL VHF-UHF power amplifiers

TPL brings you the finest amateur RF amplifiers for VHF FM available today. Only state-of-the-art techniques in circuit and semi conductor technology make an amplifier of this quality possible.

The amplifying transistors are of the balanced emitter silicon power type. Each one is individually checked for power output and reliability during mismatch conditions. They are operated *well within the factory's suggested limitations* for added reliability and life. Most circuitry is of micro-strip technique for stability and broadband characteristics. Antenna switching is accomplished through the use of a specially selected RF relay . . . activated by only one watt of RF power through an RF sensing circuit. During receive, the antenna by-passes the amplifier and is fed through the relay to the transceiver. Also of note is a reverse voltage protection diode which protects the power transistors from destruction in the event the amplifier is connected to the wrong polarity. *TPL amplifiers are simple to install and fool-proof* to operate. With proper care, they will provide a lifetime of dependable service.

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TPL is the largest manufacturer of accessory solid state RF power amplifiers in the world.
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TWO GREATS for GREAT TWO METERS

FROM ICOM.....of course

IC-21····24 channel capability, with 7 channels supplied. It's MOSFET front end provides better than .4uv sensitivity at 20 db quieting. 5 helical filters virtually eliminate intermodulation. Built in AC and DC power supplies. Modular construction, of course. Many other features make the **IC-21** a great two meter transceiver.

IC-230····67 channels with 30KHz separation for simplex operation from 146.01 to 147.99MHz, synthesized with INOUE'S unique Phase Locked Loop (PLL) system. One switch puts you up or down 600 KHz for use with repeaters. Modular construction makes service a snap, if it's ever needed.

Helical filters, MOSFET front end, and an Automatic Protection Circuit, for the final transistors, are only some of the outstanding features of the **IC-230**. It's the great synthesized two meter radio today, and will still be tomorrow!

The **IC-3PA** is a regulated DC power supply for all the INOUE mobile transceivers. Use it with your **IC-230** for base operation. It's completely regulated, and gives you an indication of it's operating condition; normal, low voltage, excessive current, or if the protection circuit is working. These are shown through the use of eye catching indicator lamps. There is also a built in speaker in the cabinet.

ICOM

INOUE COMM.EQUIP.CORP.
3-8 Kamikurazukuri-cho
Higashi Sumiyoshi-ku
Osaka, Japan

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QSLs CATALOG SAMPLES 35¢. Ritz Print Shop, 5810 Detroit Avenue, Cleveland, Ohio 44102.

MONTREAL HAMFEST 74, August 4, MacDonald College Farm, Ste. Anne de Bellevue. Prizes, giant fleamarket, technical sessions, family fun, $2.50/adult. Info contact: VE2RM, Box 201, Pointe Claire-Dorval, Quebec, H9R 4N9.

6939's, 6360's, Guaranteed good, $2.50 each. Jack W6TNR, 15718 Mayall, Sepulveda, Calif. 91340.

JUNE 2 — SRRC HAMFEST — new site — Bureau County Fairgrounds, Princeton, Illinois. Formerly held at Ottawa, Illinois. Easy access Rtes. 80-180-6-29-34. Advance registration, $1.50 before May 20, $2.00 at the gate. See our notice in QST or write G. E. Keith, W9QLZ/W9MKS, Rfd #1, Box 171, Oglesby, Illinois 61348.

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QSL's, *Sample catalog 20¢.* N & S Print, P. O. Box 11184, Phoenix, Ariz. 85061.

WANTED: Commercial test equipment catalogs, 1955 or earlier thru 1972. Alfred, Ballantine, Fluke, General Radio, Hewlett-Packard, Lambda, L&N, Kintel, Measurements, Tektronix, etc. Short-time loan for research project. All items will be returned if requested. Jim Fisk, W1DTY, editor-in-chief, **ham-radio**, Greenville, NH 03048.

LEDS, sample pack of 10, includes green and yellow, $3.25 postpaid U.S.A. East Coast Electronics, 50 Scott St., Hamburg, N. Y. 14075.

HALLICRAFTERS STATION — SX101 with matching speaker, manual, $135; HT-32A, $195. Pick up both for $310, take TA33jr/AR22 FREE. Will demonstrate on air or in shack. WA2RJZ, 416 Victory Dr., Lake Ronkonkoma, N. Y. 11779.

THE TRI-STATE ARS will hold their annual hamfest on May 11, 1974, at the 4-H Fairgrounds, U.S. 41, three miles north of town. Overnight camping, auction, flea market, door prizes, and ladies bingo. For information or advanced registration contact: Steve, WB9MDB, 5805 Berry Lane, Evansville, Indiana 47710.

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SELL THE FOLLOWING: HW101, HP23, SB600, $250 firm! WB9KUQ, Box 28, Bunker Hill, In. 46914.

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SOLARWIND . . . The New Sun Power — Wind Power Newsletter . . . News, Theory, Experiments, Projects, Plans . . . Sample Copy $1.00. Mallmann Optics and Electronics, Dept.-S1, 836 South 113, West Allis, Wisconsin 53214.

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More Details? CHECK—OFF Page 110

THE MARYLAND MOBILEERS ARC Hamfest is June 16, at Anne Arundel Community College, Arnold, Maryland at 10:00 a.m. rain or shine. Talk-in on 146.10/.70 and 146.94. Games, refreshments, contests and an auction are planned. Top awards a two-meter transceiver and an electronic calculator. Registration $2.00, tailgating $2.00. Free parking. For information contact Ted Redick, K3UPU, 2 Acton Place, Annapolis, Md. 21401. Phone (301) 269-5577.

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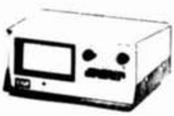

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PRINTED CIRCUIT BOARD 2 oz. copper on glass epoxy base, approx. 5″ x 6″. Your choice copper on one or both sides. **3/$1.25**

IN 914 DIODES **$.10 each, $1.00 dozen**

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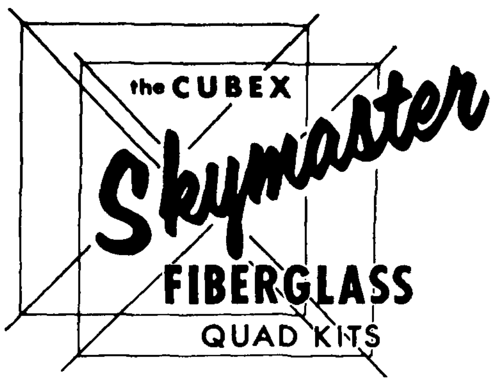

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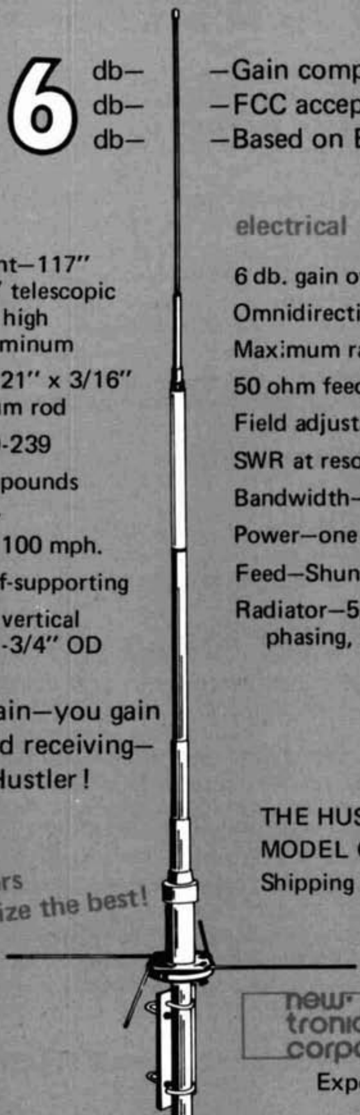

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