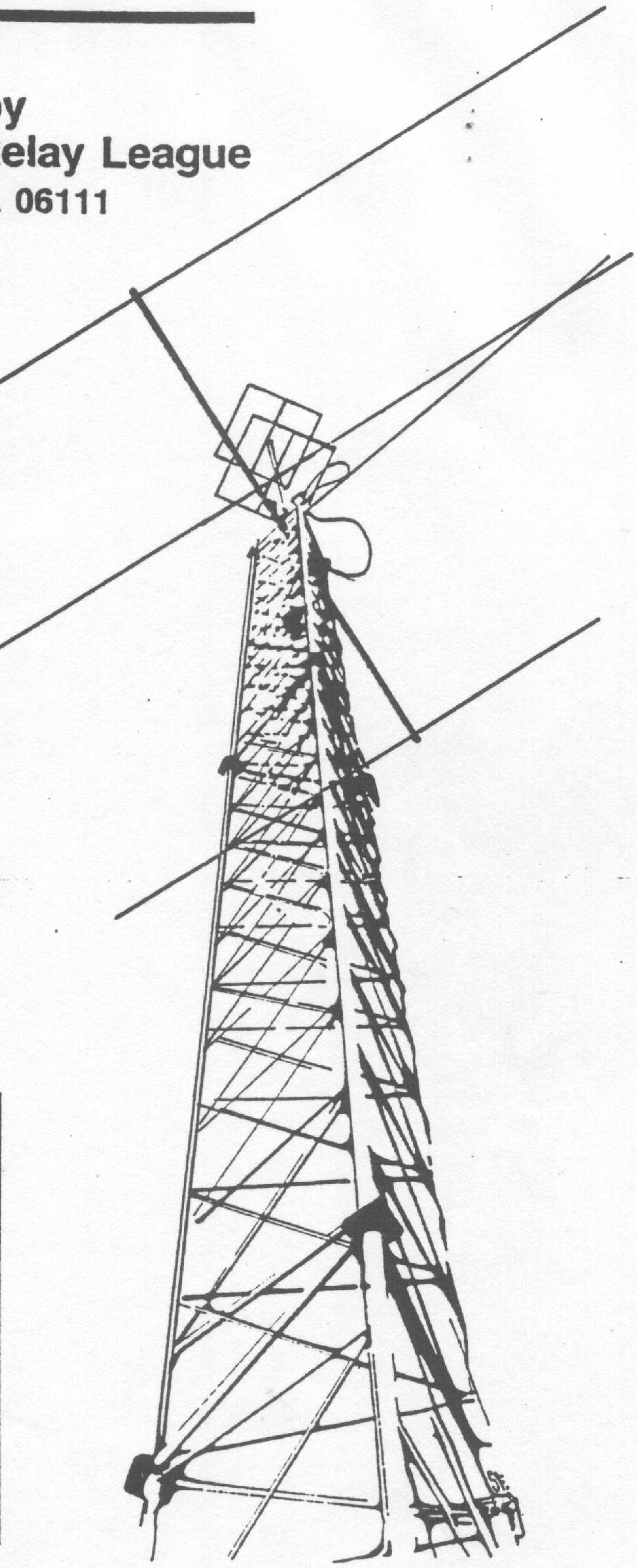
The ARRL Antenna Book

Published by
The American Radio Relay League
Newington, CT USA 06111



Editor
Gerald (Jerry) Hall, K1TD

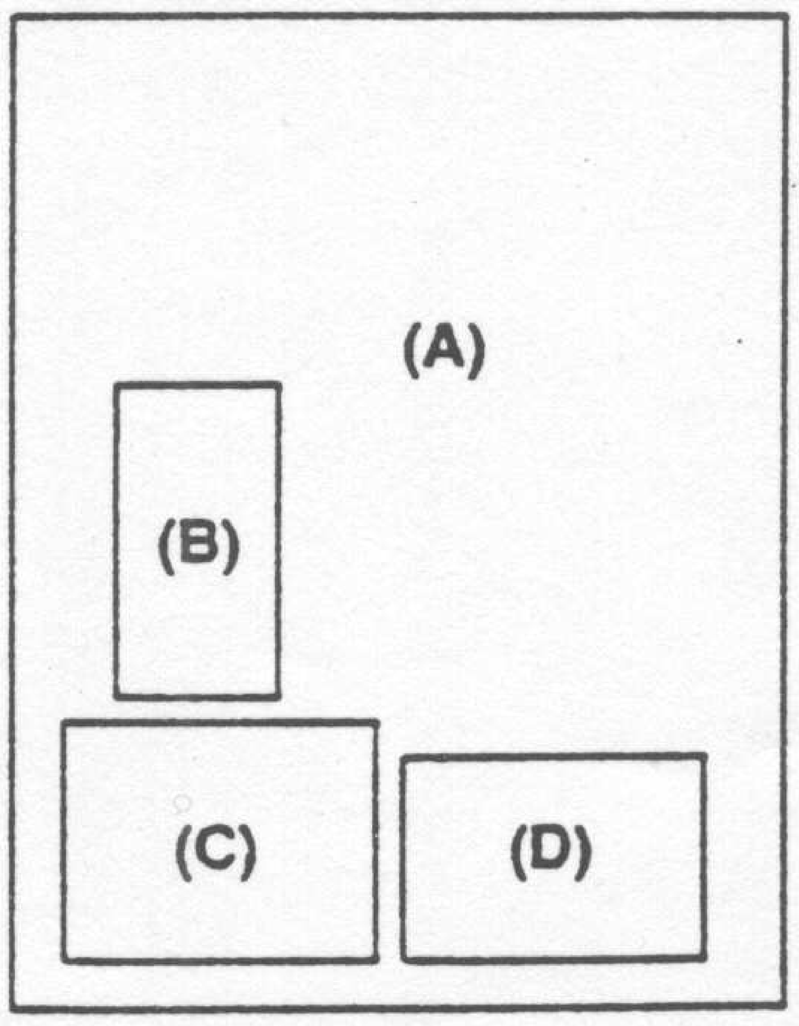
Associate Editor
James W. Healy, NJ2L

Assistant Editors
Bruce S. Hale, KB1MW
Charles L. Hutchinson, K8CH
Mark J. Wilson, AA2Z
Larry Wolfgang, WA3VIL

Contributing Authors
John Almeida, KA1AIR
Wilfred N. Caron
Steve Cerwin, WA5FRF
Roger A. Cox, WB0DGF
Philip V. D'Agostino, W1KSC
Richard Guski, KC2MK
Robert (Ted) Hart, W5QJR
F. Robert Hawk, K0YEH
John Kraus, W8JK
Roy W. Lewallen, W7EL
Domenic M. Mallozzi, N1DM
Jim McKim, W0CY
William T. Schrader, K2TNO
Ralph Shaw, K5CAV
Allan White, W1EYI
Thomas Willeford, N8ETU

Contributors
Chip Angle, N6CA
Bob Atkins, KA1GT
Thomas A. Beery, WD5CAW
Dennis Bodson, W4PWF
Bruce Brown, W6TWW
Warren Bruene, W5OLY
Robert E. Cowan, K5QIN
Dave Fisher, W0MHS
Donald K. Johnson, W6AAQ
M. Walter Maxwell, W2DU
Charles J. Michaels, W7XC
Bill Myers, K1GQ
Jack Sobel, W0SVM
John J. Uhl, KV5E
Brian L. Wermager, K0EOU
Frank J. Witt, AI1H
Deane J. Yungling, KI6O

Production
Leslie Bartoloth, KA1MJP
Laird Campbell, W1CUT
Michelle Chrisjohn, WB1ENT
Sue Fagan, cover
Alison Halapin
Mark Kajpust
Joel Kleinman, N1BKE
Steffie Nelson, KA1IFB
David Pingree
Jean Wilson



A—Photo of 120-foot tower at W1AW by Meyers Studio. Moon photo courtesy Chuck Hutchinson, K8CH

B—Photo courtesy Bob Cutter, KI0G

C—30-foot polar-mount dish at K5AZU

D—12 17-element long-boom 2-meter Yagis at N5BLZ ntenna whose height is equal to or greater than the loop effective height. This vertical is physically close to the loop, and when its omnidirectional pattern is adjusted so that its amplitude and phase are equal to one of the loop lobes, the patterns combine to form a cardioid. This antenna can be made quite compact by use of a ferrite loop to form a portable DF antenna for HF direction finding. Chapter 14 contains additional information and construction projects using sensing elements.

Arrays of Loops

A more advanced array which can develop more diverse patterns consists of two or more loops. Their outputs are combined through appropriate phasing lines and combiners to form a phased array. Two loops can also be formed into an array which can be rotated without physically turning the loops themselves. This method was developed by Bellini and Tosi in 1907 and performs this apparently contradictory feat by use of a special transformer called a goniometer. The goniometer is described in Chapter 14.

Aperiodic Arrays

The aperiodic loop array is a wide-band antenna. This type of array is useful over at least a decade of frequency, such as 2 MHz to 20 MHz. Unlike most of the loops discussed up to now, the loop elements in an aperiodic array are untuned. Such arrays have been used commercially for many years. One loop used in such an array is shown in Fig 13. This loop is quite different from all the loops discussed so far in this chapter because its pattern is not the familiar figure eight. Rather, it is omnidirectional.

The antenna is omnidirectional because it is purposely unbalanced, and also because the isolating resistor causes the antenna to appear as two closely spaced short monopoles. The loop maintains the omnidirectional characteristics over a frequency range of at least four or five to one. These loops, when combined into end-fire or broadside phased arrays, can provide quite impressive performance. A commercially made end-fire array of this type consisting of four loops equally spaced along a 25-meter baseline can provide gains in excess of 5 dBi over a range of 2 to 30 MHz. Over a considerable portion of this frequency range, the array can maintain F/B ratios of 10 dB. Even though the commercial version is very expensive, an amateur version can be constructed using the information provided by Lambert. One interesting feature of this type of array is that, with the proper combination of hybrids and combiners, the antenna can simultaneously feed two receivers with signals from different directions, as shown in Fig 14. This antenna may be especially interesting to one wanting a directional receiving array for two or more adjacent amateur bands.

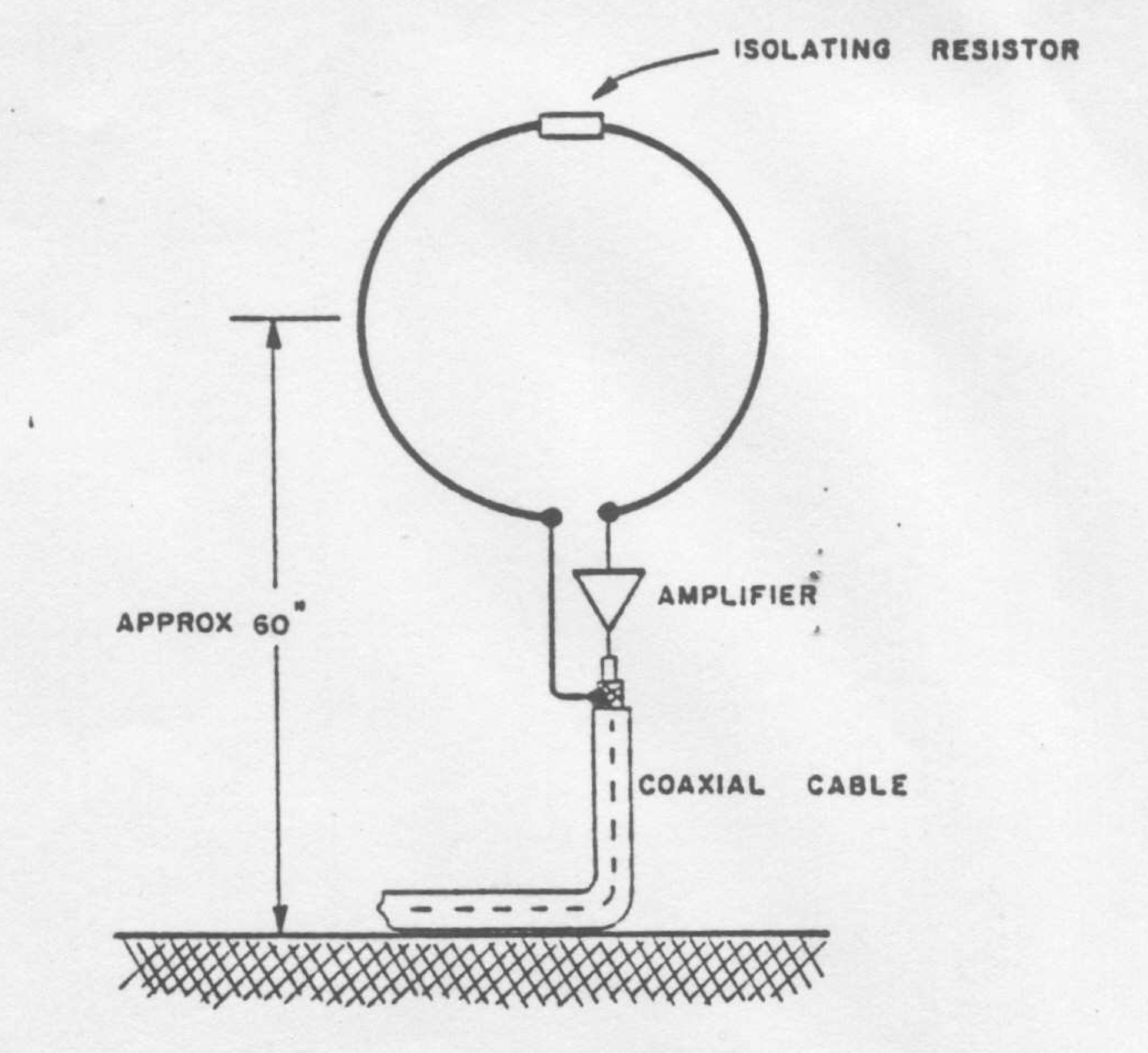


Fig 13—A single wide-band loop antenna used in an aperiodic array.

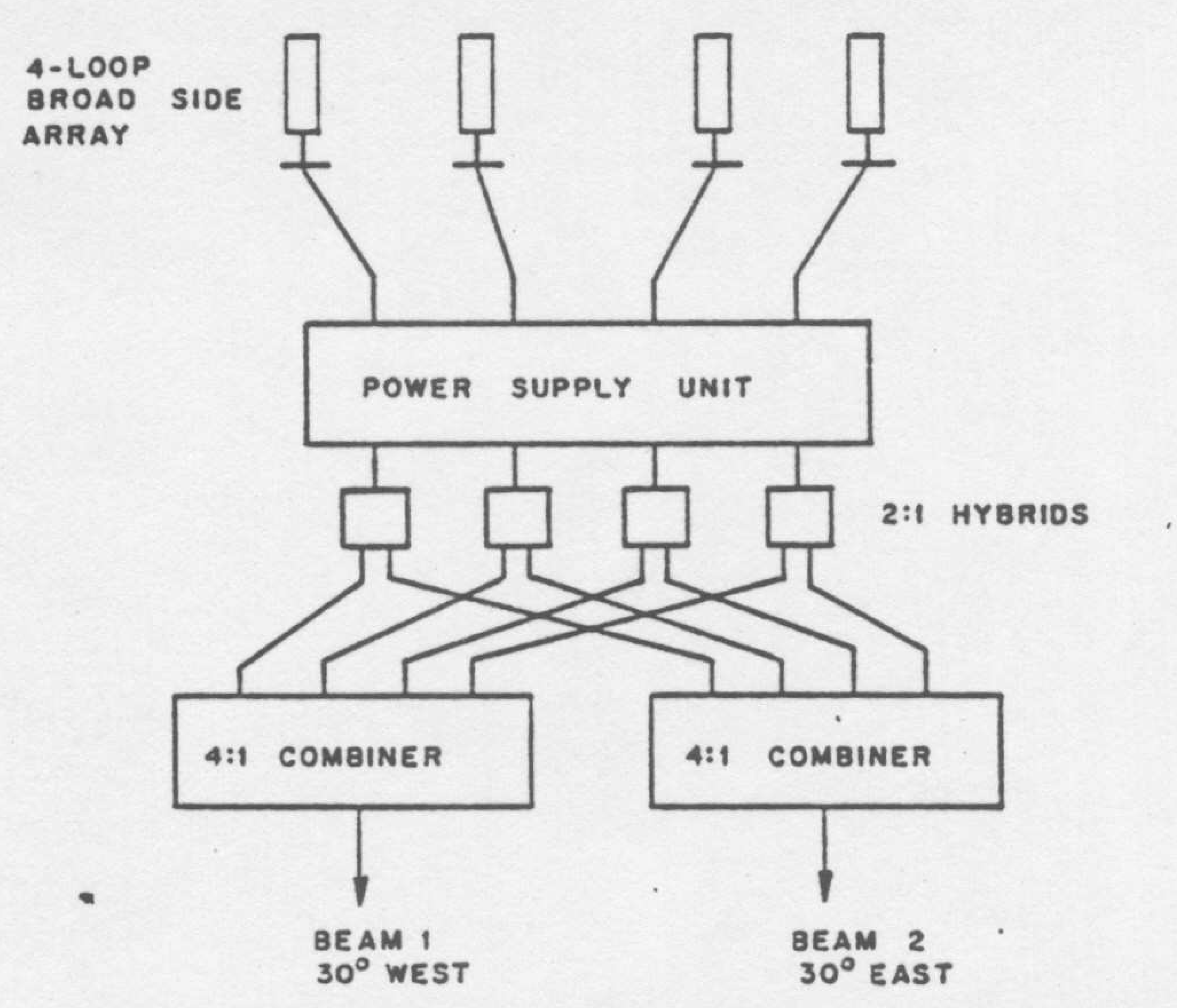


Fig 14—Block diagram of a four-loop broadside array with dual beams separated by 60° in azimuth.

TRANSMITTING LOOP ANTENNAS

The electrically small transmitting loop antenna involves ome different design considerations from receiving loops. Jnlike receiving loops, the size limitations of the antenna are ot as clearly defined. For most purposes, any transmitting oop whose physical circumference (not total conductor ngth) is less than ¼ λ can be considered small. In most cases, s a consequence of their relatively large size (when compared) a receiving loop), transmitting loops have a nonuniform urrent distribution along their circumference. This leads to me performance changes from a receiving loop.

The transmitting loop is a parallel-tuned circuit with a large inductor acting as the radiator. As with the receiving loop, the calculation of the transmitting loop inductance may be carried out with the equations in Table 1. Avoid equations for long solenoids found in most texts. Other fundamental equations for a transmitting loop are given in Table 3.

In recent years, two types of transmitting loops have been predominant in the amateur literature: the "army loop" by Lew McCoy, W1ICP, and the "high efficiency" loop by Ted Hart, W5QJR. The army loop is a version of a loop designed

Table 3
Transmitting Loop Equations

$X_L = 2\pi fL$ ohms

$$Q = \frac{f}{\Delta f} = \frac{X_L}{2(R_R + R_L)}$$

$$R_R = 3.12 \times 10^4 \left[\frac{NA}{\lambda^2}\right]^2 \text{ ohms}$$

$$V_c = \sqrt{PX_LQ}$$

$$I_L = \sqrt{\frac{PQ}{X_L}}$$

where

X_L = inductive reactance, ohms
f = frequency, Hz
Δf = bandwidth, Hz
R_R = radiation resistance, ohms
R_L = loss resistance, ohms (see text)
N = number of turns
A = area enclosed by loop, square meters
λ = wavelength at operating frequency, meters
V_c = voltage across capacitor
P = power, watts
I_L = resonant circulating current in loop

for portable use in Southeast Asia by Patterson of the US Army. This loop is diagrammed in Fig 15A. It can be seen by examination that this loop appears as a parallel tuned circuit, fed by a tapped capacitance impedance-matching network. The Hart loop, shown in Fig 15B, has the tuning capacitor separate from the matching network. The matching network is basically a form of gamma match. (Additional da and construction details for the Hart loop are presented lat in this chapter.) Here we cover some matters which ar common to both antennas.

The radiation resistance of a loop in ohms is given b

$$R_R = 3.12 \times 10^4 \left(\frac{N A}{\lambda^2}\right)^2 \qquad \text{(Eq 1}$$

where

N = number of turns
A = area of loop in square meters
λ = wavelength of operation in meters

It is obvious that within the constraints given, th radiation resistance is very small. Unfortunately the loop ha losses, both ohmic and from skin effect. By using th information, the radiation efficiency of a loop can b calculated from

$$\eta = \frac{R_R}{R_R + R_L} \times 100 \qquad \text{(Eq 1}$$

where

η = antenna efficiency, %
R_R = radiation resistance, Ω
R_L = loss resistance, Ω

A simple ratio of R_R versus R_L shows the effects on th efficiency, as can be seen from Fig 16. The loss resistance i primarily the ac resistance of the conductor. This can be calculated from Eq 6. A transmitting loop generally require the use of copper conductors of at least ¾ inch in diamete in order to obtain efficiencies that are reasonable. Tubing i as useful as a solid conductor because high-frequency current flow only along a very small depth of the surface of the conductor; the center of the conductor has almost no effec on current flow.

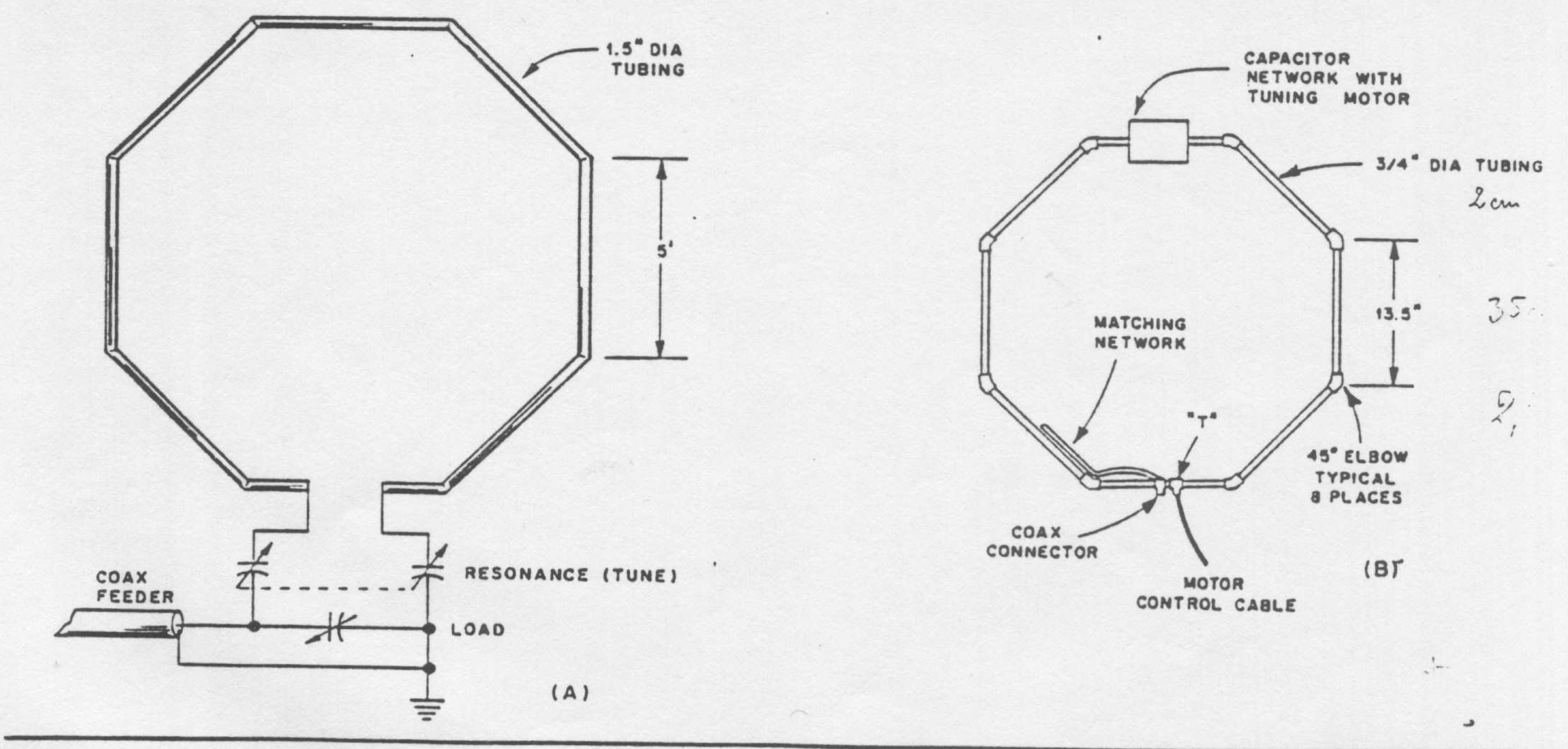


Fig 15—At A, a simplified diagram of the army loop. At B, the W5QJR Hart loop, which is described in more detail later in this chapter.

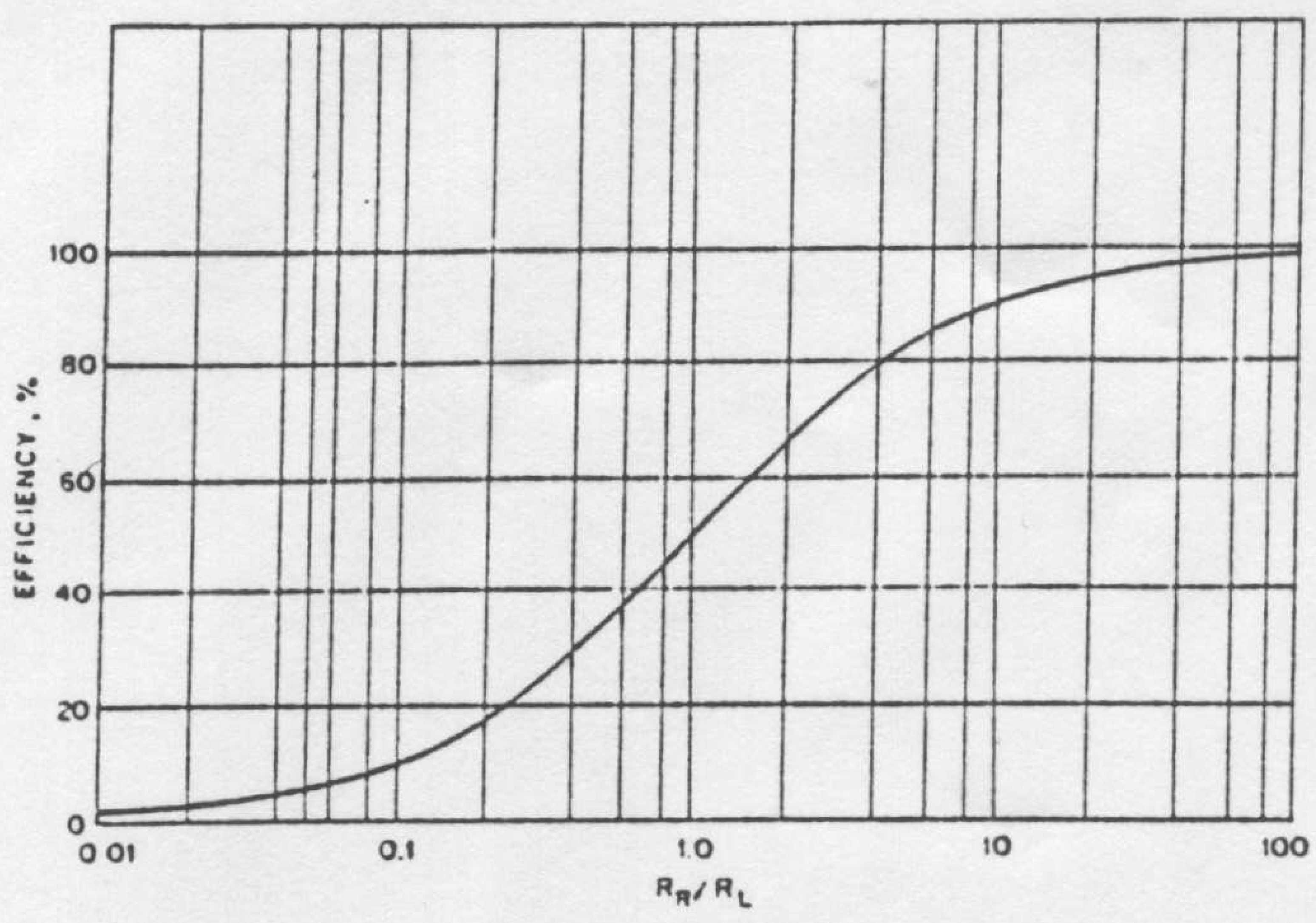


Fig 16—Effect of the ratio of R_R/R_L on loop efficiency.

In the case of multiturn loops there is an additional loss related to a term called proximity effect. The proximity effect occurs in cases where the turns are closely spaced (such as being spaced one wire diameter apart). As these current-carrying conductors are brought close to each other, the current density around the circumference of each conductor gets redistributed. The result is that more current per square meter is flowing at the surfaces adjacent to other conductors. This means that the loss is higher than a simple skin-effect analysis would indicate, because the current is bunched so it flows through a smaller cross section of the conductor than if the other turns were not present.

As the efficiency of a loop approaches 90%, the proximity effect is less serious. But unfortunately, the less efficient the loop, the worse the effect. For example, an 8-turn transmitting loop with an efficiency of 10% (calculated by the skin-effect method) actually only has an efficiency of 3% because of the additional losses introduced by the proximity effect. If you are contemplating construction of a multiturn transmitting loop, you might want to consider spreading the conductors apart to reduce this effect. G. S. Smith includes graphs that detail this effect in his 1972 IEEE paper.

The components in a resonated transmitting loop are subject to both high currents and voltages as a result of the large circulating currents found in the high-Q tuned circuit formed by the antenna. This makes it important that the capacitors have a high RF current rating, such as transmitting micas or the Centralab 850 series. Be aware that even a 100-watt transmitter can develop currents in the tens of amperes, and voltages across the tuning capacitor in excess of 10,000 volts. This consideration also applies to any conductors used to connect the loop to the capacitors. A piece of no. 14 wire may have more resistance than the rest of the loop conductor. It is therefore best to use copper strips or the braid from a piece of large coax cable to make any connections. Make the best electrical connection possible, using soldered or welded joints. Using nuts and bolts should be avoided, because at RF these joints generally have high resistance, especially after being subjected to weathering.

An unfortunate consequence of having a small but high-efficiency transmitting loop is high Q, and therefore limited bandwidth. This type of antenna may require retuning for frequency changes as little as 5 kHz. If you are using any wide-band mode such as AM or FM, this might cause fidelity problems and you might wish to sacrifice a little efficiency to obtain the required bandwidth.

A special case of the transmitting loop is that of the ferrite loaded loop. This is a logical extension of the transmitting loop if we consider the improvement that a ferrite core makes in receiving loops. The use of ferrites in a transmitting loop is still under development. (See the bibliography reference for DeVore and Bohley.)

Small High Efficiency Loop Antennas for Transmitting

The ideal small transmitting antenna would have performance equal to a large antenna. A small loop antenna can approach that performance except for a reduction in bandwidth, but that effect can be overcome by retuning. This section was written by Robert T. (Ted) Hart, W5QJR. It includes information extracted from his book, *Small High Efficiency Antennas Alias the Loop.*

Small antennas are characterized by low radiation resistance. Typically, loading coils are added to small antennas to achieve resonance. However, the loss in the coils results in an antenna with low efficiency. If instead of coils a large capacitor is added to a low-loss conductor to achieve resonance, and if the antenna conductor is bent to connect the ends to the capacitor, a loop is formed. Based on this concept, the small loop is capable of high efficiency. In addition, the small loop, when mounted vertically, has the unique characteristic of radiation at all elevation angles. Therefore it can replace both vertical and dipole antennas. Small size and high efficiency are advantages of using a properly designed and constructed loop on the lower frequency bands.

The only deficiency in a small loop antenna is narrow bandwidth; it must be tuned to the operating frequency. However, the use of a remote motor drive allows the loop to be tuned over a wide frequency range. For example, two loops could be constructed to provide continuous frequency coverage from 3.5 to 30 MHz.

The small transmitting loop has been around since 1957 (see the Patterson bibliography reference). Only recently has the small loop been developed into a practical antenna for amateurs. The most important aspect of the development was establishing a complete set of mathematical equations to define the loop. This was followed by designing a simple feed system, and finally a practical tuning capacitor was found. The results of this development program are presented here. Fig 17 presents computer-derived data for various size loop antennas for the HF amateur bands.

Loop Fundamentals

A small loop has the radiation pattern shown in Fig 18. The pattern is easily conceived as a doughnut with a hole (null) in the pattern through the center of the loop at low elevation angles. When the circumference of the loop is less than ⅓ λ, regardless of the shape of the loop (round or square), that pattern will be obtained. In the majority of applications the loop will be mounted vertically. Mounted this way, it radiates at all vertical angles in the plane of the loop.

The loop has been defined mathematically by the

$\omega\lambda = 2\pi f$ $\lambda = \frac{3 \cdot 10^8}{f}$

Loop No. 1
Frequency range, MHz 40 - 7.6-29.4
Loop circumference, feet 8.5 2,6 m → d = 83 cm
Conductor dia, inches 0.9 2,28 cm 33,5 cm
Radials No

Frequency, MHz	10.1	14.2	18.0	21.2	24.0	29.0
Efficiency, dB below 100%	−6.5	−3.1	−1.6	−1.0	−0.7	−0.4
Bandwidth, kHz	5.5	9.9	18.2	30.2	46.0	91.4
Q	1552	1212	835	591	439	267
Tuning capacitance, pF	102.6	48.0	26.8	17.1	11.6	5.4
Capacitor voltage, kV P-P	38.21	40.03	37.40	34.16	31.32	26.86
Capacitor spacing, inches	0.255	0.267	0.249	0.228	0.209	0.179
Radiation resistance, ohms	0.009	0.034	0.088	0.170	0.279	0.594
Loss resistance, ohms	0.030	0.035	0.040	0.043	0.046	0.051

Loop No. 2
Frequency range, MHz 3.6-16.4
Loop circumference, feet 20
Conductor dia, inches 0.9
Radials No

Frequency, MHz	4.0	7.2	10.1	14.2
Efficiency, dB below 100%	−8.9	−2.7	−1.0	−0.3
Bandwidth, kHz	3.3	8.4	22.1	73.8
Q	1356	965	515	217
Tuning capacitance, pF	310.5	86.1	36.8	11.6
Capacitor voltage, kV P-P	38.28	43.33	37.48	28.83
Capacitor spacing, inches	0.255	0.289	0.250	0.192
Radiation resistance, ohms	0.007	0.069	0.268	1.047
Loss resistance, ohms	0.044	0.059	0.070	0.083

Loop No. 3
Frequency range, MHz 2.1-10.0
Loop circumference, feet 38
Conductor dia, inches 0.9
Radials No

Frequency, MHz	3.5	4.0	7.2
Efficiency, dB below 100%	−4.1	−3.0	−0.5
Bandwidth, kHz	4.2	5.6	33.2
Q	1014	880	265
Tuning capacitance, pF	192.3	142.4	29.9
Capacitor voltage, kV P-P	45.63	45.43	33.47
Capacitor spacing, inches	0.304	0.303	0.223
Radiation resistance, ohms	0.050	0.086	0.902
Loss resistance, ohms	0.079	0.084	0.113

Loop No. 4
Frequency range, MHz 0.9-4.1
Loop circumference, feet 100 30,5 d = 9,7 m.
Conductor dia, inches 0.9
Radials No

Frequency, MHz	1.8	2.0	3.5	4.0
Efficiency, dB below 100%	−2.7	−2.1	−0.4	−0.2
Bandwidth, kHz	3.4	4.4	27.7	45.9
Q	663	565	156	108
Tuning capacitance, pF	215.7	166.4	24.9	8.8
Capacitor voltage, kV P-P	46.75	45.48	31.63	28.09
Capacitor spacing, inches	0.312	0.303	0.211	0.187
Radiation resistance, ohms	0.169	0.257	2.415	4.120
Loss resistance, ohms	0.148	0.157	0.207	0.221

Fig 17—Design data for loops to cover various frequency ranges. The information is calculated for an 8-sided loop, as shown in Fig 20. The capacitor specification data is based on 1000 W of transmitted power. See text for modifying these specifications for other power levels.

equations in Table 4. By using a computer and entering the circumference of the loop and the conductor diameter, all of the performance parameters can be calculated from these equations. Through such an analysis, it has been determined that the optimum size conductor is ¾-inch copper pipe, considering both performance and cost.

The loop circumference should be between 1/4 and 1/8 λ at the operating frequency. It will become self-resonant above ¼ λ, and efficiency drops rapidly below 1/8 λ. In the frequency ranges shown in Fig 17, the high frequency is for 5 pF of tuning capacitance, and the low frequency is that at which the loop efficiency is down from 100% by 10 dB.

Where smaller loops are needed, the efficiency can be increased by increasing the pipe size or by adding radials to form a ground screen under the loop (data are given in Fig 17). The effect of radials is to double the antenna area

Loop No. 5							
Frequency range, MHz	5.1-29.4						
Loop circumference, feet	8.5						
Conductor dia, inches	0.9						
Radials	Yes						
Frequency, MHz	*7.2*	*10.1*	*14.2*	*18.0*	*21.2*	*24.0*	*29.0*
Efficiency, dB below 100%	−5.8	−2.7	−1.0	−0.5	−0.3	−0.2	−0.1
Bandwidth, kHz	4.9	9.2	24.4	55.7	102.4	164.6	344.1
Q	1248	925	490	272	174	123	71
Tuning capacitance, pF	209.7	102.6	48.0	26.8	17.1	11.6	5.4
Capacitor voltage, kV P-P	28.92	29.49	25.46	21.36	18.55	16.56	13.84
Capacitor spacing, inches	0.193	0.197	0.170	0.142	0.124	0.110	0.092
Radiation resistance, ohms	0.009	0.035	0.137	0.353	0.679	1.115	2.377
Loss resistance, ohms	0.025	0.030	0.035	0.040	0.043	0.046	0.051

Loop No. 6					
Frequency range, MHz	2.4-16.4				
Loop circumference, feet	20				
Conductor dia, inches	0.9				
Radials	Yes				
Frequency, MHz	*3.5*	*4.0*	*7.2*	*10.1*	*14.2*
Efficiency, dB below 100%	−5.7	−4.3	−0.8	−0.3	−0.1
Bandwidth, kHz	3.7	4.6	21.9	74.5	278.7
Q	1061	976	369	152	57
Tuning capacitance, pF	409.8	310.5	86.1	36.8	11.6
Capacitor voltage, kV P-P	31.68	32.48	26.80	20.40	14.83
Capacitor spacing, inches	0.211	0.217	0.179	0.136	0.099
Radiation resistance, ohms	0.015	0.026	0.277	1.072	4.187
Loss resistance, ohms	0.041	0.044	0.059	0.070	0.083

Loop No. 7					
Frequency range, MHz	1.4-10.0				
Loop circumference, feet	38				
Conductor dia, inches	0.9				
Radials	Yes				
Frequency, MHz	*1.8*	*2.0*	*3.5*	*4.0*	*7.2*
Efficiency, dB below 100%	−7.0	−5.8	−1.4	−1.0	−0.1
Bandwidth, kHz	2.3	2.6	9.2	14.0	121.8
Q	955	924	467	350	72
Tuning capacitance, pF	783.7	630.9	192.3	142.4	29.9
Capacitor voltage, kV P-P	31.74	32.92	30.97	28.64	17.48
Capacitor spacing, inches	0.212	0.219	0.206	0.191	0.117
Radiation resistance, ohms	0.014	0.021	0.201	0.344	3.607
Loss resistance, ohms	0.056	0.059	0.079	0.084	0.113

Loop No. 8				
Frequency range, MHz	0.6-4.1			
Loop circumference, feet	100			
Conductor dia, inches	0.9			
Radials	Yes			
Frequency, MHz	*1.8*	*2.0*	*3.5*	*4.0*
Efficiency, dB below 100%	−0.9	−0.6	−0.1	−0.1
Bandwidth, kHz	8.7	12.5	104.2	176.4
Q	255	197	41	28
Tuning capacitance, pF	215.7	166.4	24.9	8.8
Capacitor voltage, kV P-P	29.01	26.87	16.30	14.32
Capacitor spacing, inches	0.193	0.179	0.109	0.095
Radiation resistance, ohms	0.676	1.030	9.659	16.478
Loss resistance, ohms	0.148	0.157	0.207	0.221

Fig 17 Continued.

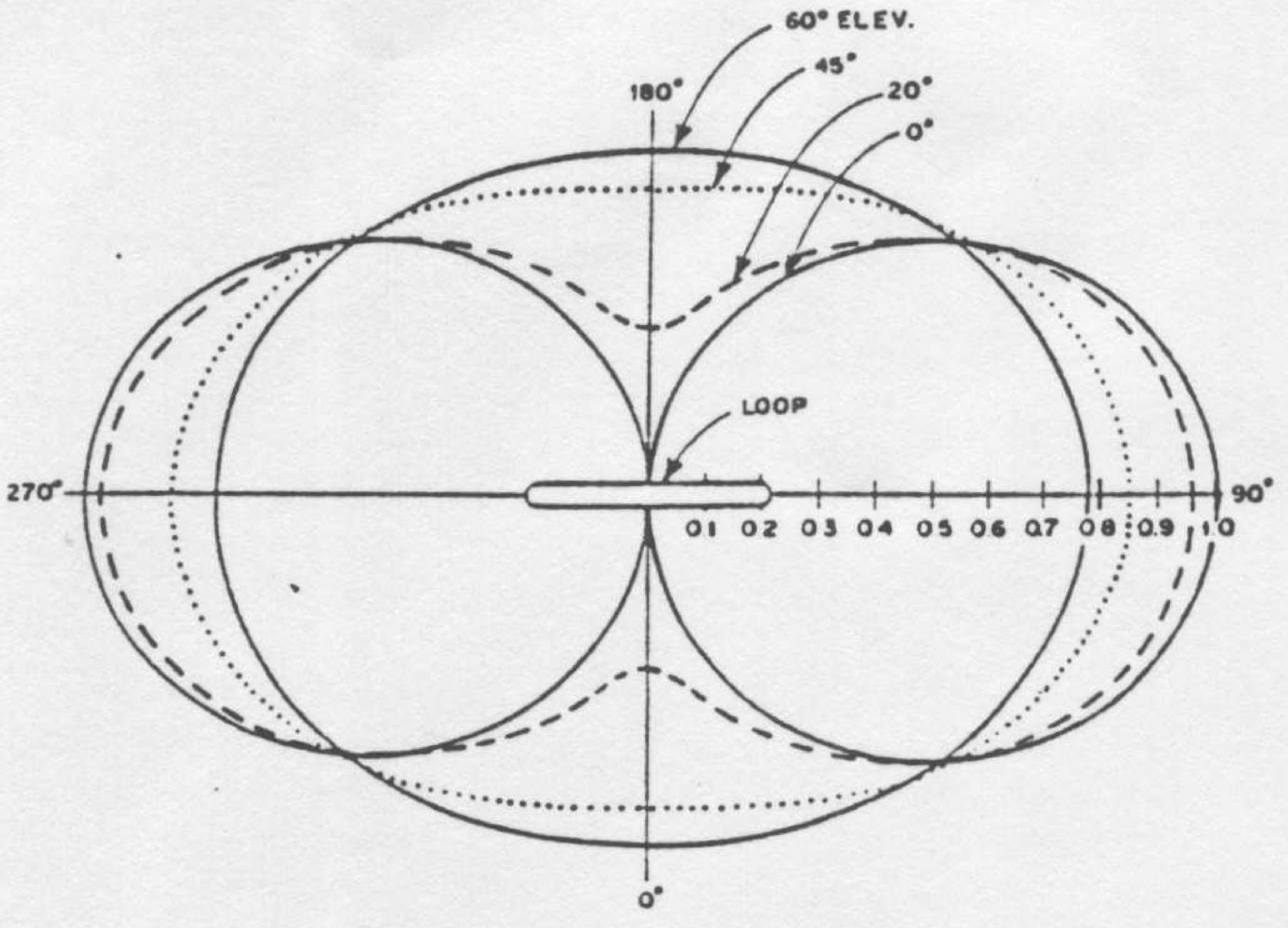


Fig 18—Azimuth patterns of a small vertical loop antenna at various elevation angles. The loop is bidirectional, with the greatest signal strength in the plane of the loop, as shown. In these directions the loop is vertically polarized.

because of the loop image. The length of each radial need be only twice the loop diameter. It should be noted that $\frac{1}{4}\ \lambda$ radials should be used for loops mounted over poor ground to improve performance. Data for Fig 17 was computed for $\frac{3}{4}$ inch copper water pipe (nominal OD of 0.9 inch). By comparing figures with radials (perfect screen assumed) and without, you will note that the effect of radials is greater for loops with a smaller circumference, for a given frequency. Also note the efficiency is higher and the Q is lower for loops having a circumference near $\frac{1}{4}\ \lambda$. Larger pipe size will reduce the loss resistance, but the Q increases. Therefore the bandwidth decreases, and the voltage across the tuning capacitor increases.

The shape of the pipe forms a single-turn coil. The value of inductance and stray capacitance can be calculated and a corresponding value of tuning capacitance calculated to provide resonance for a given frequency. Fig 19 allows the selection of loop size versus tuning capacitance for any desired operating frequency range for the HF amateur bands. For example, a capacitor that varies from 5 to 50 pF, used with a loop 10 feet in circumference, tunes from 13 to 27 MHz (represented by the left dark vertical bar). A 25-150 pF

Table 4
Basic Equations for a Small Loop

Radiation resistance, ohms	$R_R = 3.38 \times 10^{-8} (f^2A)^2$
Loss resistance, ohms	$R_L = 9.96 \times 10^{-4} \sqrt{f}\,\frac{S}{d}$
Efficiency	$\eta = \frac{R_R}{R_R + R_L}$
Inductance, henrys	$L = 1.9 \times 10^{-8}\, S\left(7.353 \log_{10} \frac{96\ S}{\pi\ d} - 6.386\right)$
Inductive reactance, ohms	$X_L = 2\ \pi\ fL \times 10^6$
Tuning capacitor, farads	$C_T = \frac{1}{2\ \pi\ f\ X_L \times 10^6}$
Quality factor	$Q = \frac{f \times 10^6}{\Delta f} = \frac{X_L}{2(R_R + R_L)}$
Bandwidth, hertz	$\Delta f = \frac{f \times 10^6}{Q} = (f_1 - f_2) \times 10^6$
Distributed capacity, pF	$C_D = 0.82S$
Capacitor potential, volts	$V_C = \sqrt{PX_LQ}$

where
- f = operating frequency, MHz
- A = area of loop, square feet
- S = conductor length, feet
- d = conductor diameter, inches
- η = decimal value; dB = $10 \log_{10} \eta$
- P = transmitter power, watts

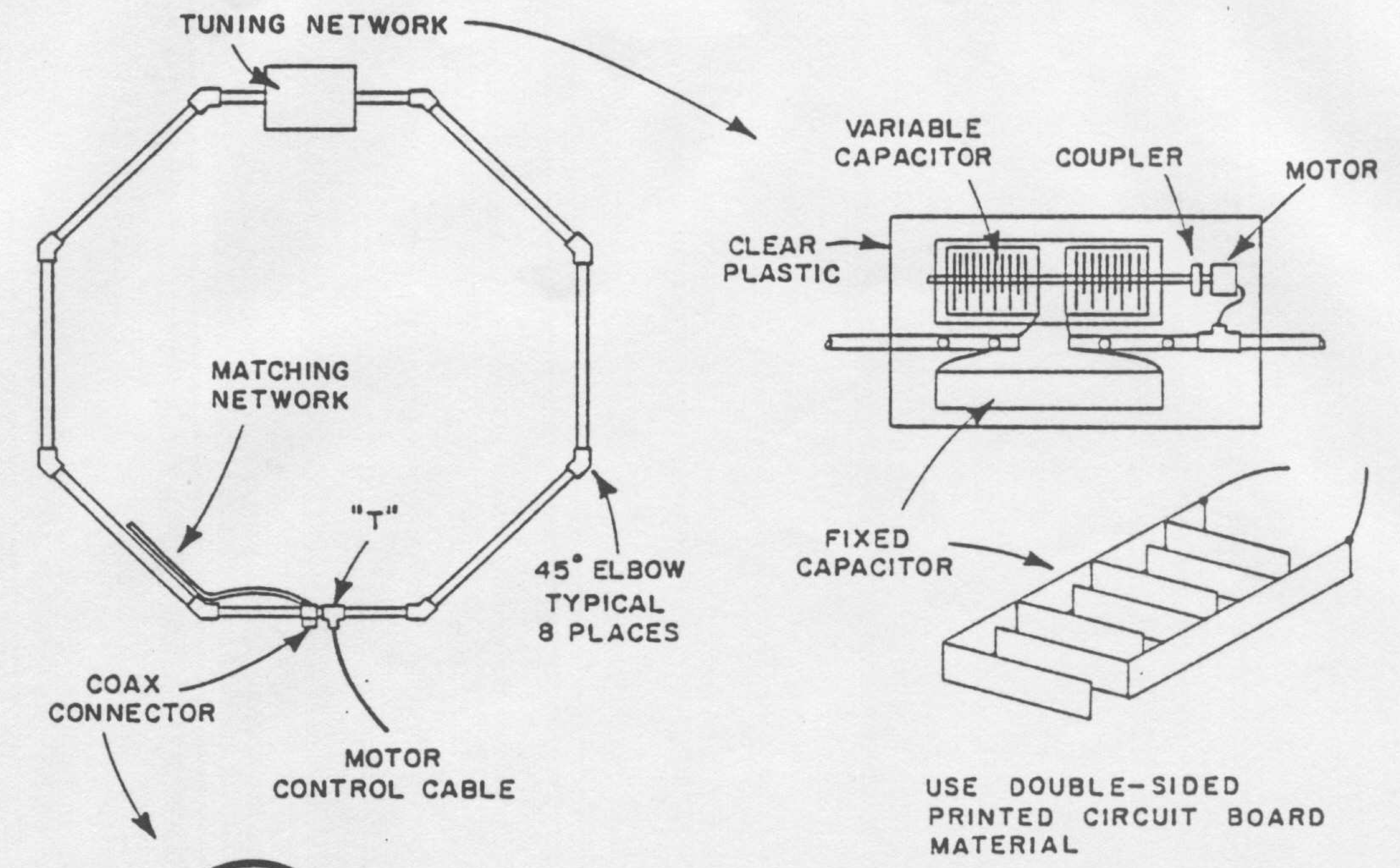
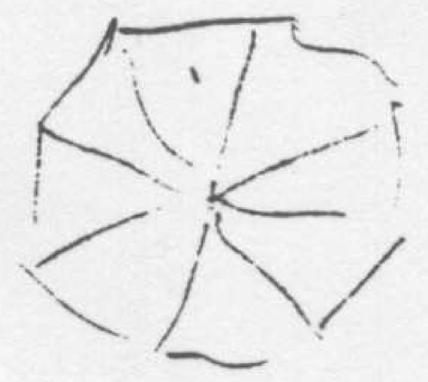


Fig 20—Loop construction details. Fig 18 gives loop design data for various frequency ranges. A variable capacitor designed specifically for transmitting loop use is available from W5QJR Antenna Products, PO Box 334, Melbourne, FL 32902. (Send SASE for information.) See text for information on tuning motor.

48 x 8



135°

capacitor and drive motor. The side of the box that mounts to the loop and the capacitor should be at least 1/4 inch thick, preferably 3/8 inch. The remainder of the box can be 1/8-inch plastic sheet. Any good sign shop will cut the pieces to size for you. Mount the loop to the plastic using 1/4-inch bolts (two on either side of center). Remove the bolts and cut out a section of pipe 2 inches wide in the center. On the motor side of the capacitor, cut the pipe and install a copper T for the motor wiring.

The next step is to solder copper straps to the loop ends and to the capacitor stators, then remount the loop to the plastic. If you insert wood dowels, the pipe will remain round when you tighten the bolts.

Now you can install the motor drive cable through the loop and connect it to the motor. Antenna rotator cable is a good choice for this cable. Complete the plastic box using short pieces of aluminum angle and small sheet metal screws to join the pieces.

The loop is now ready to raise to the vertical position. Remember, no metal is allowed near the loop. Make a pole of 2 × 4-inch lumber with 1 × 4-inch boards on either side to form an I section. Hold the boards together with ¼-inch bolts, 2 feet apart. Tie rope guys to the top. This makes an excellent mast up to 50 feet high. The pole height should be one foot greater than the loop diameter, to allow room for cutting grass or weeds at the bottom of the loop. By installing a pulley at the top, the loop can be raised and supported by rope. Support the bottom of the loop by tying it to the pole. Tie guy ropes to the sides of the loop to keep it from rotating in the wind. By moving the anchor points, the loop can be rotated in the azimuth plane.

With the loop in the vertical position, cut a piece of ¼-inch copper tubing the length of one of the sides of the loop. Flatten one end and solder a piece of flexible wire to the other. Wrap the tubing with electrical tape or cover with plastic tubing for insulation. Connect the flexible wire to the coax connector and install the tubing against the inside of the loop. Hold in place with tape. Solder the flat part to the loop. You have just constructed a form of gamma match, but without reactive components. This simple feed will provide better than 1.7:1 SWR over a 2:1 frequency range for the resonated loop. For safety, install a good ground rod under the loop and connect it to the strap for the coax connector, using large flexible wire.

TUNE-UP PROCEDURE

The resonant frequency of the loop can be readily found by setting the receiver to a desired frequency and rotating the capacitor (via remote control) until signals peak. The peak will be very sharp because of the high Q of the loop. Incidentally, the loop typically reduces electrostatic noise 26 dB compared to dipoles or verticals, thus allowing improved reception in noisy areas.

Turn on the transmitter in the TUNE mode and adjust either the transmitter frequency or the loop capacitor for maximum signal on a field strength meter, or for maximum forward signal on an SWR bridge. Adjust the matching network for minimum SWR by bending the matching line. Normally a small hump in the ¼-inch tubing line, as shown in Fig 20, will give the desired results. For a loop that covers two or more bands, adjust the feed to give equally low SWR at each end of the tuning range. The SWR will be very low in the center of the tuning range but will rise at each end.

If there is metal near the loop, the additional loss will reduce the Q and therefore the impedance of the loop. In those cases it will be necessary to increase the length of the matching line and tap higher up on the loop to obtain a 50-Ω match.

PERFORMANCE COMPARISON

As previously indicated, the loop will provide performance approaching full-size dipoles and verticals. To illustrate one case, a loop 100 feet in circumference would be 30 feet high for 1.8 MHz. However, a good dipole would be 240 feet (½ λ) in length and 120 feet high (¼ λ). A ¼-λ vertical would be 120 feet tall with a large number of radials, each 120 feet in length. The small loop would replace both of those antennas. Since very few hams have full-size antennas on 1.8 MHz, it is easy for a loop to emanate the "big signal on the band."

On the higher frequencies, the same ratios apply, but the full-size antennas are less dramatic. However, very few city dwellers can erect good verticals even on 7 MHz with a full-size counterpoise. Even on 14 MHz a loop about 3 feet high can work the world.

Additional Comments

The loop should not be mounted horizontally except at great heights. The pattern for a horizontal loop will be horizontally polarized, but it will have a null overhead and be omnidirectional in the azimuth plane. The effect of the earth would be the same as on the pattern of a horizontal dipole at the same height.

It has taken a number of years to develop this small loop into a practical antenna for amateurs. Other than trading small size for narrow bandwidth, the loop is an excellent antenna and will find use where large antennas are not practical. It should be a useful antenna to a large number of amateurs.

The Loop Skywire

Are you looking for a multiband HF antenna that is easy to construct, costs nearly nothing and works great? Try this one. This information is based on a November 1985 *QST* article by Dave Fischer, WØMHS.

There is one wire antenna that performs exceptionally well on the lower HF bands, but relatively few amateurs use it. This is a full-size horizontal loop. The Loop Skywire antenna is that type. It is fundamental and simple, easy to construct, costs nearly nothing, and eliminates the need for multiple antennas to cover the HF bands. It is made only of wire and coaxial cable, and often needs no Transmatch. It is an efficient antenna that is omnidirectional over real earth. It is noticeably less susceptible than dipoles and verticals to man-made and atmospheric noise. The antenna can also be used on harmonics of the fundamental frequency, and fits on almost every amateur's lot.

It is curious that many references to this antenna are brief pronouncements that it operates best as a high-angle radiator and is good for only short-distance contacts. Such statements, in effect, dismiss this antenna as useless for most amateur work. This is not the case! Those who use the Loop Skywire know that its performance far exceeds the short haul. DX is easy to work.

THE DESIGN

The Loop Skywire is shown in Fig 21. This antenna is a magnetic version of the open-wire, center-fed electric dipole that has performed extraordinarily well for many decades. Yet this one is less difficult to match and use. It is simply a loop antenna erected horizontal to the earth. Maximum enclosed area within the wire loop is the fundamental rule. The antenna has one wavelength of wire in its perimeter at the design or fundamental frequency. If you choose to calculate L_{total} in feet, the following equation should be used.

$$L_{total} = \frac{1005}{f}$$

where f equals the frequency in MHz

Given any length of wire, the maximum possible area the antenna can enclose is with the wire in the shape of a circle. Since it takes an infinite number of supports to hang a circular loop, the square loop (four supports) is the most practical. Further reducing the area enclosed by the wire loop (fewer supports) brings the antenna closer to the properties of the folded dipole, and both harmonic-impedance and feed-line voltage problems can result. Loop geometries other than a square are thus possible, but remember the two fundamental requirements for the Loop Skywire—its horizontal position and maximum enclosed area.

A little-known fact in the amateur community is that loops can be fed simply at all harmonics of the design frequency. There is another great advantage to this antenna system. It can be operated as a vertical antenna with top-hat