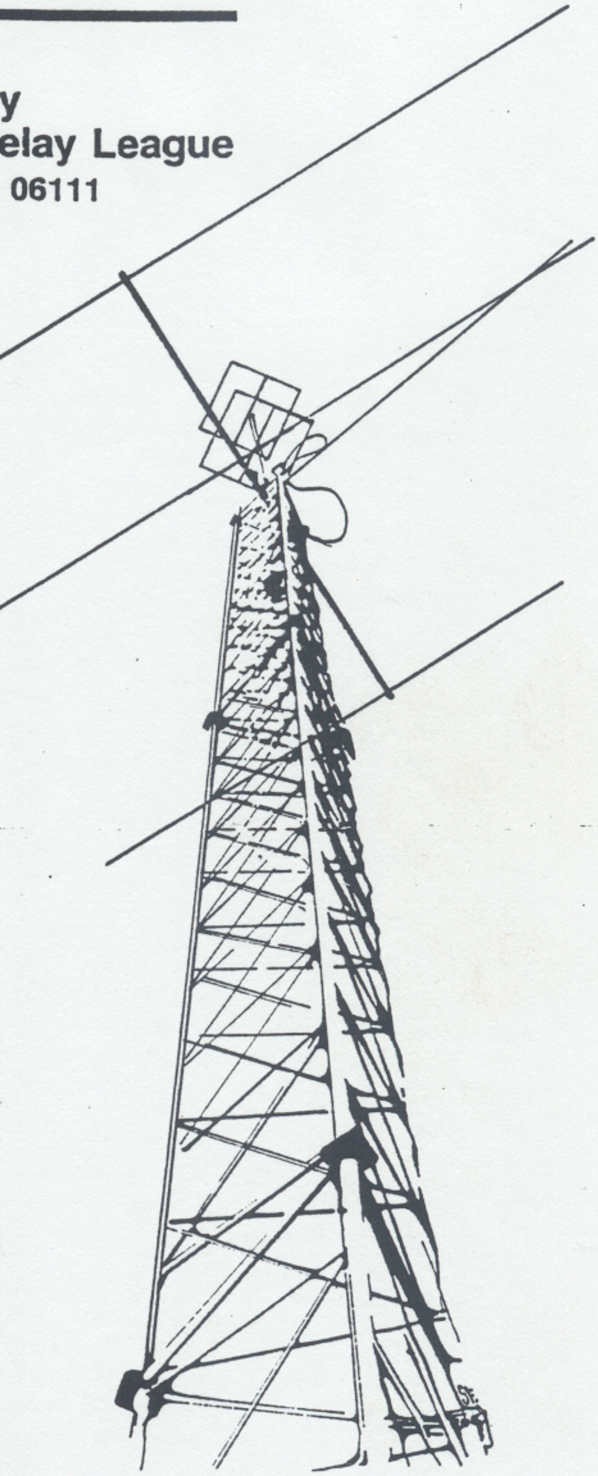
The ARRL Antenna Book

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



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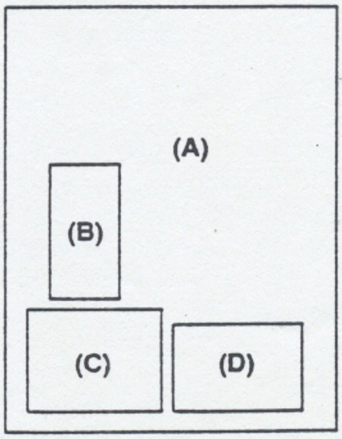


—Photo of 120-foot tower at W1AW by Meyers Studio.
Moon photo courtesy Chuck Hutchinson, K8CH

—Photo courtesy Bob Cutter, KI0G

C—30-foot polar-mount dish at K5AZU

D—12 17-element long-boom 2-meter Yagis at N5BLZ tenna 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.

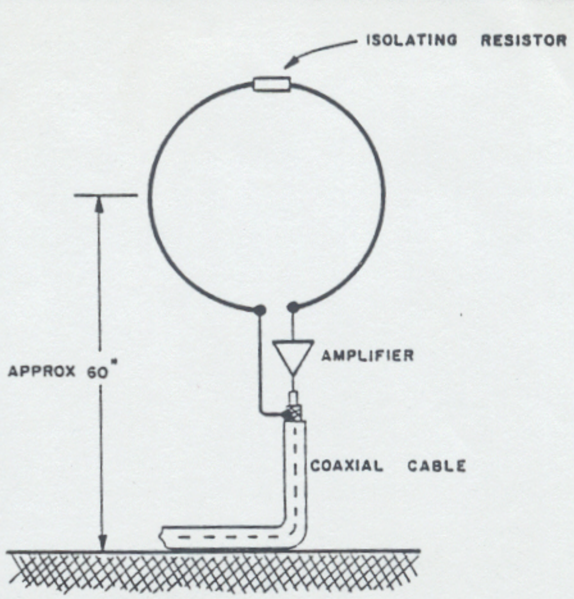


Fig 13—A single wide-band loop antenna used in an aperiodic array.

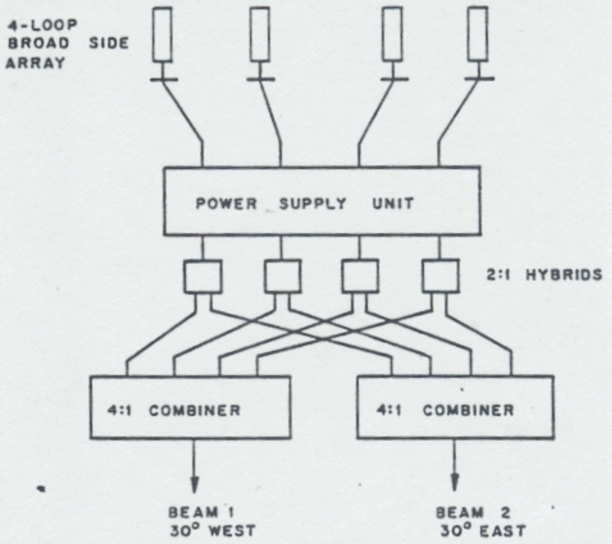


Fig 14—Block diagram of a four-loop broadside array with dual beams separated by 60° in azimuth.

TRANSMITTING LOOP ANTENNAS

The electrically small transmitting loop antenna involves ome different design considerations from receiving loops. nlike receiving loops, the size limitations of the antenna are ot as clearly defined. For most purposes, any transmitting op 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 rrent 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

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

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

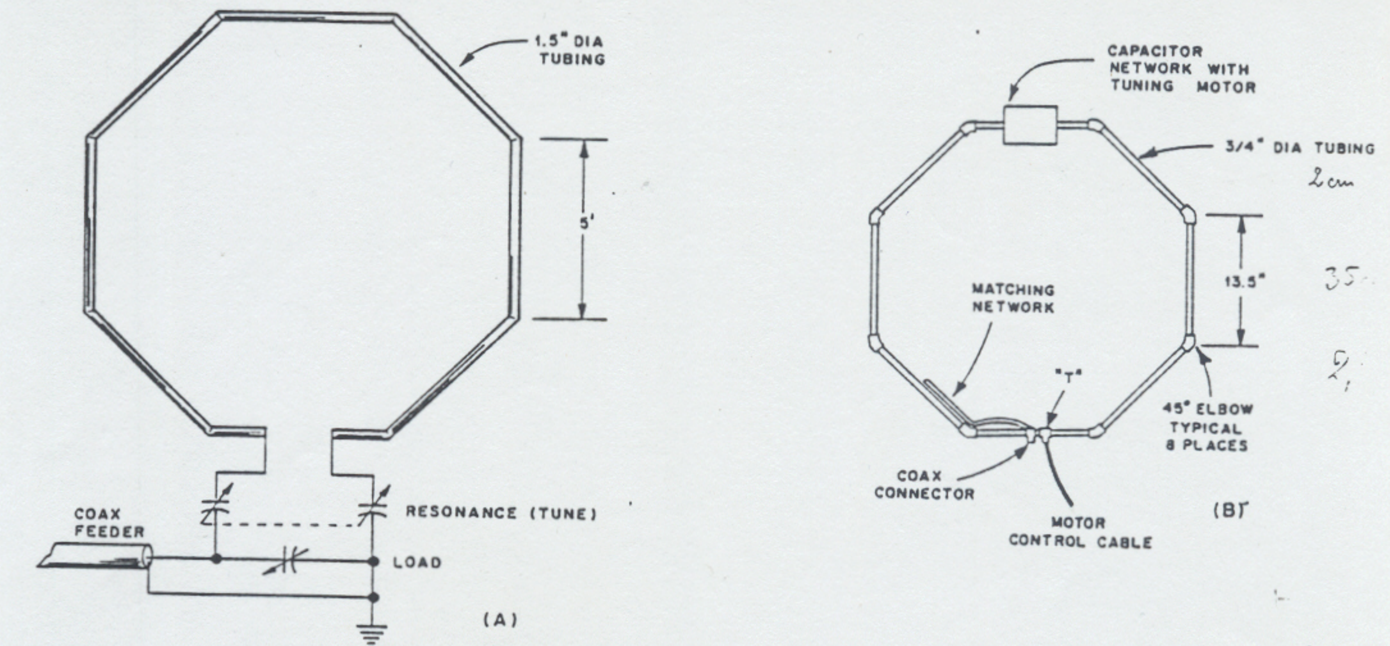


Fig 15—At A, a simplified diagram of the army loop. At B, the W5QJR Hart loop, which is described in more detail later in this chapter.

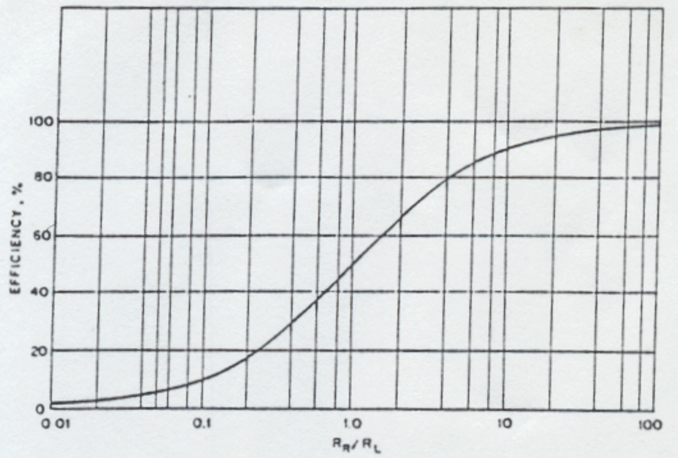


Fig 16—Effect of the ratio of R_R/R_L on loop efficiency.

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

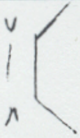
A small loop has the radiation pattern shown in Fig 18. The pattern is easily conceived as a doughnut with a hole (null) in the pattern through the center of the loop at low elevation angles. When the circumference of the loop is less than ⅓ λ, regardless of the shape of the loop (round or square), that 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

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

Loop No. 1
40 -
Frequency range, MHz 7.6-29.4
Loop circumference, feet 8.5
Conductor dia, inches 0.9
Radials No

2,6 m → d = 83 cm
2,58 cm
32,5 cm



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

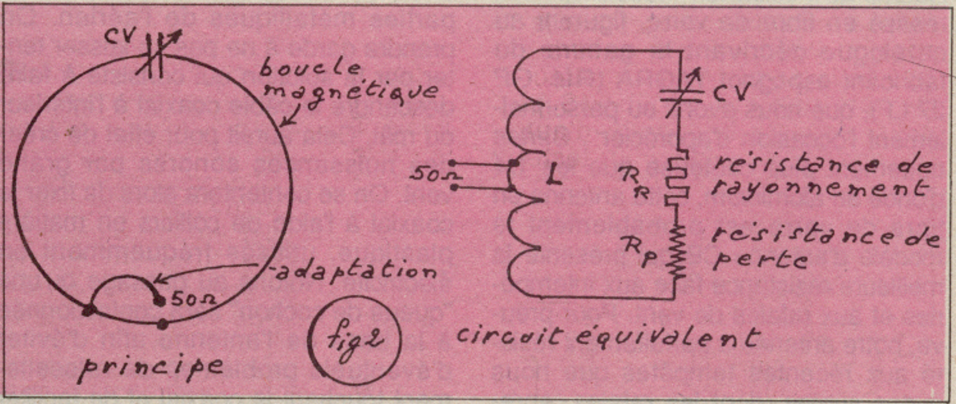
Frequency, MHz	*1.8*	*2.0*	*3.5*	*4.0*
Efficiency, dB below 100%	−0.9	−0.6	−0.1	−0.1
Bandwidth, kHz	8.7	12.5	104.2	176.4
Q	255	197	41	28
Tuning capacitance, pF	215.7	166.4	24.9	8.8
Capacitor voltage, kV P-P	29.01	26.87	16.30	14.32
Capacitor spacing, inches	0.193	0.179	0.109	0.095
Radiation resistance, ohms	0.676	1.030	9.659	16.478
Loss resistance, ohms	0.148	0.157	0.207	0.221

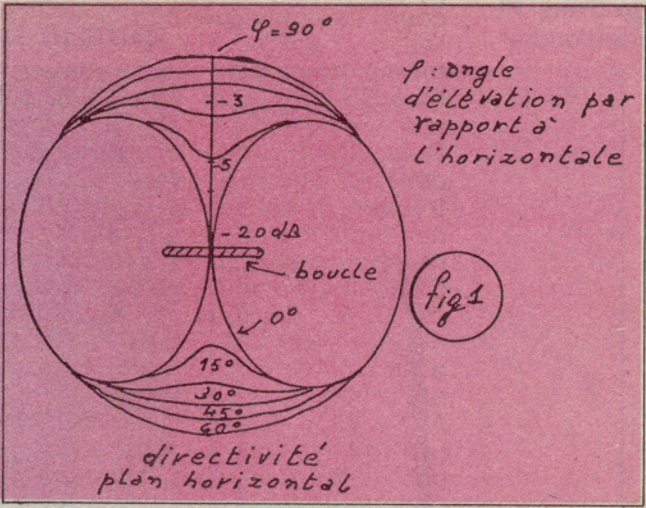
Fig 17 Continued.

UN CADRE MAGNETIQUE CB

Le principe de cette antenne d'émission et de réception n'est pas nouveau. Elle est surtout utilisée par les militaires, les ambassades et des stations officieuses, vu ses faibles dimensions et sa discrétion. Il existe actuellement des versions bandes amateurs d'origine allemande et anglaise, mais d'un QSJ de l'ordre de 4000 FF.

L'ensemble est constitué d'un cadre rond, d'un condensateur variable et d'une boucle de couplage (Fig.1.).





Parmi ses principales caractéristiques, on citera la faible résistance de rayonnement, de l'ordre de 0,3 à 0,8 ohms, à aucun plan de sol, des performances peu influencées à l'intérieur d'immeubles ou par les obstacles, la polarisation verticale, un angle de rayonnement vertical compris entre 0° et 90°, une directivité par rotation du cadre permettant de réduire un brouilleur de près de 20 dB (Fig.2), et une grande sélectivité réduisant fortement les signaux indésirables tant à l'émission qu'à la réception.

RÉALISATION :

La réalisation pro est assez complexe (moteurs, relais, accord automatique et télécommande rotation par micro-processeur) la version CB est simplifiée à l'extrème par accord et rotation manuels et la puissance est limitée sans nuire aux performances. Vu la très faibles résistance de rayonnement, le grand secret de cette antenne est d'arriver à une résistance de pertes de quelques % de celle de rayonnement. Il est possible alors d'obtenir un gain de 1,25 dB par rapport à une GP quart d'onde à 5 m du sol.

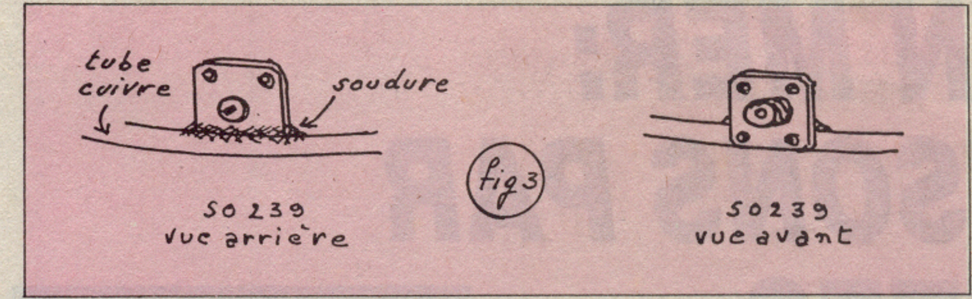
CONSTRUCTION :

Elle est illustrée sur la Fig.3. Si possible, les soudures devraient être réalisées à base d'argent (utilisées par les bijoutiers), en utilisant un petit fer à souder à gaz, type porte-plume.

La boucle en cuivre est courbée à peu près en demi-cercle. d'un côté, elle est soudée au centre de la prise S0239 et l'extrémité pincée au cadre par la croco à environ 10 cm. Accorder le CV pour obtenir en réception un signal maximum sur le canal 20. Le CV devrait être à mi-course. Sinon, ajouter en série ou en parallèle un condensateur ajustable céramique de l'ordre de 20 pF. Passer en émission AM avec puissance réduite si possible. Déplacer la croco avec l'extrémité du fil pour obtenir un ROS minimum. Arrêter l'émetteur, enlever la croco et souder le fil au cadre. Faire pivoter le cadre pour obtenir un maximum de signal ou réduire un brouilleur. Pour d'autres canaux de la bande CB, régler le CV pour obtenir le maximum de signal en réception, ceci pour environ tous les 5 canaux adjacents.

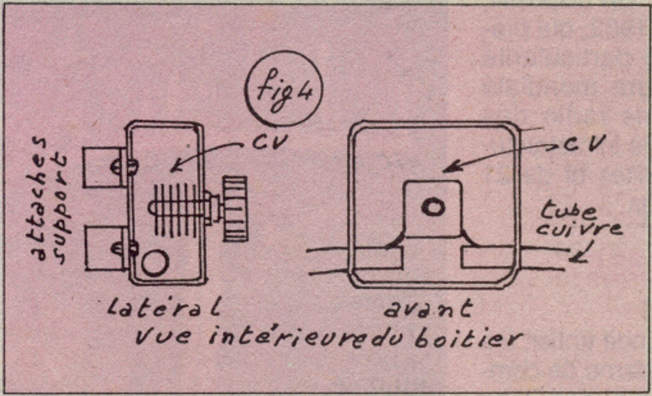
BIDOUILLE : UN ATTENUATEUR 50 OHMS

Pour pratiquer la radiogoniométrie, il suffit d'avoir un TX portable, une antenne directive et un atténuateur (voir RCB Mag N°82, avril 1988). Le rôle de cet atténuateur est de



réduire les signaux reçus par le TX pour pouvoir faire une mesure précise de la direction de l'émetteur

Cet atténuateur 50 OHMS peut aussi servir à beaucoup d'autres choses, par exemple pour tester la sensibilité d'un récepteur.



Il est facile à réaliser, et d'un prix de revient assez modique.

PRINCIPE :

C'est une succession de cellules en II (fig.1.).

Les impédaries d'entrée et de sortie de chaque cellule sont d'environs 50 OHMS. Les cellules sont commutées par des interrupteurs doubles (fig.2.), et isolées entre elles par une paroi blindée. Ces blindages réduisent énormément la transmission des signaux par rayonnement.

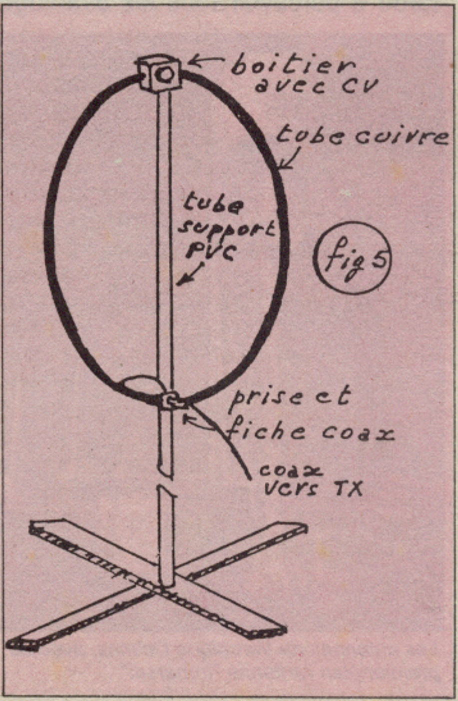
Pour obtenir exactement 50 OHMS, il faut utiliser des résistances de valeur très précise. Par exemple, pour 10 dB d'atténuation, il faut théoriquement deux résistances de 96,2 OHMS et une de 71,2. En pratique, l'atténuateur marche bien avec 2 x 100 OHMS et 68 OHMS, et ces valeurs font parties des séries normalisées. Bien que l'inpédance ne reste pas rigoureusement égale à 50 OHMS, la différence reste acceptable pour les utilisations courantes.

LA REALISATION :

Comme toujours, le plus difficile reste la réalisation mécanique. Mais TEKO fabrique des boîtiers en tôle d'acier étamée, avec des séparations internes amovibles, pour réaliser des montages HF. Ce type de boîtier convient parfaitement pour notre réalisation .

Le boîtier utilisé a pour dimensions : 160 x 50 x 36 (TEKO modèle 374, prix de vente : environ 60 F). Avec des séparations internes, ce boîtier permet de réaliser huit cellules blindées.

Attention, ces cellules n'ont pas exactement la même largeur, mais la différence est faible. Ce boîtier doit être percé de huit trous pour les interrupteurs et de deux pour la fixation des prises BNC (ou éventuellement des prises PL, type 50 239).



LISTE DES COMPOSANTS :

- 1 tube de cuivre d'au moins 2 cm de diamètre sous forme de cadre rond de 83 cm de diamètre. Un tube d'alu ou un fil de cuivre ont un rendement faible.
- 1 condensateur variable à air, si possible à lames argentées (type UHF) d'environ 25 pF.
- 1 bouton plastique de grand diamètre pour éviter l'effet de mains.
- 1 fil de cuivre non étamé ou un tube de cuivre de 2 mm de diamètre et de 16 cm de long.
- 1 prise S0239.
- 1 fiche PL259.
- 1 coax à faible perte de 50 ohms vers le TX.
- 1 boîtier plastique de type électrique 4 x 4 cm.
- 1 prise croco type batterie (utilisation provisoire).
- 1 support en tube plastique de 2 m de long avec pied en croisillon.

Il faut souder les résistances et les ponts de liason avec des fils aussi courts que possible afin de réduire les transmissions par rayonnement. Pour pouvoir fonctionner à fréquence assez élevée, il est recommandé de choisir des résistances en carbone aggloméré, celles-ci sont cependant difficiles à trouver. A défaut, on peut utiliser des résistances plus classiques...

Le choix de la valeur de l'atténuation des différentes cellules (3 x 20 dB, 5 dB, 3 dB, 2 dB) permet de réaliser toute atténuation de 2 dB à 90 dB. Dans la plupart des cas, 90 dB sont largement suffisants. Avec une telle atténuation sur l'antenne, les vrais problèmes se posent au niveau du blindage du récepteur.

Dernière remarque : cet atténuateur n'est dimensionné que pour fonctionner en réception. Il n'est pas prévu pour atténuer l'émission d'un TX.

J-P Y.