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LOOP SENSE CARDIOID ARRAY

Part I - Introduction and Orientation

For as long as the DXer of the medium waves has enjoyed the blessings of the loop antenna, he has dreamed of the unidirectional loop - one free of the superfluous null that otherwise limits its ideal capabilities. Thus it is no surprise that, when we introduced the Loop-Sense Cardioid Array to North-American DX'ers in 1971, a storm of controversy swept the continent. To dare to claim "invention" of the "unidirectional loop" means anxiety for the masses, glory for the designer, and jealousy from his peers; and we have undergone the experience of all three!

Now it is time to end the controversy, first by stating some strong facts:

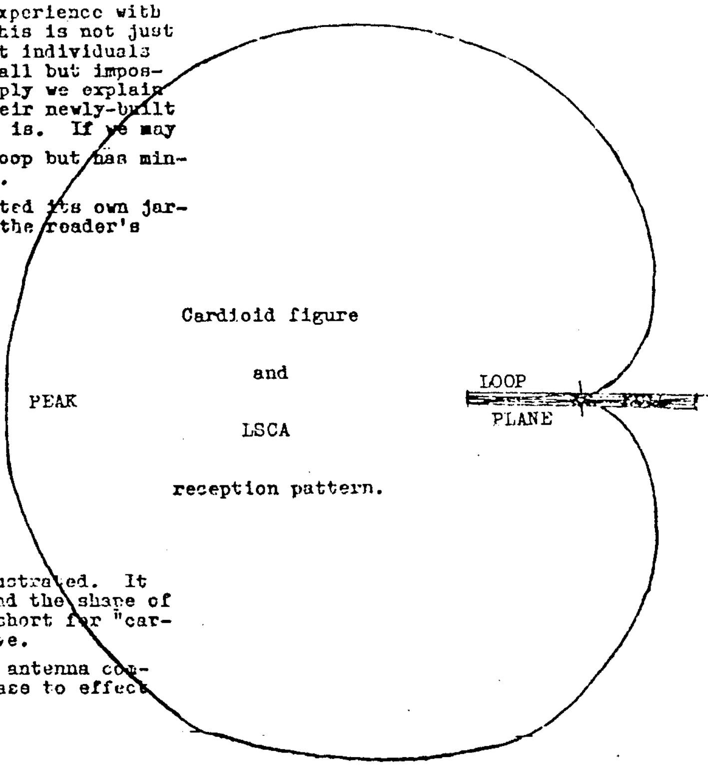
1) The "unidirectional loop" is a technical impossibility; anyone who claims to invent one is either a fraud or has misnamed something else.
2) The Loop-Sense Cardioid Array (hereafter referred to as the LSCA) is not a unidirectional loop but a "cardioid array".
3) Cardioid arrays, better known to navigators as "DF" antennas, have been in use on ships and aircraft for many decades!

So the LSCA is not the long-awaited unidirectional loop of DX'ers' dreams, rather it is something different - an entity in itself to be judged by its own merits. The LSCA may resemble a modified loop, which is its loudest component, but its performance is like no loop, nor like any other antenna or array in common use. Therefore, the reader who insists upon classifying the LSCA as a "loop" and compares its operation to one is prejudiced and will do this article, the device, and himself a disservice.

This article is the end result of tens of hours of theoretical study and research into cardioid arrays and hundreds of hours of empirical experience that has surpassed the experimental stage. Invaluable data was contributed by Richard Clark of Fort Lauderdale, whose largely independent and extensive empirical results with a LSCA of his own design were a useful check on our own. In addition, various comments and criticisms, many valid - some irresponsible, were directed to our efforts; their effect can only have a beneficial influence on the quality and standards of this article.

Unfortunately, expediency requires sacrafice: This article assumes that the reader possesses basic knowledge and experience with both loops and vertical, omnidirectional antennas. This is not just a space saver; it has been our experience to note that individuals who are poorly adept at basic antenna theory find it all but impossible to grasp cardioid theory, regardless of how simply we explain it. And they will be even less successful getting their newly-built LSCA's to work, the nature of the beast being what it is. If we may draw a line, the DX'er who regularly uses a tunable loop but has minimal technical background should survive this article.

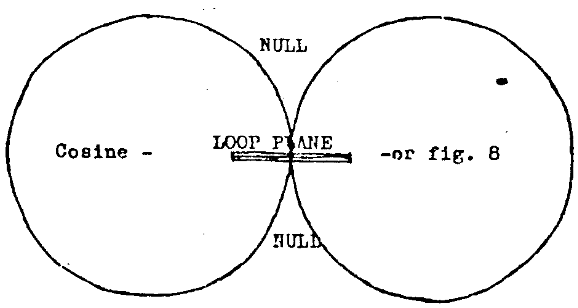
As rapid progress in the cardioid field has created its own jargon, we present a brief glossary of common terms for the reader's benefit in comprehending the rest of the article:



CARDIOID - the heart-shaped geometric figure here illustrated. It is the polar graph of the function "$1 - \cos\Theta$", and the shape of the basic reception pattern of the LSCA. Also, short for "cardioid array", especially when used as an adjective.

CARDIOID ARRAY - in this article, a loop and vertical antenna combined equal in signal strength and 90° out of phase to effect the cardioid reception pattern.

COSINE - the "figure-of-8" reception pattern of loop antennas (Note illustration); the polar graph of the cosine function.



DF ANTENNA - the common name for the cardioid array as used in navigation. It normally appears as part of a multi-band receiver, on top of which are mounted a rotatable ferrite loop over a setting circle, a vertical whip antenna, and a control for matching their signals for determining the bearing of a measured station without ambiguity. Receivers so equipped are sold in most good marine electronic stores at a price of US$150 and better.

K-POT - on the LSCA, a control matching the signals of the loop and the sense antenna.

LOOP - an antenna in the shape of a coil. To the layman it is the ferrite rod of portable receivers. For most DX'ers, a kite-shaped rotatable device oriented vertically, consisting of a "tank" circuit of some 8-10 turns of wire connected to a variable capacitor, and a parallel 1-2 turn winding connected to the receiver. It features two opposing nulls perpendicular to the plane of the windings; the nulls are useful for direction finding and eliminating interference.

LSCA - (pron. "LESS-ca"), the cardioid array designed for the DX'er as developed by Ronald F. Schatz. Its correct name should be "melonoid array", but popular usage retains "LSCA".

MELONOID - meaning "apple-shaped", describing the true, three-dimensional reception pattern of the LSCA.

180° AMBIGUITY - that undesirable feature of loop antennas that renders them unable to determine which of two opposing bearings is the correct one.

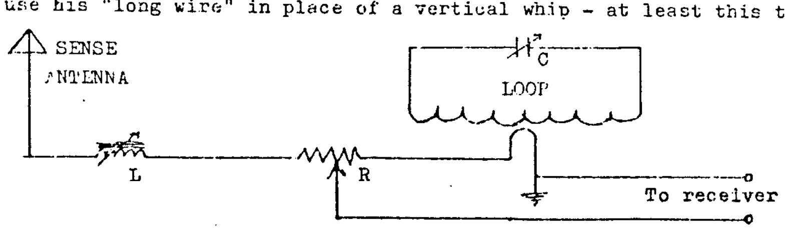
PATTERN-CONTROLLED LOOP - PCL (pron. "pickle"), the primitive loop-sense array as expounded by Gordon P. Nelson. It is basically identical to the prototype LSCA, but Nelson stresses its use in other than the cardioid mode.

PR-SWITCH - (pattern reversal), on some LSCA's and all MPA's, a switch that reverses the cardioid pattern electrically 180°, without the need to turn the loop by hand. Useful for checking MPA balance in the cosine mode.

SENSE ANTENNA - usually a vertical whip antenna used in conjunction with a loop to resolve the 180° ambiguity.

MULTI-PATTERN ARRAY - or MPA, a LSCA in which both the loop and the vertical antenna may be used separately for selection between cardioid, cosine, and omnidirectional modes.

For the reader who is too impatient to wait for Part III of this series, we begin by offering the above design for a simple, but practical, cardioid array. Any regular loop will serve (NRC "AA" loop, SM-1, etc.). Just add a 2-k potentiometer for R and, say, an old IF can for L. And we will forgive the reader if he decides to use his "long wire" in place of a vertical whip - at least this time.



Basic Cardioid Array (Schematic diagram)

The above is experimental only; the components should be left loose on the work-bench. Save the buzz-saw and hammer for better designs to come.

Building the experimental array is easy; operating it is not. To operate:

1) Tune in a station, preferably a strong one.
2) Rotate and tune the loop for maximum signal (as normally done with a plain loop).
3) Detune the loop slightly; on one side of the peak a <u>null</u> should be found (This null is a characteristic malady of poorly-designed loops but the sign of a healthy cardioid array).
4) Adjust the potentiometer for minimum signal (Be careful; this is a very sharp, delicate adjustment).
5) Continue to adjust all controls (C, R, L) for minimum signal. If unsuccessful, rotate the loop 180° and try from scratch (The loop-tuned null will then appear on the opposite side of the peak).
6) Rotate the loop to check the pattern.

If the reader is still unsuccessful, other stations should be tried and the circuit checked for errors in construction, etc.

Once we have the cardioid pattern we can make some empirical observations:

1) The cardioid has a single, WIDE null, compared to the two sharp nulls of the loop. Here a comparison between cardioid and loop nulls is unavoidable, and we offer a table of relative null widths for given values of signal attenuation from peak:

-dB:	0	-10	-20	-30	-40	-50	-60	-70
∞:	180°	37°	11°	4°	1°	.5°	...	...
C:	360°	137°	74°	41°	23°	13°	7°	4°

This null is of tremendous size indeed. While the loop null is normally effective against only one station at a time, the cardioid null can wipe out <u>tens</u> of stations in a wide sector. Our classic example is 1340 kHz from Miami: With the pattern aimed SE, all that can be heard on the receiver are AFRS in Guantánamo Bay, Radio Olimpica in Barranquilla, and Reloj Nacional in Colón, Cuba. All North American graveyarders are too weak to be detected!

2) The nature of the cardioid permits reception of stations lying opposite strong, interfering stations. The superfluous null of the loop, of course, will either knock out both at once or neither, but the cardioid will not. Needless to say, the cardioid user has a host of "opposite" stations available to him that he could never hear before with a loop. CKLW-800 from Miami and Limoges-710 from Boston are prime examples.

3) And will wonders never cease? The LSCA will null out a super-local to reveal the station behind it - in the same direction! Our classic example is 940 kHz in Miami: If we aim the cardioid SE as before, we null out super-local WINZ, permitting a strong, dominant signal from Radio Punto Fijo, lying in the opposite direction. When RPF closes down at 2300, the dominant station then becomes WMAZ in Macon, Georgia. WINZ's tower, only 4 miles from our location, lies right between ourselves and Macon!

While this "transparent tower" effect may seem to be incredible, note that the LSCA's reception pattern is really a three-dimensional, apple-shaped <u>melonoid</u>, with a single null where the "stem" would be. In a way, WMAZ's signal "skips over" WINZ's tower at an angle that misses the melonoid null. This will be explained in full in Part II.

4) Other possibilities exist for the LSCA. For example, a strong, local noise source will paralyze any loop, but not the LSCA, which can tune out the noise in any position.

But every blessing has its equity, and the LSCA is no exception. There must be a reason why such a wonderful device has not been widely used in spite of its relative simplicity, and this is why:

Cardiod arrays are extremely <u>delicate</u> instruments. The slightest change in their environment (people, switches, metallic furniture, swaying palm trees, etc.) will upset the loop-sense balance and destroy the null. Moving one between rooms may render it useless without compensating modifications. Just tuning one can make a minister swear. Yes, the proud owner of a LSCA must have the patience of Job.

Fortunately, advanced LSCA and MPA designs tend to overcome these adverse effects with ample shielding and fine adjustments. While that still doesn't make them as simple to operate as a loop, the improvement in performance is very notable. Cardioid arrays owe their former obscurity to past experimenters who tore their hair rather than improve the product.

In conclusion, we see that the LSCA is not really the legendary "unidirectional loop", but to think of it as a loop-like device with a single, super-wide null and "X-ray vision" would not be grossly abstract. But it's quite an uncooperative beast!

Part II § Cardioid Theory and Propagation

In Part I of this series we found out that cardioid arrays are not unidirectional loops, rather they are an old idea widely used in marine direction-finding equipment. Empirical research has demonstrated that these versatile, but tempermental, instruments can, at least in theory, permit the DX'er to hear almost anything on the dial strong enough for his receiver to detect. They feature wide nulls that can block a continent of stations, especially on "graveyard" channels, and can even make signals audible "through" interfering locals - the "transparent tower" effect. Cardioid arrays can and will do things that the impossible unidirectional loop was never expected to accomplish.

We also hinted in Part I that the proud owner of a cardioid array, unlike most loop users, must have some idea of how it works, since it is much more complicated than the simple "turn-&-tune" loop. Cardioid users ignorant of theory may have success with the device, but it will be a matter of blind luck and little else. For this reason we are hitting theory at this time - <u>before</u> we build any cardioid arrays.

Again, a cardioid array consists of two separate antennas, a loop and a vertical whip. By electrical mathematics the patterns of both aerials are combined in a certain way to form the cardioid pattern.

The reception pattern of the vertical whip is omnidirectional - a circle. Its pattern on a polar graph is a circle, and a straight horizontal line on a cartesian graph. Since its pick-up at any horizontal direction from the antenna is the same, its mathematical representation is "K" - a constant:

The loop exhibits the familiar "figure-8" pattern on a polar graph and a "cosine wave" on a cartesian graph, thus the term "cosine loop". Naturally, its mathematical representation is the cosine function, "cosθ":

Now we have the pattern formulas for the whip and the loop, K and cosθ. K is constant; cosθ varies from plus one to minus one (actually: +1 ... 0 ... -1 ... 0 ... +1).

Wherever cosθ equals zero, there is a null in the loop pattern. Cosθ = 0 twice, thus two nulls; +1 and -1 give the two peaks.

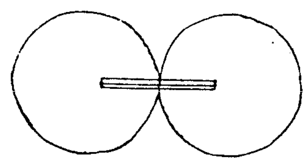
Problem: What value(s) of K will combine with cosθ to produce a pattern with only one null - the cardioid pattern? A little high-school algebra will show two values - +1 and -1.

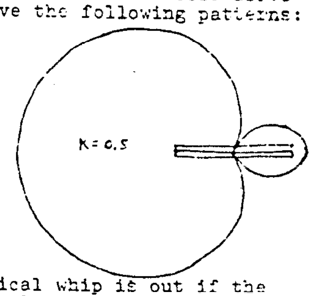
The cardioid formula, then, is either 1 - cosθ or cosθ - 1. The patterns given by both formulas are identical, except that they point in opposite directions (east or west). For our purposes in this article we will concentrate on 1 - cosθ.

If the cardioid pattern can be represented by 1 - cosθ, then any off-cardioid shape has the formula K - cosθ; by varying the value of K from zero to infinity various "sub-cardioid" patterns can be created. First, let us prepare a table for different values of K - cosθ:

	-cosθ	K=0	K=.5	K=1	K=1.5
000°	-1	-1	-0.5	0	0.5
030°	-0.866	-0.866	-0.366	0.134	0.634
060°	-0.5	-0.5	0	0.5	1
090°	0	0	0.5	1	1.5
120°	0.5	0.5	1	1.5	2
150°	0.866	0.866	1.366	1.866	2.366
180°	1	1	1.5	2	2.5
210°	0.866	0.866	1.366	1.866	2.366
240°	0.5	0.5	1	1.5	2
270°	0	0	0.5	1	1.5
300°	-0.5	-0.5	0	0.5	1
330°	-0.866	-0.866	-0.366	0.134	0.634
360°	-1	-1	-0.5	0	0.5

Now, by plotting the values of K - cosθ above on a polar graph, we derive the following patterns:

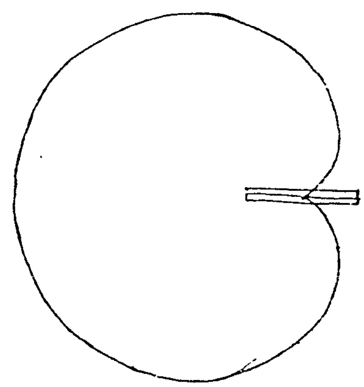




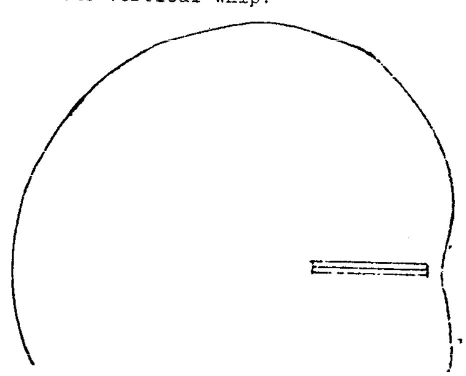
When K = 0, the vertical whip is out of the circuit and the loop acts alone. The classic figure-8 pattern with its opposing nulls is the result.

When K = 0.5, the nulls appear at 60° and 300° with a 120° separation between them. There is now a 9.54 dB difference between the two peaks.

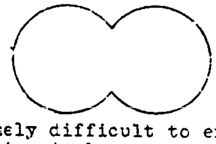
When K = 1, the two nulls combine at 000°/360° and we have the classic cardioid pattern:



When K = 1.5 the null disappears, and a 9.54 dB difference remains between the peak and where the null used to be. Further increases in K will produce patterns approaching the omnidirectional circle of the vertical whip:



Yet another condition must be met to form all these patterns: There must be a 90° phase difference existing between the loop and the vertical signals ($\phi = 90°$). Failure to achieve this 90° difference will result in a variety of useless peanut-shaped patterns:

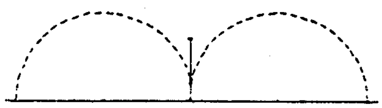


It is extremely difficult to explain this 90° phase difference in simple terms, so we ask the reader to accept our theorem without proof from us.

To summarise, the basic cardioid pattern is effected when the signals of the loop and vertical whip are equal at the points of maximum pick-up ($K = \cos 0°/360°$ or $K = \cos 180°$) and their relative signal phases are 90° apart ($\phi = 90$).

So far, the theory being presented considers cardioid arrays only on the horizontal plane, but the LSCA has a vertical pattern as well. This vertical pattern is of extreme importance:

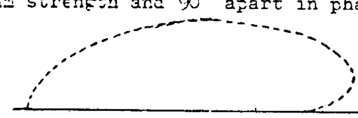
The vertical pattern of the vertical whip is not omnidirectional; there is a sharp null directly overhead. Thus, signals coming in at low angles are best received:



... while the vertical pattern of the loop antenna, under average ground conditions, may be described as "semi-omnidirectional":

As the illustration above suggests, the loop is most sensitive to signals arriving at low angles; otherwise, it can be said that the horizontal reception pattern of one antenna is the vertical pattern of the other, notwithstanding the fact that the vertical patterns are half-above/half-below ground.

The vertical cardioid (or semi-cardioid) pattern is created according to the same conditions as its horizontal counterpart - signals must be equal in maximum strength and 90° apart in phase:



Falling between the horizontal and vertical planes are an infinite number of diagonal planes. Together they form a solid, three-dimensional reception pattern which the author terms a "melonoid" (Greek: "apple-shaped"). Of course, it is difficult to illustrate such a pattern on flat paper, but the following three figures give a general idea of its solid shape:

top view | side view | front view

Even though our device is called a "cardioid array", it is more precisely a "melonoid array". Although we will keep the traditional terminology by necessity, the reader will be wise to think "melonoid" and "apple-shaped" and picture the pattern in his mind whenever LSCA's, MPA's, etc., have his attention.

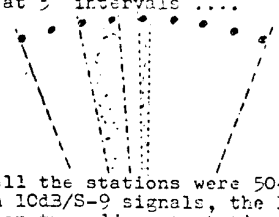
Now that we are familiar with the melonoid pattern, we can study its reaction and orientation to incoming signals.

First of all, we mentioned in Part I the fact that the LSCA pattern has a relatively wide null. This is true for the most part, but an attempt to null out a super-local will give the impression that the null is quite sharp. This phenomenon is somewhat of an illusion; it affects figure-8 loops, but it is far more pronounced on the LSCA.

E.g., the standard loop will null out a signal with the strength of 10 dB over S-9 when the null is only a small fraction of a degree wide. A 4° null, however, will be sufficient to handle a signal strength of S-5. On the LSCA, the maximum null width that will eliminate a 10dB/S-9 signal is 7°, but a wide 41° for the S-5 signal!

In the case of a multitude of stations, the number of stations that can be nulled simultaneously depends upon their angular separations and their various signal strengths.

In the hypothetical case of nine stations aligned in an arc at 5° intervals ....

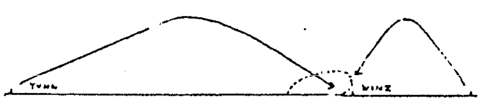


.... if all the stations were 50-kilowatters coming in with 10dB/S-9 signals, the LSCA could null out no more than two adjacent stations at a time.

If all the stations were 250-watt graveyarders with S-5 signals, the LSCA could null out all of them!

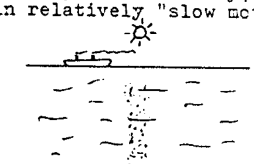
In both cases the figure-8 loop could null out no more than one station at a time! No wonder the LSCA is such a boon on crowded graveyard channels!!

Now let us examine melonoid behaviour under more general cases:



Illustrated above is the "Miami-940" case mentioned in Part I. WINZ is a 10-kw (night) super-local only four miles NW of the author's location. Inter-station propagation, of course, is via the ground wave. WMAZ and YVNN are heard in Miami via the sky wave only.

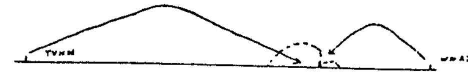
Almost everybody thinks of the ionosphere as some gigantic mirror. It should be viewed as more like a transparent, turbulent, upside-down ocean. If you could see the ionosphere and the signals refracting through it, it would resemble the reflection of the sun or the moon on the ocean; the reflected image would not be clear but would look like a sparkling path. A signal leaves the ionosphere from several points at once - and from each point only briefly. Fortunately, the ionospheric turbulence is in relatively "slow motion".



The arrows seen in the Miami-940 illustration are really the statistical means of many separate signal paths. These means shift relatively slowly but constantly.

In the same illustration, the melonoid null is aimed directly at WINZ's powerful ground-wave signal. WINZ cannot be heard, but YVNN gets through - as expected. After YVNN closes down, leaving nothing powerful to the SE, WMAZ becomes the only station heard. WMAZ's signal enters above the melonoid null, so it is received with still no WINZ! That explains the so-called "transparent tower effect".

When dealing with sky-wave signals, we must resort to a "sub-melonoid" pattern, as illustrated below:



One of the drawbacks of the LSCA is that the controls must be adjusted often in order to keep the null and the incoming signal in line. Stronger signals require more frequent and delicate adjustments.

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That completes basic theory and propagation, but there is one more slight controversy to put to rest:

A few years ago, when cardioid arrays were given renewed popular attention, an unfinished article appeared in the National Radio Club's "DX News" entitled "Pattern-Controlled Loops". In it author Gordon P. Nelson took a generally pessimistic view of cardioid arrays and gave emphasis to the project of their being able to null out any two stations of any angular separation - just by employing the appropriate sub-cardioid pattern. Let's look into this a bit further:

In order to be truer to theory, the sub-cardioid nulls mentioned by Nelson must be realised as a single sub-melonoid null. We will refer to it as an "arc-null":

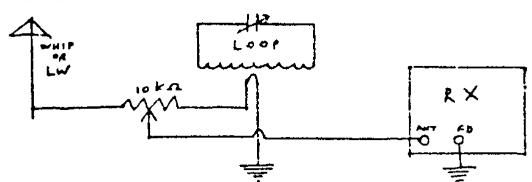
According to theory the arc-null can be fit over any two signals with the proper electrical and mechanical orientation of the array. Under certain situations, even three or more signals may be accomodated thusly. However, we must heed the laws of statistical probability:

Let "Pd" be the degree of difficulty encountered in nulling out a given signal with the LSCA. A second signal will compound this difficulty, Pd x Pd = Pd^2. We regret to say that we have proven this fact empirically, and we have yet to waste our time trying to overcome three signals at Pd^3!

Our empirical conclusion, then, is that, short of the "wide null" feature of cardioid arrays, it is impractical to use them for simultaneously nulling out two or more stations.

This concludes Part II of this series. Part III, to appear in a few months, will cover the circuitry of cardioid arrays and their construction, and will supply sufficient information for the reader to design his own LSCA or MPA.

I note that more reporters are using cardioid arrays, useful for stations in a "straight line". To appease a lot of questions, I'll repeat the schematic below:



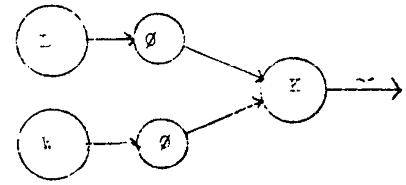
To operate: Aim the plane of the loop at the wanted or unwanted station, then detune the tuning capacitor and adjust the potentiometer for the clearest signal or the best null. More LSCA articles will follow shortly in DX MONITOR.

Part III § Cardioid Circuitry and Construction

Before we begin, the reader is reminded to retain knowledge of the information contained in the first two parts of this series on the LSCA; failure to do so will make Part III difficult to follow. Reprints of Parts I and II are available from club headquarters for a nominal fee.

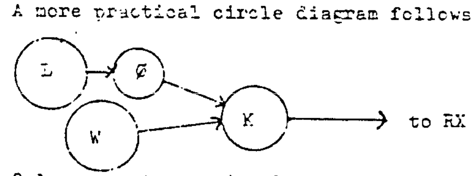
So far, we have learned that the LSCA is the common "sensed loop" DF antenna long in use by navigators. It consists of the ordinary loop we are familiar with plus a vertical-whip "sensing" antenna. By maintaining the two antenna signals equal in strength and 90° out of phase, an "apple-shaped" reception pattern is provided, with a single wide point-null or arc-null and sharp vertical directivity. Such a reception pattern, called a "melonoid", can perform the following useful feats for the DX'er:

1) Permit reception of stations lying opposite in bearing from a strong, interfering station.
2) Permit reception of stations lying beyond a strong, interfering station on the same bearing.
3) Mass-null stations on crowded channels.
4) Sense (determine) the true bearing of an unknown station.



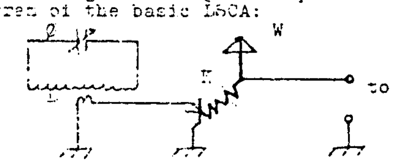
Above is a circle diagram of a basic cardioid array: The signals from the loop (L) and the whip (W) are differentiated 90° at (Ø) and matched for equal signal strengths at (K), whence the product is fed to the receiver.

A more practical circle diagram follows:



Only one antenna signal needs to be shifted in phase, since phase is a relative parameter. For medium-wave use it is far easier to shift the phase of the loop, since phase shifting is a matter of "detuning", with accompanying signal attenuation, so that the relatively greater signal pickup of the loop over the whip makes this the more economical practice. Construction is simplified as well, since the necessity of a complicated whip circuit is avoided, and since the loop inherently possesses a means of shifting its own phase - the loop tuning capacitor.

The reader now knows enough about cardioid arrays to build one: the addition of a potentiometer to match signal strengths completes the schematic diagram of the basic LSCA:



While the basic circuit above will perform wonders, it has its drawbacks - weak signal pickup, difficult operation and control, instability, limited frequency range, etc.

A good LSCA must possess the following attributes:

1) Satisfactory signal pickup
2) Simple, stable, reliable, and efficient operation.
3) Freedom from body capacitance.
4) Minimum phase-shift attenuation.
5) Maximum combined signal.
6) Equal performance throughout its frequency range.

Covering each of these points further:

1) In addition to the measures below, a good LSCA, like any good loop, employs preamplification to boost its signal output.

2) Mechanical stability is important in a good loop; electrical stability is essential in a LSCA, while mechanical stability is not as serious a factor. Wiring must be shielded wherever possible; the use of vernier dials, large knobs, and "fine-tu-

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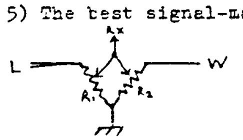
ning" controls is encouraged; potentiometers must be noise free. § Simplicity and efficiency means the best performance with the fewest controls. "Tuning" time should be a matter of a few seconds, not more than three times that required to face and tune an ordinary loop. § "Reliable" performance is predictability, eliminating the need for time-consuming trial-error operation.

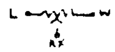
3) Through proper shielding and by locating the whip antenna away from the operator and his controls, body capacitance, a major cause of instability, is minimised.

4) A low-Q circuit will minimise phase-shift attenuation. A loop using high-gauge wire and a multi-turn secondary winding is ideal for use in a cardioid array.

5) The best signal-matching circuit is illustrated.

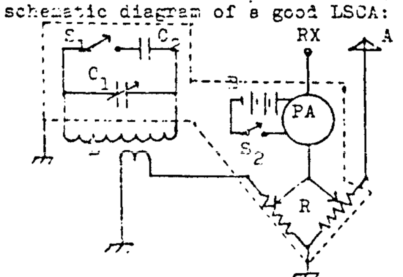


The matching circuit in the basic diagram is useless when the whip signal predominates, as often happens on the high end of the band. A one-pot "balanced" circuit (illustrated) offers too much signal attenuation or is limited in range.



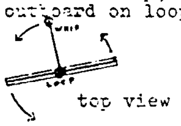
6) The loop must be able to tune well beyond the limits of the broadcast band in order to cover the proper phase-shifting "territory". Sufficient potentiometer range will compensate for the whip's tendency to increase signal pickup towards the high end of the band.

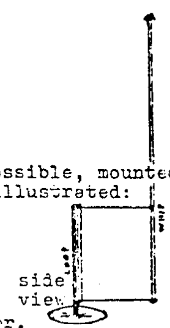
Now we can incorporate our ideas above into a schematic diagram of a good LSCA:



Components:

A Vertical whip, as long as possible, mounted outboard on loop frame, as illustrated:





B Battery to power preamplifier.

C_1 Loop tuning capacitor, provided with vernier dial for fine control, 10-365 pfd.

C_2 Low-band range-extention capacitor, mica, 220 pfd.

L Low-Q loop, 10:3 ratio, 110 µH.

PA Unbalanced FET preamplifier.

R Network of signal-matching potentiometers, noise-free and stable, 50 k each.

S_1 High-band/low-band select switch.

S_2 On-off power switch.

Dotted-line boxes indicate grounded metal chassis to shield components from body capacitance.

Component values are typical; other values may serve well.

To summarise good LSCA construction practices:

1) Avoid using a high-Q loop.

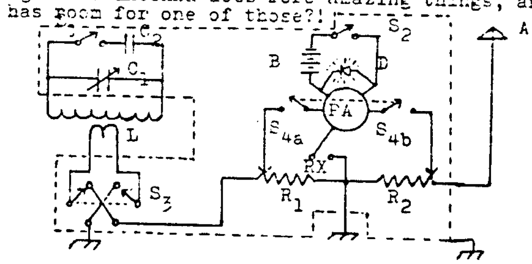
2) Mount the whip outboard of the loop frame so as to rotate with it (absolutely necessary to preserve the pattern, yet not be approached by the operator.

3) Shield everything - except the loop coils and the whip. Ground the shielding.

4) Use "fine-tuning" devices to advantage.

THE ULTIMATE ANTENNA

.... is the Multi-Pattern Array, or MPA. This is a cardioid array, regular loop, and vertical antenna rolled into one; and one can choose any three patterns at the flick of a switch! Only the Beverage-wave antenna does more amazing things, and who has room for one of those?!



Note the following additional components in the MPA schematic diagram above:

D LED, a battery-saving warning "ON" lamp.

S_3 "Pattern-reversing" (PR) switch, has no effect in the omnidirectional or figure-8 mode, but flips the cardioid peak and null 180°, DPDT.

S_4 "Mode-select" switch, a rotary switch on the MPA-1, a level switch on the MPA-2, selects either an omnidirectional, cardioid, or figure-8 reception pattern.

The MPA-1 was built by the author in 1972 especially for the NRC annual convention in Coral Gables. Although it performed very well - better than anything in existance in its time - the whip was too short in length, shielding was poor and ungrounded, and the battery - prone to be left on after use - was hard to replace. Such a worn-out battery led to a disasterous demonstration during the author's lecture on cardioid arrays at the Coral Gables convention.

The MPA-2 is the product of the lessons learned from the MPA-1. Complete plans for building and operating the MPA-2, the "ultimate antenna", will be the subject of Part IV in this series.

The author regrets that he is unable to answer individual queries by mail.