SOME COMMENTS ON "THE LOOP-SENSOR CARDIOID ARRAY"

by Gordon P. Nelson

Quite a number of technically inclined BCB DX'ers have experimented with "cardioid" loops over the years, but have generally reported rather disappointing results. In our experience this has resulted from a combination of the inadequate theoretical discussions given in the standard technical references, the inherent complexity of the equations for practical cardioid type arrays, and the physical and electronic delicacy of these arrays in actual use. Based upon several years of both theoretical and practical work on pattern controlled loops (of which the cardioid is a special case) we would like to make a few comments on Mr. Schatz' interesting recent article.

Paragraph (2). A cardioid loop pattern can never be obtained by a combination of a loop and "horizontal long-wire". A cardioid pattern can only result if the electric field antenna (with which the loop is summed) is perfectly omnidirectional. Unless the pickup of the electric antenna is completely invariant of azimuth (i.e., has an azimuthal pickup function of the form f(Θ) = constant, where Θ is the azimuth) the resulting pattern cannot be a cardioid, no matter how the signals are combined. In the very realistic case that the electric fi field (or "sense") antenna is not omnidirectional in azimuth (most certainly the case if it's a horizontal longwire!) but has instead a signal pickup which varies with azimuth as given by some arbitrary function f(Θ), the resulting pattern is not a cardioid but a nameless form with the general pickup given by

$$\text{Pickup} = k\sqrt{\cos^2\Theta + 2f(\Theta)R\cos\Theta\sin\phi + R^2 f(\Theta)^2}$$

where R is the ratio of electric to loop antenna signal ratio, ϕ is the relative phase relationship, and k consists of sundry lumped physical and electrical constants. A cardioid pattern can exist only if $R = 1$, $\phi = 90°$, and $f(\Theta)$ = constant since only when all of these conditions are met will the general pickup equation given above reduce to that for a cardioid pattern - thus completely ruling out the use of an "horizontal long-wire" to generate a cardioid pattern. Only a perfectly omnidirectional antenna (i.e., a vertical) can sum with a cosine loop pattern to produce a cardioid.

Paragraph (2). The cardioid pattern equation given in DXM is incorrect; the slightly different version given in the DX NEWS version of this article is also in error. If ϕ is set at 90° the general equation given above reduces to the form $(\cos\Theta + R)$ where R is the "sensor" to loop voltage ratio. If the sensor to loop voltage is equal to one, this becomes $(\cos\Theta + 1)$; the choice of sign determines whether the cardioid null occurs at $\Theta = 0°$ (- sign) or at 180° (+ sign). Under no conditions can the argument of the cosine function be anything other than Θ. The version in DX NEWS is correct if the "X" under the cosine is neglected.

Paragraph (5). (If the values in the table are assumed correct, then ... -RFS). For the "Figure-8" the values should be: 37°, 12°, 4°, 1°, 0.4°, 0.1°, and 0.04° respectively. For the LSCA they are: 137°, 74°, 41°, 23°, 13°, 7°, and 4°.

Paragraph (7), part (d). This is a most serious and fundamental error as it suggests that it is possible to construct a simple LSCA which is insensitive to changes in the effective polarization figure of the signal wavefront at the receiving site. This is not only impossible in practice but in theory as well. The equations for a cardioid loop given in most texts and literature references implicitly contain a number of unrealistic simplifying assumptions which are invalid in the case of real antennas operating over real MW signals over nonideal ear earth. Simple "quasi-cardioid" arrays such as the LSCA behave roughly like the simple idealized cardioid for nearby stations received primarily by groundwave if they are carefully designed and adjusted. Even arrays exhibiting good cardioid-type patterns for predominantly skywave signals behave erratically and uncontrollably for distant stations received via skywave, however. It can be rigorously shown that no linear combination of vertical (or any other form of electric field antenna) and cosine loop signals can be made to exhibit a cardioid pattern independent of the effective polarization figure of the signal wavefront at the receiving site. In practice this means that the effective shape of the LSCA pattern will vary significantly with time for skywave signals as the effective resultant polarization figure changes from second-to-second, minute-to-minute, and hour-to-hour. Intuitively this makes sense when you consider that a cardioid pattern can only exist when the phase and amplitude relationship between the two antenna signals remains fixed ($\phi = 90°$ and $R = 1$ in our notation). While the former condition can be met by simple passive circuitry, the latter one cannot be expected to hold for real skywave signals since the vertical patterns (not to mention the polarization responses) of vertical and loop antennas are quite different. It should not be too surprising then to discover that simple loop-vertical arrays do not exhibit cardioid patterns for skywave signals except when the pickup ratio R happens to instantaneously exactly equal unity due to a fortuitous combination of antenna and signal polarization effects. (We have derived and evaluated on the computor the generalized equations for arrays of this type taking into account all of the physically significant complications neglected in the standard textbook treatments including resultant signal wavefront tilt due to skywave reception, the effect of the nonideal ground beneath the antenna, the differential phase shift between the signal components, a generalized electric antenna pickup function, effective polarization angle of the signal wavefront, et al.; the derivation is about 6 pages long and much too complex to include here; copies are available from the author upon request. Extensive experimentation with actual arrays agrees with the theoretical expectations.)

Paragraph(8). Two more disadvantages should perhaps be mentioned, and another given by Mr. Schatz underscored. Much of the usefulness of the loop antenna arises from its ability to effectively "ignore" nearby man-made local noise as from neon lights, etc.; this is due to the fact that a well designed and constructed loop responds only to the magnetic component of both the desired signal and the local noise. Since there is actually more power in the electric component of a nearby noise signal than in the magnetic component, the loop can provide significantly quieter reception than long-wires or verticals of equivalent sensitivity for distant signals. Summation of the signal from the noise-resistant loop antenna with that of the signal from the relatively noise-sensitive electric antenna reintroduces a very considerable amount of the local noise which would have been rejected by the loop alone. Thus an LSCA-type of array cannot be expected to provide quite as much local noise rejection as a good loop by itself under the same conditions. Secondly, it will be much more difficult to produce extremely deep nulls on powerful local stations (say a 50 kw'er within a few miles) with an LSCA-type array than with a well balanced loop. This is because extremely small fluctuations in the ratio of electric to loop antenna pickup (as are introduced by drifting in the electronics) and the relative phase shift result in very substantial modifications to the effective pattern. Fluctuations in the relative pickup smaller than one part in a thousand or drifts in the phase shift of less than one degree are enough to prevent us from being able to null our superlocal WMC-680 down to the level of backscattered skywave. The actual numbers showing the influence of minor drifts in R and ϕ on null location and depth are given in a recent issue of DX NEWS; this confirms Mr. Schatz' observation in part (c): "Using the LSCA, especially tuning the null, is a test of patience." While we believe that we have made some significant advances in the area of drift reduction in the necessary electronics, a good deal of work still needs to be done before the pattern controlled loop (or the special case of the LSCA) is easy enough to use for casual DX'ing.

Once again we request that <u>all</u> "deciBel" figures appearing in "ISCA - I" be changed to read 0.6x their stated values. We thoroughly apologise for this accidental blunder of haste.

Many of the "Comments" brought forth by Mr. Nelson in his article above are quite valid within certain confines. If we may expand some ideas on some:

P.2 (first): A cardioid reception pattern <u>can</u> be created with the use of a non-omnidirectional sense antenna, but <u>only</u> with reference to a single particular station for which R_x is <u>equal</u> to unity. Furthermore, it should be mentioned that the reception pattern created when f(Θ) is introduced into the general pickup equation does not rotate along with the loop, better it changes shape constantly as the cosine pattern varies in azimuth.

P.2 (second): Our formula for the cardioid, K + cosΘX, (K = 1), though not standard, is still mathematically correct, as an attempt to graph the equation as defined will reveal.

P.7d. The ISCA is inherently immune to many of the adverse factors which afflict the common figure-8 loop, including imbalance and dynamic polarisation effects. Our statement, though strong, does hold true but constant manual or automatic control is mandatory to achieve this condition.

P.8: First, contrary to Mr. Nelson's predictions, we have developed a relatively noise-insensitive vertical/omnidirectional antenna with magnetic characteristics, which is why we have not included noise as a disadvantage. Second, we have not experienced the difficultied so experienced by Mr. Nelson with regards to deep nulling powerful local stations, so this also was not mentioned as a disadvantage. However, we have found that the cardioid null is highly frequency selective, and the effects are interesting. Although we can eliminate the carrier of our superlocal WINZ-940 the higher audio frequencies still make it through the passband, often giving an SSB effect in the audio quality when a second carrier is not present.

Recent successful experiments with a revolutionarily new type of omnidirectional antenna element has led us away from further development of the ISCA in favour of a "multi-pattern array". The "MPA" will be noise resistant and free from adverse dynamic polarisation effects among other advantages. / Ron Schatz /