Part 3 - Pair of Orthogonal Loops

Pair of Orthogonal Square Loops - 3 Meters on Edge							
	Edge					Area	
Antenna	Meters	Feet	Wire	L (uH)	R (Ohms)	m^2	ft^2
Loop #1 NE/SW (115/315°)	3	9.84	AWG 14	17.9	0.107	9	96.8
Loop #2 NW/SE (45/225°)	3	9.84	AWG 14	18.6	0.110	9	96.8
AWG 14 Wire: Multistrand, diameter = 0.0641 in, 1.628 mm							

Note: The signal/noise data in the following is necessarily split into two tables since two independent loops are in view. The markers 'Null' and 'Max' in the "Orientation" column are NOT to be taken literally for neither of the loops are directly aligned with any of the three NDB signal sources. These markers indicate only a very approximate relationship helpful when considering the data.

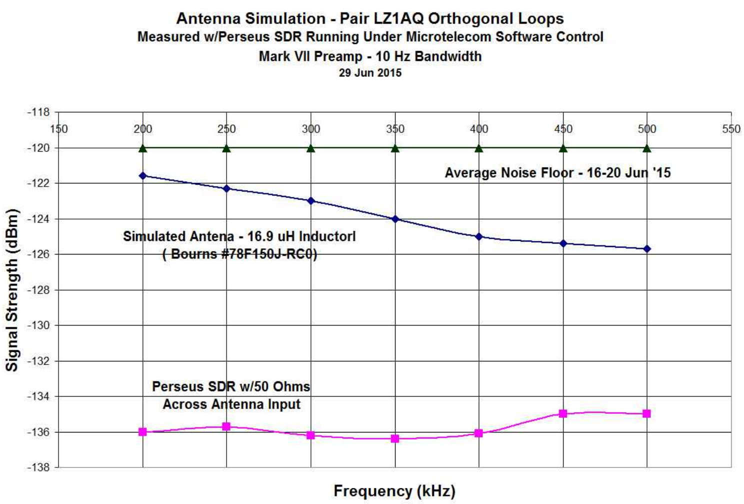
Table 1 - Signal & Noise - Loop #1 Orientation Northeast/Southwest						
	Orientation		**Signal**	**Noise**	**Signal/Noise**	***Δ (S/N)***
NEL_396	'Null'	LZ1AQ Loop	-73.2 ± 0.4	-119.8 ± 1.2	46.7 ± 0.9	***+10.9***
		Wellbrook Loop	-79.8 ±3.5	-115.6 ± 2.9	35.8 ± 1.7	

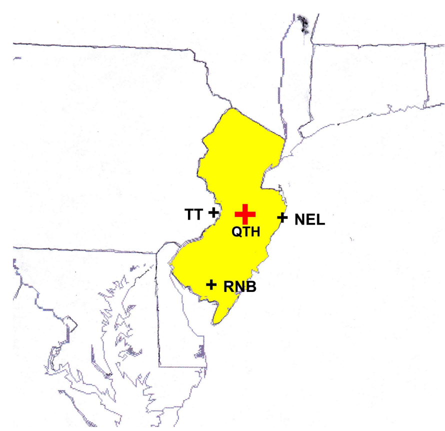
Summary: This pair of orthognal loops are excellent NDB DX performers.. When compared with the well-regarded Wellbrook ALA 1530 Loop, their individual signal/ noise advantage arises from their lower noise floor (~4 dB) and their greater antenna gain (~4 to 10 dB).

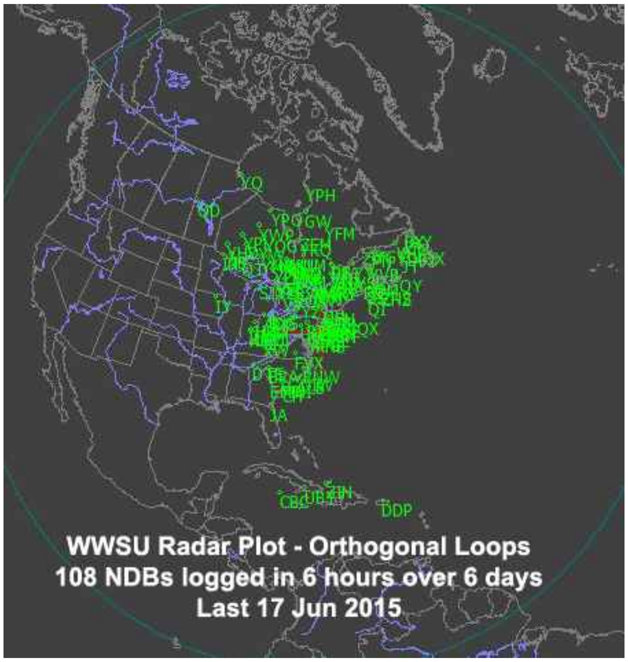
Table 2 - Signal & Noise - Loop #2 Orientation Northwest/Southeast						
	Orientation		**Signal**	**Noise**	**Signal/Noise**	***Δ (S/N)***
NEL_396	'Max'	LZ1AQ Loop	-69.6 ± 0.5	-119.5 ± 1.3	49.9 ± 0.9	
		Wellbrook Loop	-73.2 ± 1.4	-114.9 ± 1.7	41.7 ± 2.2	***+8.2***
RNB_363	'Null'	RNB_363 was OTA on the days these measurements were made.				
TT_369	'Max'	LZ1AQ Loop	-80.7 ± 0.1	-120.0 ± 0.9	39.3 ± 0.9	
		Wellbrook Loop	-94.7 ± 0.3	-115.5 ± 0.7	21.0 ± 0.7	***+17.4***
					Average =	***+12.8***
Δ (S/N) = S/N(LZ1AQ Loop) - S/N(Wellbrook Loop)						

Their greater gain in the NDB frequency range is attributed to their greater loop area relative the Wellbrook Loop, a factor of ~ x8, which implies a power gain of ~18 dBm. Note the order-of-magnitude agreement with the entries in the Δ(S/N) column in Tables 1 & 2..

Their lower noise floor is attributed to their high loop impedance relative to the input impedance of the preamp. For further explanation see the discussion by Chavdar:

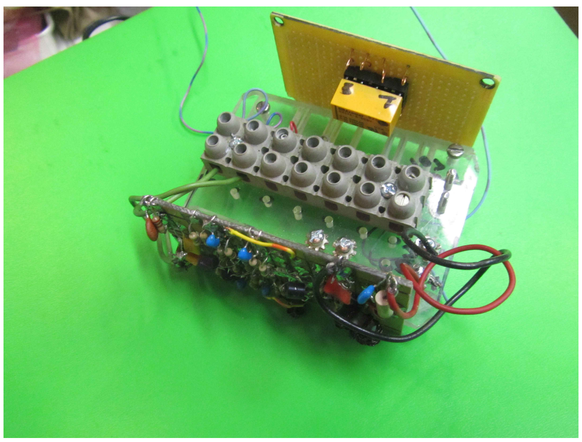






(Pic at left) The NDBs seen afar in the northwest quadrant of this Radar Beacon Plot were all logged with the Northwest/Southeast oriented loop. Four of these could not be heard nor seen (on the waterfall display) with the Wellbrook although the plane of the Wellbrook's loop was oriented at the expected optimum position parallel to the NDB's azimuth.

(Pic below) View of overall setup of the Orthogonal Pair at my NJ QTH. The long red cord leading to the bottom left corner of the picture and the blue cord leading to the mid-right side of the picture serve both as guy lines supporting the pole and also as extenders to hold the corners of the square loop in position. The loops themselves are constructed of red insulted copper cable intertwined with the guy cords for support.

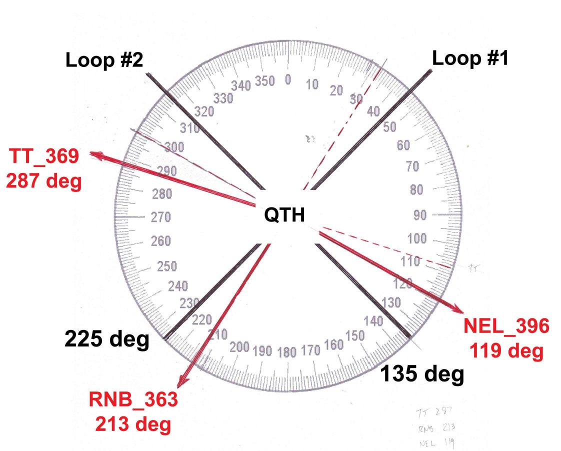


(Pic above) View of the Mark VII preamp and associated loop switching relay (in yellow rectangular box) ready for installation in waterproof box on the antenna mast. Although in use only for a brief period before the relay began behaving erratically, if was found to add a very convenient feature - with the flip of a switch the receiver could quickly be transferred from one loop to its orthogonal counterpart. The mechanical problem with the relay was caused when the antenna assembly toppled in a strong straight-line ground-level wind severely jarring the relay's inners.

Additional Comments: again recall that 'Max' and 'Min' in the following table are NOT to be taken literally; they are only to provide a marker to keep track of the calculation.

Table 3 - Measured Signal Strength
The Wellbrook ALA1530 Loop was aligned parallel to the LZ1AQ antennae for these measurements.
The orientation of Loop #1 was 135° and that of Loop #2 was 225° (both true).

NDB	NDB Azimuth (True)		Signal (dBm) (Loop #1)	Signal (dBm) (Loop #2)
NEL_396	119°	LZ1AQ Loop	-73.2 (Min)	-69.6 (Max)
		Wellbrook	-79.8 (Min)	-73.2 (Max)



Antenna Null – Properly constructed loop antennae are known to have a broad forward gain and a sharp null. The data presented above permit an estimate of the azimuthal dependence of this quantity. When the Wellbrook Loop is oriented parallel to Loop #2 and tuned to NEL_396, it is at an angle of 16° to the 'optimal' orientation and down 1.9 dBm (= -71.3 + 73.2). See Table 4.

Table 4 – Wellbrook ALA1530 Null Measurement
Antenna aligned along true azimuth. Average of 468 data points taken over a two month period (May/June 2015),

NDB	Azimuth (true)		dBm	***Null Depth***
NEL_ 396	119°	Signal Max	-71.3 ± 0.1	***42 dB***
	209°	Signal Min	-113.0 ± 2.1	

If it is assumed that the fall-off of the Wellbrook signal-azimuth plot and that of the Orthogonal Loop pair are identical then it follows that when at 'optimal' orientation, Loop #2 would have reported a signal of -67.7 dBm (= -69.6 + 1.9) for NEL-396. Likewise the signal of Loop #2 at null orientation would have been reported as -111.1 dBm (-113.0 + 1.9) and the null depth of Loop #2 would be roughly estimated as ~43 dB.

When 16° off the 'optimal' null direction on Loop #1, the Wellbrook ALA1530 gain is -79.8 dBm (Table 4). If a linear variation is assumed, this implies that the slope to the null position 16° distant (at -113.0 dBm) is ~2 dBm/deg, a very sharp null. By analogy, the LZ1AQ Orthogonal Pair is expected to display a parallel behavior.

Antenna Forward Gain Or viewed another way … if the NDB is located aong an azimuth bisecting the orthogonal loops (i.e. 45°), in the worst case the signal amplitude received at each loop is equal and down by 1/√2 (= sin/cos 45°) or ~70% (~5 dB down) relative to the incoming signal. But appreciate that this is an estimate of the upper limit to signal loss. Additional loss would be due to the shape of the loop's gain-azimuth contour. From the above null estimate, an additional loss of perhaps 2 additional dB might be expected.

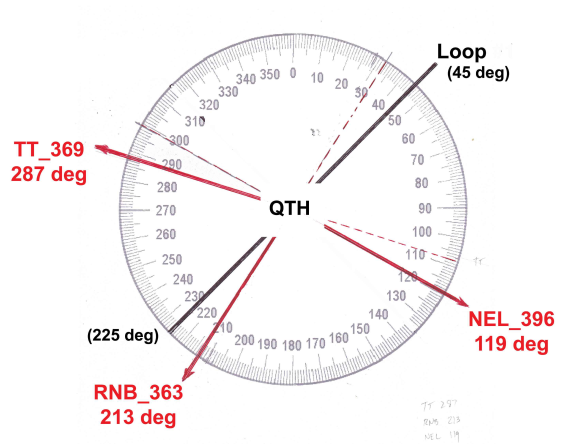
Certainly when trying to log a "weak one", the loss of 5-7 dB may be a serious matter … but then again not a trivial matter is an attempt to overcome this loss by reorienting a 20 x 10 ft loop antenna on a stable mounting and rotating base.

Perhaps this difficulty with a large fixed-orientation orthogonal loops can be surmounted by using the antenna in a 'direction-finding' mode. In principle the full signal is recovered with the Bellini-Tosi stator/rotor scheme to effect an electrically-rotation of the antennae. But in practice questions remain. I am currently investigating this approach with a pair of orthogonal loops each separately equiped with a LZ1AQ preamp feeding a home-brew stator-rotor assembly. We will see what develops.

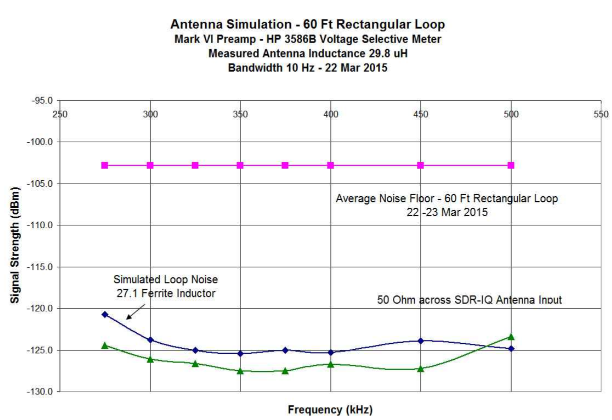
Antenna	Loop Circuference	Construction	L (uH)	R (Ohms)	Area (ft^2)
20 x 10 Ft Rectangular	60Feet	AWG #14 Copper Wire	29.8	0.15	200
AWG 14 Wire: Multistrand Diameter = 0.0641 in / 1.628 mm					

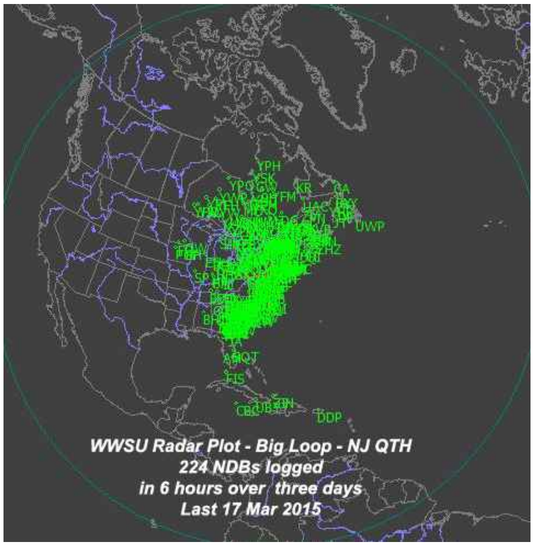
Note: the data reported next was taken with a different experimental scheme (SDR-IQ running under SDR Console control) than that used for all other data in this report (Perseus running under Microtelecom software control). Later discovered that the two different schemes give S-meter readings differing by 2- 4 dBm. Was unable to rerun measurements with the preferred Perseus receiver because a late-March ice/snow/wind storm destroyed the antenna. Data shown next are as originally recorded with SDR-IQ receiver.

Signal & Noise - 20 x 10 Ft Rectangular Loop - Daytime Data Mark VI Preamp - 4/6 Mar 2015 - Bandwidth 10 Hz Loop oriented Northeast/Southwest (45°/225°)						
	Azimuth	Antenna	Signal (dBm)	Noise (dBm)	Signal/Noise	***Δ(S/N)***
NEL_396	119°					
		LZ1AQ Loop	-85.1 ± 0.1	-102.5 ± 1.9	17.4	***+2.8***
		ALA1530	-86.6 ± 0.1	-101.2 ± 1.0	14.6	
RNB_363	213°					
		LZ1AQ Loop	-72.0 ± 0.1	-102.6 ± 0.8	30.6	***+3.4***
		ALA1530	-73.9 ± 0.1	-101.1 ± 1.2	27.2	
TT_369	287°					
		LZ1AQ Loop	-83.2 ± 0.1	-102.0 ± 0.9	18.8	***+2.5***
		ALA1530	-85.1 ± 0.1	-101.4 ± 0.7	16.3	
					Average =	***+2.9***
Δ(S/N) = (S/N LZ1AQ Loop) - (S/N Wellbrook ALA 1530 Loop)						



Note: in the table above only RNB-363 is close to being aligned (within 12°) with the Rectangular Loop's NE/SW orientation and hence exhibits a relatively strong signal pickup. NEL_396 and TT_369 are close to the antenna's null orientation (within 16° and 32° respectively) and hence exhibit a much reduced signal strength.





A combination of the excellent propagation conditions coupled with the rectangular loop's antenna's performance allowed the stellar nighttime performance shown in the WWSU Radar Beacon plot at left - in 6 hours total time listening over the 5 day period, the 224 beacons were being logged at an average of a beacon every 2 minutes.

Daytime vs. Nighttime Signal Strength

As the project developed and more nighttime listing data was accumulated, a curious point was noted. In a few instances, although both the LZ1AQ and Wellbrook Loops were aligned parallel, an NDB would be heard on one of the loops but not the other. Others have reported this 'phenomena' but usually for an antenna pair consisting of E-field and H-field antennae ... not both on loop antennae as considered here.

With the daytime S/N ratio of results for both the LZ1AQ and Wellbrook Loops both already in hand, out of curiosity the relative nighttime signal strength for an arbitrarily chosen set of NDB was recorded. In the table next are the S-meter data from SDR Console (v2.1 beta) driving a SDR-IQ receiver for one pre-dawn listening session.

This data is not to be directly compared with the daytime Δ(S/N) ratio (+2.9 dB in the in favor of the LZ1AQ Rectangular Loop) since the table entries at right are of signal strength... no attempt was made to estimate the noise floor for the nighttime listening.

Yet since (presumably) the Signal/Noise ratio of an antenna/preamp combination is a function only of the antenna's construction, independent of when the measurement is made. If so, then given the aperture ratio of ~16 in favor of the Rectangular Loop, one would expect ~24 dB difference in their signal strength ... much less than Δ in the table [note not Δ(S/N)].

Which leads to consideration of the ...

Rectangular Loop - Wellbrook ALA1530 Loop
Comparison Nighttime Signal Strength (dBm) - 19 Mar 2015
Both loops oriented parallel directed to northeast/southwest.
SDR-IQ Receiver Bandwidth 10 Hz

NDB	kHz	Rectangular Loop	Wellbrook ALA1530	Dist (Miles)	Azimuth	Pwr		**Δ**
DIW	198.0	-93	-103	416	204°	2000		***10.0***
CLB	216.0	-94	-104	457	205°	1500		***10.0***
BX	220.0	-107	-115	1138	41°	2000		***8.0***
EZF	237.0	-110	-117	202	231°	25		***7.0***
IL	248.0	-92	-101	69	237°	50		***9.0***
CAT	254.0	-88	-95	43	7°	25		***7.0***
BZJ	328.0	-106	-115	108	282°			***9.0***
APG	349.0	-92	-99	93	244°	25		***7.0***
PN	360.0	-102	-115	833	33°			***13.0***
RNB	363.0	-82	-89	59	213°	37		***7.0***
JWE	363.0	-102	-106	114	40°			***4.0***
AM	388.0	-103	-109	963	211°			***6.0***
DDP	391.0	-93	-102	1573	160°	2000		***9.0***
NEL	396.0	-86	-93	17	119°	75		***7.0***
FR	407.0	-96	-99	71	51°			***3.0***
Δ = Signal Difference (Rectangular Loop - Wellbrook) Average = 7.7 ± 2.5								

Precipitous Decline in Δ(S/N) for this antenna ... Too Large a Loop Inductance (?):
A 'large' loop inductance is certainly required to maintain the loop's low frequency gain ... but is there an upper bound beyond which increasing this parameter defeats this purpose? Consider the comparison in the table next assembled from data in earlier tables:

Antenna	L(uH)	Δ(S/N)	Aperture (ft^2)
Loop #2	18.6	+13.9	96.8
60 Ft Rectangular Loop	27.1	+2.9	200

Note that an increase by a factor of ~1.5 in inductance leads to a decrease by a factor of ~5 in Δ(S/N). But relative to Loop #2, the Rectangular Loop has ~2x the loop area and hence is expected to have a advantage of about 6 dB in signal strength. Also, it is expected to have a lower noise floor by ~5-6 dB. But such is not the case.

While at my secondary QTH in Tennessee, these measurements were extended to loops with even larger apertures ... two additional loops along with a copy of the NJ 60 Ft version were constructed.[1] The results are summarized in the table next.

Rectangular Loops - New Construction - TN QTH 8-25 Jul 2015		
Dimensions (ft)	Aperture (ft^2)	Comment
10x40	400	Distinctly inferior to the ALA1530
10x30	300	Marginally comparable (?) to the ALA1530
10x20	200	Sensibly identical in construction and results with the NJ unit

Clearly as the aperture increases the loop's performance deteriorates.

The magnitude of the loop impedance relative to the input impedance of the preamp is the parameter that determines an LZ1AQ loop's overall performance. Chavdar L. (*loc. cit.)* has modeled these antennae with LT Spice and reports that " ... *the input loop impedance acts a negative feedback for the internal noise source of the emitter-base junction of the input transistors of the amplifier*."

I speculate that perhaps raising the loop inductance to too high a value can cause the negative feedback to also severely dampen the antenna's gain. Such may be the explanation for the seemingly precipitous decline in the Δ(S/N) for the 60 Ft Rectangular Loop relative to Loop #2 as well as for first two the Tennessee results listed in the table directly above.

And there the matter remains for I have not the expertise to develop the question further. Comments, criticism, and corrections will be gratefully received.

[1] Took care to insure that these three new TN loops were indeed rectangular in shape and of well-defined size. To maintain the shape/size, the loop wire (AWG #14 stranded Cu) at its center was threaded through a T-fitting at the top of a 10 ft length of 1/2 inch PVC pipes which was suspended vertically from a tree to hold the top of the loop ~20 ft above the ground in an open field except for a copse of trees from which the antenna was suspended. The loop's top wire was extended out and threaded through a pair of vertically suspended 10 ft PVC pipes positioned so as to determine the loop's horizontal dimension and hence back to the preamp positioned at the bottom of the center PVC pipe. By simply moving the end PVC pipes in/out, the dimension of the antenna was readily varied. Used two 'local' NDBs as signal sources ... HZD_217 (39 miles, Carroll County Airport, TN) and FK_273 (47 miles, Ft Campbell, KY). S-meter readings were made using a Perseus SDR running under Mictrotelecom software control. Wellbrook ALA 1530 was always aligned parallel to the rectangular loop.