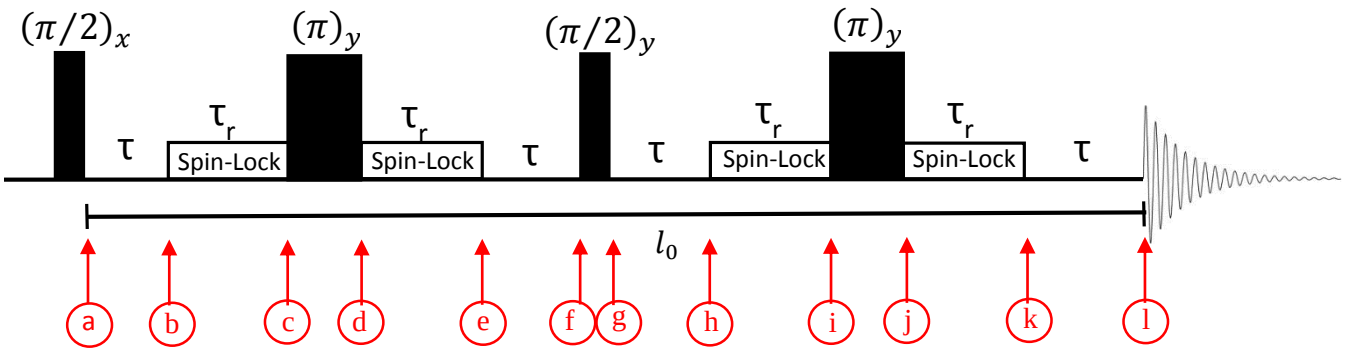
Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information



(New improved LLC Sequence)

Delay $\tau = 1/2\Delta\nu_{IS}$ and $\tau_r = 1/4J$ where $\Delta\nu_{IS}$ is the chemical shift difference and J is coupling constant.

(I) Product operators at different time points of pulse sequence are as following:

a) $-I_y - S_y$

b) $I_x - S_x$

c) $(I_x - S_x)\cos\theta + (2I_yS_z - 2I_zS_y)\sin\theta$

d) $(-I_x + S_x)\cos\theta - (2I_yS_z - 2I_zS_y)\sin\theta$

e) $-I_x(\cos^2\theta - \sin^2\theta) - 2I_yS_z\ (\sin 2\theta) + S_x(\cos^2\theta - \sin^2\theta) + 2I_zS_y\ (\sin 2\theta)$

f) $-I_y(\cos^2\theta - \sin^2\theta) + 2I_xS_z\ (\sin 2\theta) - S_y(\cos^2\theta - \sin^2\theta) + 2I_zS_x\ (\sin 2\theta)$

g) $-I_y(\cos^2\theta - \sin^2\theta) - 2I_zS_x\ (\sin 2\theta) - S_y(\cos^2\theta - \sin^2\theta) - 2I_xS_z\ (\sin 2\theta)$

h) $I_x(\cos^2\theta - \sin^2\theta) - 2I_yS_z\ (\sin 2\theta) - S_x(\cos^2\theta - \sin^2\theta) + 2I_zS_y\ (\sin 2\theta)$

i) $(\cos^2\theta - \sin^2\theta)\left[I_x\cos\theta + 2I_yS_z\sin\theta - S_x\cos\theta - 2I_zS_y\sin\theta\right] + \sin 2\theta\,[\,2I_zS_y\cos\theta - S_x\sin\theta - 2I_yS_z\cos\theta + I_x\sin\theta]$

j) $(\cos^2\theta - \sin^2\theta)\left[-I_x\cos\theta - 2I_yS_z\sin\theta + S_x\cos\theta + 2I_zS_y\sin\theta\right] + \sin 2\theta\,[\,-2I_zS_y\cos\theta + S_x\sin\theta + 2I_yS_z\cos\theta - I_x\sin\theta]$

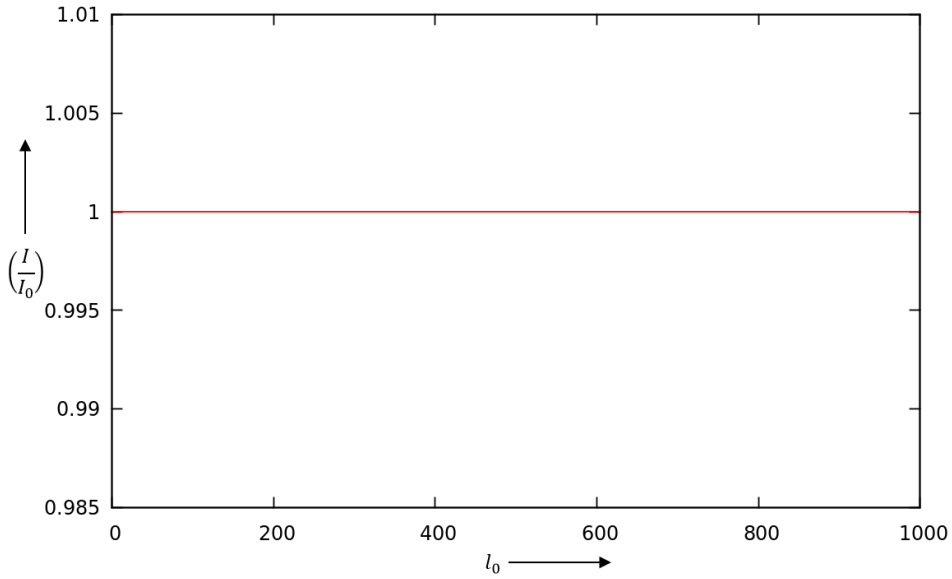
k) $-I_x + S_x$ (here all the anti-phase terms got cancelled and we are left with only in-phase terms)

l) $-I_y - S_y$

The angle θ in the above description is "$\theta = \pi J\tau_r$".

(II) Simulation of the new LLC sequence performed on GAMMA Simulation Platform showing the complete refocussing of coupling modulation. The parameters considered in simulation are:

- A spin system consisting of two weakly scalar coupled protons.
- Chemical shift difference = 50Hz.
- Scalar coupling constant = 5Hz.



The above simulation shows the variation of normalized peak intensity in the LLC spectrum as a function of no of loops "l_0" indicated in the sequence. It shows complete absence of any modulation in a weakly coupled spin-1/2 system. Relaxation is not included in the above simulation.

(III) Bruker Avance III pulse program for new improved LLC sequence:

New LLC pulse sequence:

```
;Maninder Singh. Narayanan D Kurur.
;PE-LLC sequence
;avance-version (21/07/14)
;1D sequence

#include <Avance.incl>

"p2=p1*2"
"p3=p1"
"p25=((1s/4*cnst3))"
"d6=1/(2*cnst2)"

1 ze
2 30m
  d1
  p1 ph1
3 d6 pl27:f1
  p25 ph25
  5u pl1:f1
  p2 ph2
  5u pl27:f1
  p25 ph25
  d6 pl1:f1
  p3 ph3
  d6 pl27:f1
  p25 ph25
  5u pl1:f1
  p2 ph2
  5u pl27:f1
  p25 ph25
  d6
  lo to 3 times l4
  go=2 ph31
  30m mc #0 to 2 F0(zd)
exit
```

```
ph1=0 2     /* 90d */
ph2=1      /* 180d */
ph3=1 1 3 3   /*90d refocusing */
ph25=0     /* low power sustaning pulse  */
ph31=0 2 0 2


;pl1 : f1 channel - power level for pulse (default)
;pl27 : f1 channel - power level for sustaning pulse
;p1 : f1 channel -  high power 90 degree excitation pulse
;p2 : f1 channel -  high power 180 degree refocusing pulse
;p3 : f1 channel -  high power 90 degree refocusing pulse
;p25 : f1 channel -  low power sustaning pulse
;d1 : relaxation delay; 1-5 * T1
;d6 : evolution interval to create (Ix-Sx)
;NS: 1 * n, total number of scans: NS * TDO
;cnst2:  chemical shift difference
;cnst3:  coupling constant
;l4: loop for LLC sustaning. Min value= 1 (2 echoes). Tllc sustaning time= 4*p25*l4
```

(IV) Detailed analysis of new LLC sequence:

We have prepared 4 different samples of the Uridine-5'-monophosphate (UMP) of same concentration (0.01M) and measured the LLC lifetime using both normal LLC sequence and new LLC sequence as shown in Figure (1.(a) and (b)) in the main text. The results are shown in the TABLE 1 below:

TABLE. 1

UMP Samples (0.01M)	Normal LLC lifetime (s)	RMSE (Root mean square error)	R^2
Sample 1	1.224	0.0328	0.9642
Sample 2	1.240	0.0325	0.9677
Sample 3	1.235	0.0343	0.9637
Sample 4	1.162	0.0340	0.9588
	New sequence LLC lifetime (s)		
Sample 1	1.409	0.0194	0.9938
Sample 2	1.393	0.0175	0.9947
Sample 3	1.429	0.0189	0.9951
Sample 4	1.421	0.0172	0.9952

The above results shows that LLC lifetimes obtained using the new LLC sequence is longer and more accurate than normal LLC sequence. Further, the standard deviation of LLC lifetime for both the sequences were calculated and found to be 0.0313 (normal LLC sequence) and 0.0136 (new LLC sequence) which confirms our conclusions. The mean values for LLC lifetime is 1.215 s (normal LLC sequence) and 1.413 s (new LLC sequence). All these values were obtained by fitting the experimental data on **MATLAB R2013b** software using curve fitting tool.