**Non CPMG phase modulation, the easy way.**

P. LeRoux[1]
[1]GE Healthcare, Buc, IDF, France

## Introduction

The non CPMG sequence based on a quadratic phase modulation of the refocusing pulse train (1) is able to perform a Fast Spin Echo acquisition which is insensitive to the phase of the original magnetization and without sacrificing any signal component.
Clinical applications include for instance diffusion spine imaging (2). Apart from the specification of the long term phase modulation, another set of parameters to be known is the corrective phase modulation necessary, at the beginning of the train, to stabilize the signals. In (1) the stabilization period was given in term of some internal parameters which may have made difficult the use of such modulation without a good knowledge of the underlying theory. At the occasion of a new way, not presented here, to design this modulation we give the description of this modulation in simple terms so that this kind of sequence can be easily reproduced.

## Method

For any phase modulation given by the axis $X_i$ along which the $i^{th}$ refocusing pulse is emitted, one can set the receiver axis, $R_i$, at echo i such that there is the same angle $d_i$ from $R_{i-1}$ to $X_i$ and from $X_i$ to $R_i$, see figure 1. In the special case of a quadratic emission phase $X_i = D\, i^2$, the angle $d_i$ is a linear function of i, $d_i = D\, i$, and it is easier to iterate first the values $d_i$, and then the receiver phase by $R_i = R_{i-1} + 2d_i$ and $X_i = R_{i-1} + d_i$. This is what is done in the C function below, as used on a GE Signa scanner. One

```
float dR[71] ={ -0.2376, -0.2515, -0.6971, -0.2034,  0.4780, -0.4694, -1.0170, -0.3567,  0.2410,  0.4447, \
           0.8831,  0.4056,  0.3200, -0.1339, -0.1842, -0.5396, -0.7111, -0.5064, -0.5032, -0.3439, \
          -0.3182, -0.0461,  0.1491,  0.0974,  0.3490,  0.3166,  0.4383,  0.1516,  0.1695,  0.0960, \
          -0.0437, -0.1279, -0.1294, -0.0418, -0.0780, -0.1405,  0.0213, -0.0675, -0.0285, -0.2021, \
           -0.0396, -0.1423, -0.1819, -0.1700, -0.0920, -0.0318, -0.0782,  0.0477,  0.1699,  0.1377, \
           0.1885,  0.1458,  0.2836,  0.0535,  0.0849, -0.0242,  0.0145, -0.1608, -0.1692, -0.1521, \
          -0.1479, -0.2158, -0.1574, -0.1012, -0.0503, -0.1184,  0.0042,  0.0270,  0.0595,  0.0, 0.0 };
D  = 161.0/ 843.0; d = 0 ; r = 0;
for (i=0; i< klines; i++) {
  r = 2 * d + r;   r = r - floor(r); R[i]  = r; X[i]  = R[i] - d; d = d + D; d = d -floor(d); }
ncor = 70; if (ncor > klines) ncor = klines;
 /* correction, do not forget that dR has been mutiplied by 10 !!!! */
for (i=0; i<ncor; i++) { dX  = 0.5 * 0.1 *  (dR[i] + dR[i+1]); X[i] += dX; R[i] += 0.1 * dR[i+1]; }
```

notes that it is a good idea for numerical precision purpose to regularly take the modulo 2 Π of the angles and to simplify this task, all values in the program are in unit of a full 2 Π turn. The corrective phase modulation which is added to the nominal modulation is given, after multiplication by 10, by the array called dR . This correction is directly applied to the receiver axis and serves, by bisection, to correct also the emission axis.

## Results

The figure 2 gives the signal magnitudes for the in phase and out of phase component obtained by simple Bloch simulation. One recalls that with standart CPMG the out of phase component dies away after a small number of echoes. It is also the case of previous phase modulation scheme like 'XY' modulation (3) when the nutation angle is inferior to 2.4 radians.

## References

(1). P. LeRoux, JMRE 155 p 278-292, 2002; (2). J. Ma et al. Proceeding ISMRM 2004 p. 1262;(3). J.G. Pipe et al MRM 47 p.42-52, 2002.

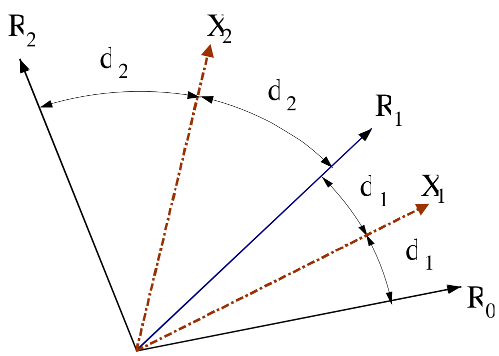


Fig. 1: The position of the exciter axes (X), and receiver axis (R) can be determined from the angles (d) Alternatively one exciter axis being the bisector of two consecutive R, only these R axis have to be known..

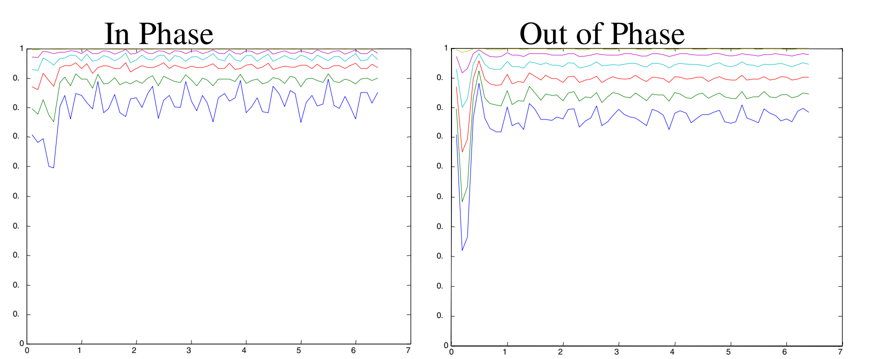


Fig. 2: Signal magnitude in function of echo number for an original magnetization positioned,after the flip pulse, along the reference axis R0 (In Phase) or perpendicular to that (Out of Phase). The nutation angle of the refocusing pulse were constant along the echotrain and equal to 3, 2.8,2.6,2.4,2.2 and 2 radians..