

Highlights:

- The exact calculation of CPMG experiments can remarkably eliminate systematic errors in measured  $R_2$ s due to the effects of frequency offset;
- CPMG experiments with group phase variation can substantially remove oscillations and effects of the field inhomogeneity;
- The second-order expression of the effective decay rate with phase variation is able to provide reliable estimates of  $R_2$  when offsets are roughly within  $\pm\frac{1}{2}\gamma B_1$ ;
- The more sophisticated optimization model using an exact solution of the discretized CPMG experiment extends, to  $\pm\gamma B_1$ , the range of offsets for which reliable estimates of  $R_2$  can be obtained when using the preferred phase variation scheme.

Graphical Abstract:

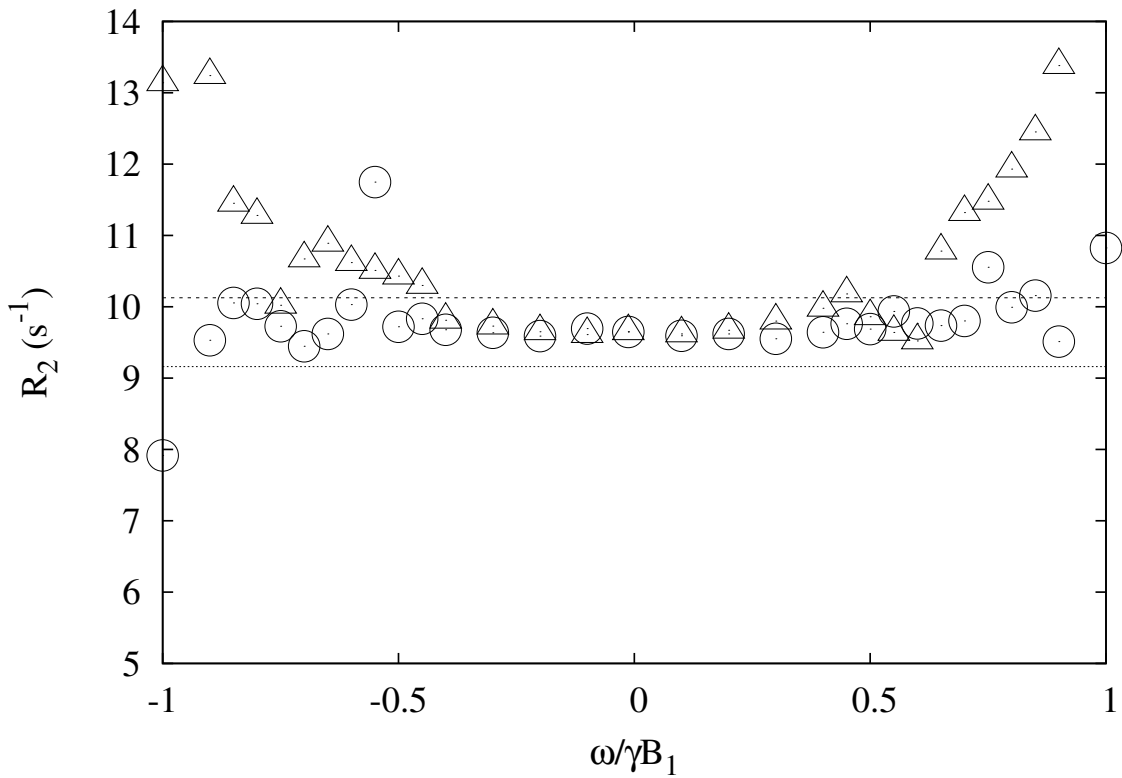


Figure 1: Measured  $R_2$  of the phase variation scheme 0013 plotted against the ratio of offset over the amplitude of the  $\pi$  pulse, including circles for exact solution fitting and triangles obtained by fitting the second-order expression to the same experiment data. This figure tells us that fitting the exact solution of the Bloch equations provides allows us to cover almost twice the offset frequency range in one experiment.