Early diagnosis and tracking of Parkinson’s disease can be achieved by detecting Substantia Nigra iron overloaded with MRI relaxometry parameter T2\*, unfortunately, accurate high-resolution T2\* mapping result is difficult to achieve at the brain stem due to tissue motion. A novel technique N-periodic ka-SPGR is proposed to be motion robust and can be used to generate quantitative T2\* mapping images, while neither analysis of the techniques’ T2\* mapping performance nor optimised scan parameters were suggested. This study provides optimised parameters (period and repetition time) of ka-SPGR specifically for PD biomarker detection based on computer simulation. It is followed by a phantom scanning experiment with the optimised ka-SPGR sequences and the T2\* mapping result using Multi-echo GRE is used as Gold-standard to compare with. 7-periodic or 12-periodic ka-SPGR with a repetition time of 6ms is suggested to optimise the performance. The 12-periodic ka-SPGR is more robust to noise, while the 7-periodic provides better efficiency. The accuracy and precision of both sequences are proven by analysing simulation and phantom experiment results, which both show a percentage bias < +-10%. However, the study is limited by the phantom’s alignment with the substantia nigra and can be improved using a phantom specifically adjust for substantia nigra tissue property. Additionally, to further prove the reliability of ka-SPGR for PD biomarker detection, massive in-vivo experiments are desirable to evaluate its performance in realistic and complex environments.