1. Theory

In MRI, the excitation is achieved by tipping the magnetised spins initially aligned with the main magnetic field (longitudinal direction) towards the transverse plane with a flip angle (α) from the longitudinal direction and a phase shift (φ) in the transverse plane using a radiofrequency pulse. After the excitation, the spin’s magnetisation relaxes towards the longitudinal direction with the recovery of the longitudinal component (with the time constant T1) and decay of the transverse component, and the transverse magnetisation is measured for MR image formation. The time between excitation and acquisition of the signal is known as echo time (TE), and the time between adjacent excitations is repetition time (TR).

Multi-echo GRE

Using a gradient echo (GRE) based pulse sequence, the acquired MR signal decay with the time constant T2\*[Method1]. The gold-standard T2\* measuring method – multi-echo GRE is performed by simply measuring the MR signal at multiple TEs in one TR with GE sequence and fit monoexponential decay to get the T2\* voxel by voxel as shown in Figure X.

图示

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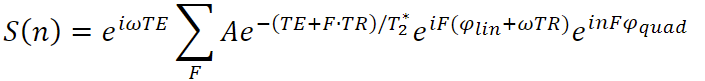
ka-SPGR

By constantly exciting the spins with a quadratic phase cycling described by function

  (for n = 0,1,2…. ) (2)

, the radiofrequency-spoiling (RF-spoiling) is applied [], it spoiled the refocusing which will generate T2 signal decay, and forming configuration state signal which from T2\* The quadratic RF-spoiling applied split

Performing the GE sequence with short TR will result in the gradual formation of a steady-state signal, by applying RF-spoiling on top of it, the steady-state signal acquired after different phase shifts will contain different components of configuration state, as shown in the analytical solution below.



S(n) is the signal acquired after n th RF-spoiling, the phase modulation applied on

* RF spoiling define the weight of configuration state in each acquired signal (image)
* But the signal will all still be together, in one point, can’t distinguish them
* Adding gradient spoiling, shift the configuration states apart.
* When reconstruct the image, cut the configuration states in k-space
* Times related weighting – RF-spoiling, forming the actual confirmation state,

An analytical solution of RF-spoiling GRE sequence is provided by [], which shows the steady state signal is the sum of configuration state of the

Adding RF-spoiling on top of a gradient echo sequence

A large spoiling gradient is applied in conventional RF-spoiling gradient echo sequence to shift the configuration states further apart from each other, and

Ka-SPGR sequence is modified based on SPGR sequence,

a. How RF-spoiling is added. Repeating quadratic phase shift. [phase shift equation]

b. Due to the periodically applied

c. The steady state signal contains information from various configuration states when RF spoiling is added during excitation, which is shown by the analytical solution\*\*\*, suggested by [].

d. The configuration states are having T2\* exponential decay relationships. (analytical solution)

e. The analytical solution shows the configuration states can be used to fit an exponential decay and T2\* can be extracted from it. Reversing the process, the configuration states are able to be reconstructed by applying phase modulation to the N-acquired image and sum together.

f. Previous analytical solutions do not take into account that the k-space is not entirely acquired in reality.

To acquire all the configuration state information, we need to apply gradient spoiling to put all configuration states in the k-space. Which is the main idea of k-space aliasing SPGR.

1. Model Simulation and analysis

图示

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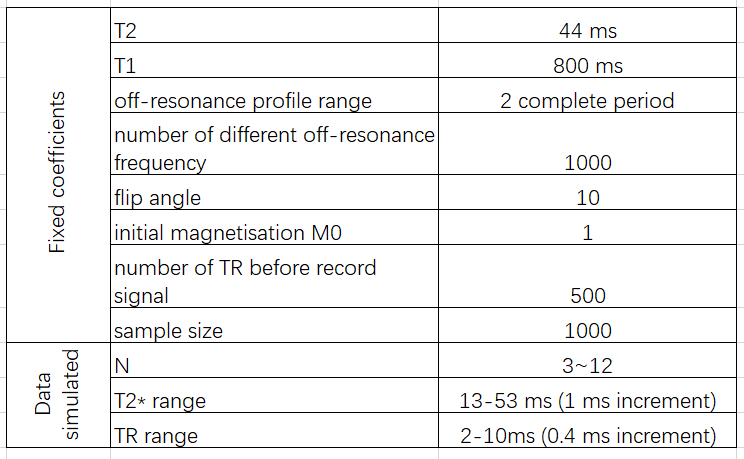
* 1. Basic simulation
  2. Choice of T2\* range

As the tissue and magnetic field inhomogeneity dependent T2\* and has a relationship

 (1)

with the pure tissue-dependent transverse decay time constant T2 [Method1], with known substantia nigra (SN) T2, PD patient SN T2\* and healthy patient SN T2\*, the field inhomogeneity caused by healthy and PD SN can be calculated.

* 1. Noise Modelling and Monte Carlo Simulation



* 1. Simulation result analysis
     1. Bias
     2. Standard deviation

1. MRI data acquisition and analysis
   1. Basic setup

图片包含 表格

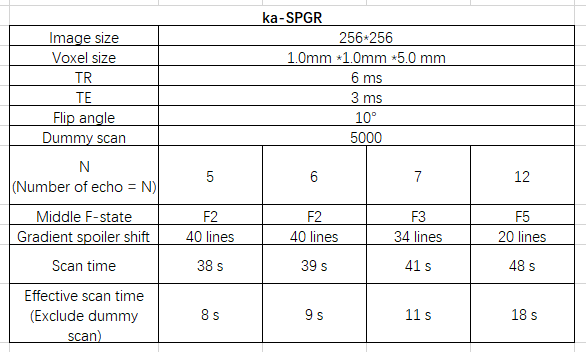
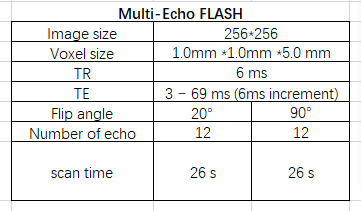
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(LHS: picture of NIST/ISMRM Premium System Phantom Model (SN:130-102), RHS: MnCl2-containing spheres layer being scanned)

NIST/ISMRM Premium System Phantom Model (SN:130-102) is used as the scanning object, and a slice acquisition is performed at the MnCl2-containing spheres layer (Figure X). The scanned layer is built for T2 mapping, so the exact T2\* value for each sphere is not given. However, the multi-echo FLASH (Siemens, 3T), one commonly used multi-echo GRE sequence, can be used as the gold standard T2\* mapping method to obtain the ground truth T2\* value for each phantom sphere.

It acquires images at multiple TEs in one TR and performs voxel-based fitting to get the T2\* value as shown in Figure X.

* 1. Scanning parameters



* 1. Image reconstruction

图示

描述已自动生成

* Data shift rela
* Shift to centre of k-space, partial fourier filling the k-space
  + 1. Gold-Standard Multi-echo GRE
    2. ka – SPGR
  1. Result analysis
     1. Percentage error
     2. Effective T2\* Signal-to-Noise ratio

Reference:

1. Principles, techniques, and applications of T2\*-based MR imaging and its special