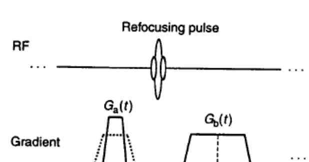
Spin Echo

Nov 14

Handbook of MR pulse sequence

Quiz

- Assume all the gradient lobes below have the same ramp time δ. if the amplitude of G_b is fixed at G_0 and half of the duration of the gradient of the plateau is Δ, calculate the amplitude and duration of lobe G_a based on the equations of wave reshaping. Present and perform all the integration steps



$$\int_0^{\tau_a} G_a(t)\,dt = \int_0^{\tau_b} G_b(t')\,dt'$$

$$\int_0^{\tau_a} G_a^2(t)\,dt = \int_0^{\tau_b} G_b^2(t')\,dt'$$

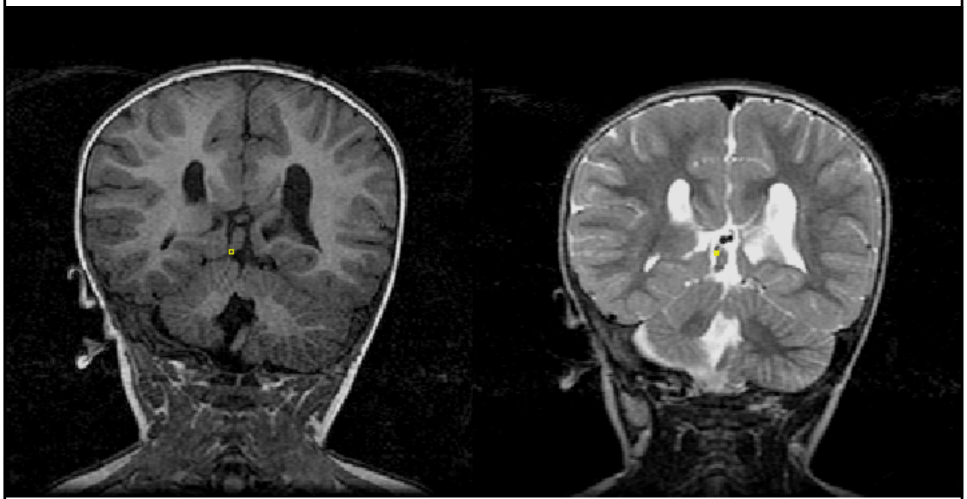
Spin-echo (SE)

- The main advantage of SE pulse sequence is its ability to obtain a specific contrast weighting (T_1, T_2, and proton density weighted)

	Short TE (<20 ms)	Long TE (>80 ms)
Short TR (<700ms)	T_1-weighted	Not commonly used
Long TR (>2000ms)	Proton density-weighted	T_2-weighted

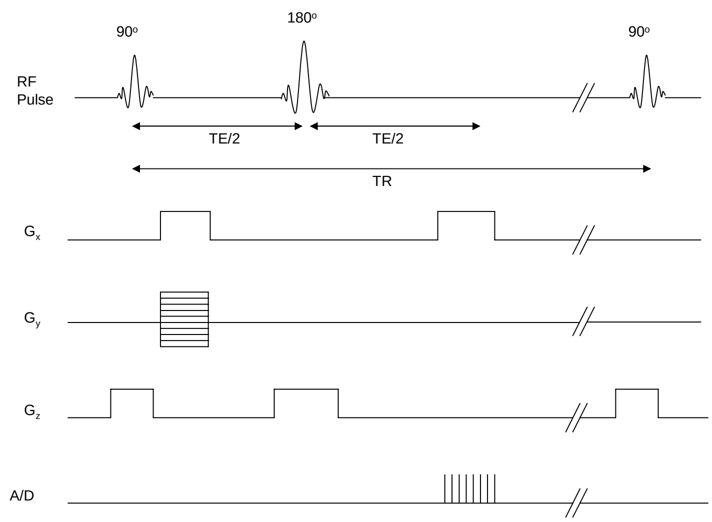
Optimal TR & TE values depend on the tissue being imaged and the B_0 field strength

T_1-Weighted Image $\quad$ T_2-Weighted Image



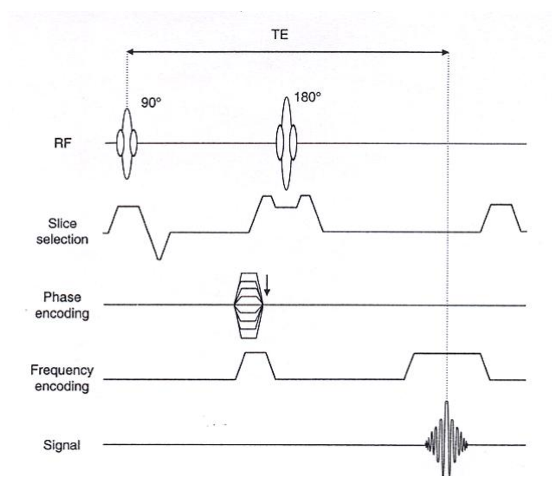
SE are weighted by $e^{-TE/T2}$
GE are weighted by $e^{-TE/T2*}$

Single Echo SE



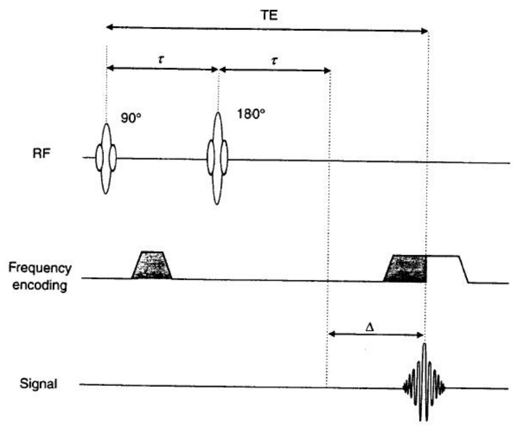
SE

Is there a crusher and a spoiler



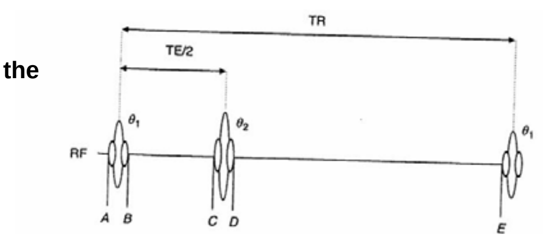
The PEAK of the echo

Is Δ always zero



Signal Formula

Using the bloch equation derive the signal formula for a SE



$$M_{zB} = M_{zA} \cos 90 = 0$$

$$M_{zC} = M_0 (1 - e^{-TE/2T_1})$$

$$M_{zD} = M_{zC} \cos 180 = -M_0 (1 - e^{-TE/2T_1})$$

$$M_{zE} = M_{zD} e^{-(TR-TE/2)/T_1} + M_0 (1 - e^{-(TR-TE/2)/T_1})$$

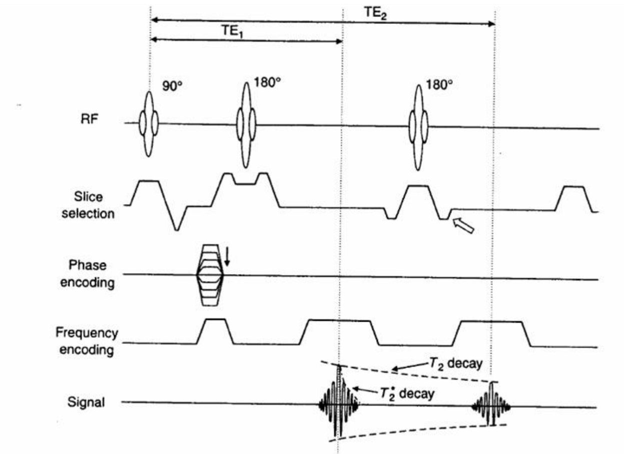
$$= M_0 (1 - 2e^{-(TR-TE/2)/T1} + e^{-TR/T_1})$$

The signal at the spin echo is given by

$$S = M_{zE} Sin 90 \sin^2 (180/2) e^{-TE/T2}$$

$$= M_0 (1 - 2e^{-(TR-TE/2)/T1} + e^{-TR/T_1}) e^{-TE/T2}$$

Multi-Echo SE



Relaxation times measurement using SE

Tissue	T_1 (msec)	T_2 (msec)
CSF	2000	160
White Matter	687	107
Gray Matter	825	110
Bone	103	28
Adipose	250	75

Relaxation times measurement

- For T_1 measurements, the repetition time (TR) is altered while for T_2 measurements the echo time (TE) is varied.
- The intensity of an image acquired using a spin echo sequence is given approximately by

$$I \propto \rho(1-e^{-TR/T_1})e^{-TE/T_2}$$

T_2 measurement
Use long TR

$$1-e^{-TR/T_1}$$

T_1 measurement
Use short TE

$$e^{-TE/T_2}$$

T1 and T2 can be found by solving the equation of SNR as a function of variable TR or TE values, respectively.

Contrast Resolution

- Relaxation times are critical for MR images because they form the basis of contrast mechanism. Contrast resolution is derived from the differences in T1 and T2 relaxation times of neighboring tissues.
- Imaging acquisition parameters can be manipulated to optimize the contrast resolution based on either T_1 or T_2 differences

Typical relaxation times measurement protocol

- The calculation of MR parameters are based on the SNR for specific region of interest (ROI) or pixel by pixel basis.
- The SNR in MR images is defined as the mean signal intensity over a ROI within the sample divided by the standard deviation (std) of the noise from region outside the image, governed by

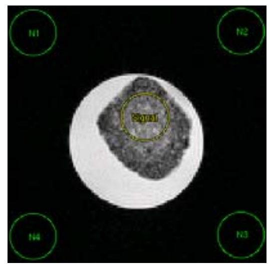
$$SNR = \frac{mean(Signal)}{std(Noise)}$$

Signal-to-Noise Ratio (SNR) Measurement

Saturation recovery with TE 7 ms, TR 50 - 6000 ms

$$\text{SNR} = \frac{\text{mean(Signal)}}{\text{mean(std(Noise))}}$$

$$\text{SNR} = \text{SNR}_0 (1 - e^{-TR/T_1})$$



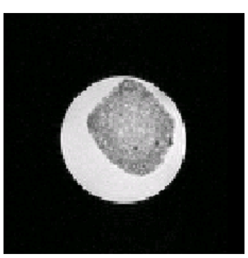
Signal	Noise				SNR
	N1	N2	N3	N4	
124	1.64	1.55	1.59	1.48	124/1.56 = 80

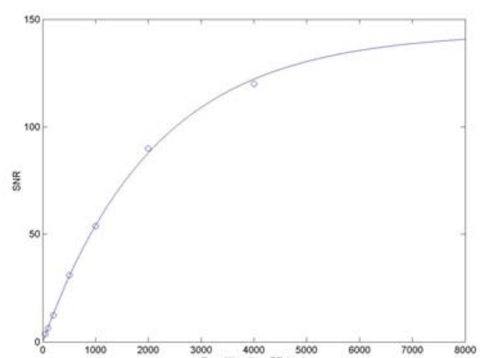
T_1 Measurement

Saturation recovery with TE 7 ms, TR 50 - 6000 ms

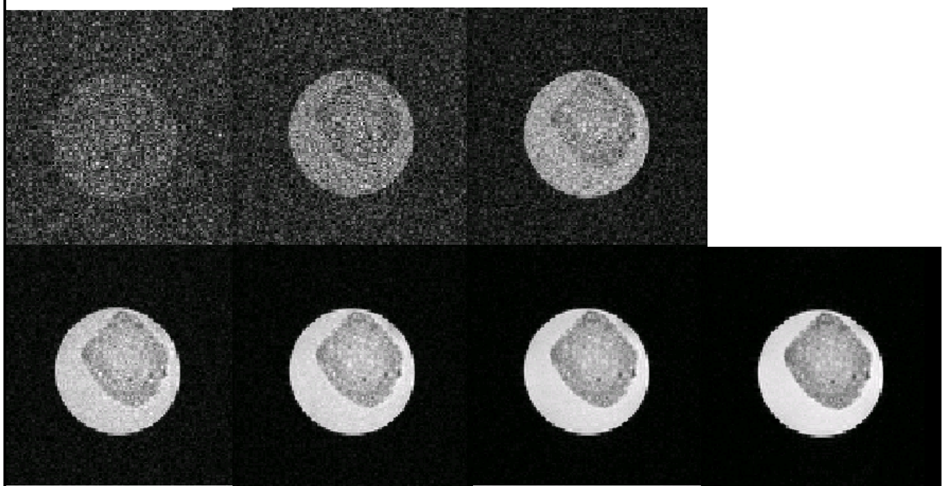
saturation recovery spin echo imaging sequence in 7 steps with TRs of 50, 100, 200, 500, 1000, 2000, and 4000 msec

$$\text{SNR} = \text{SNR}_0 (1 - e^{-TR/T_1})$$





Notice how the signal changes with changing TR



T_2 Measurement: Mono- & Bi-exp

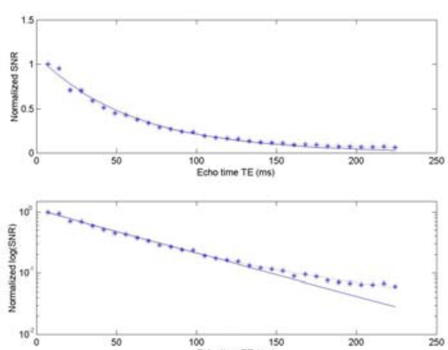
Spin echo with multiple echoes

TR 4000 ms, TE 7 - 224 ms

Mono-exp: $\mathrm{SNR} = \mathrm{SNR}_0 e^{-TE/T_2}$

Bi-exp:

$$\mathrm{SNR} = \mathrm{SNR}_0 (A_1 e^{-TE/T_{2f}} + A_2 e^{-TE/T_{2s}})$$



Notice how the signal changes with changing TE

$SNR = SNR_0 e^{-TE/T_2}$