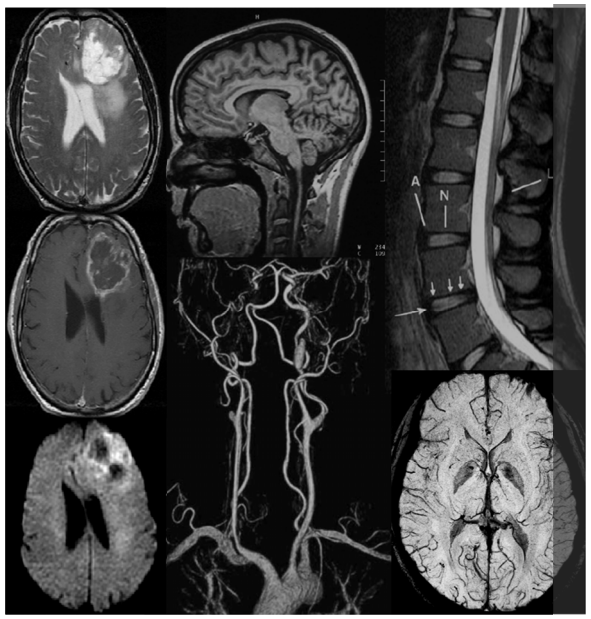
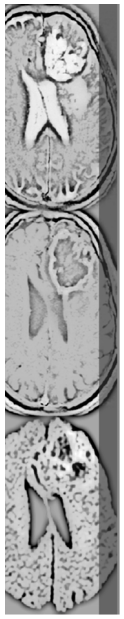


磁振影像學MRI
Spin Echo

盧家鋒 教授

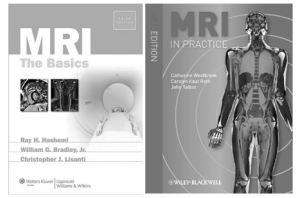
國立陽明交通大學
生物醫學影像暨放射科學系
alvin4016@nycu.edu.tw

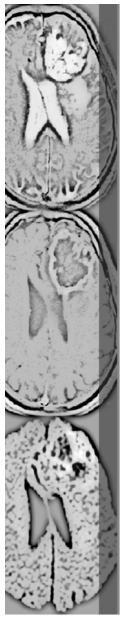


本週課程內容 http://cflu.lab.nycu. edu.tw

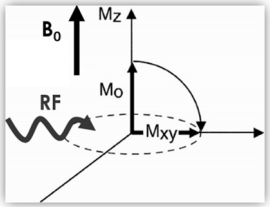
- 自旋回音(spin echo)
- 快速自旋回音(fast spin echo)

- MRI The Basics (3rd edition)
  - Chapter 8: Spin echo
  - Chapter 19: Fast spin echo
- MRI in Practice, (4th edition)
  - Chapter 5: Pulse sequences

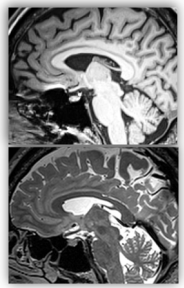




Procedure of MRI



- ☑ Alignment (magnetization) B_0
- ☑ Precession $\omega_0 = \gamma B_0$
- ☑ Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
  - The most effective resonance is produced when $\omega_0 = \omega_2$
- ☑ MR signal (EMF, relaxation time)
- ☐ Imaging (Pulse sequencing: SE, GRE, EPI)
  - ☑ Tissue Contrast: Image weighting
  - ☑ Spatial localization: Slice selection & Spatial Encoding
  - ☑ Data space/K space



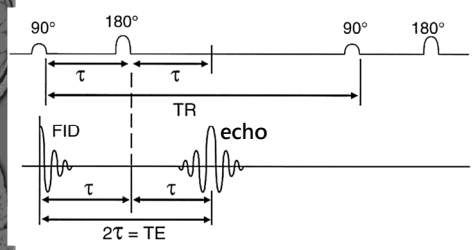
自旋回音

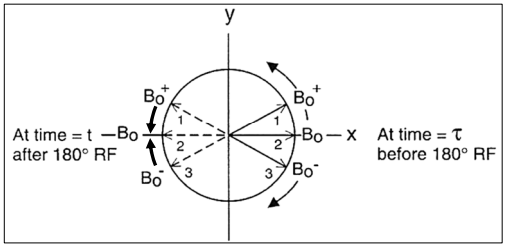
Spin echo (SE)
Conventional spin echo (CSE)

Rephasing 180° RF

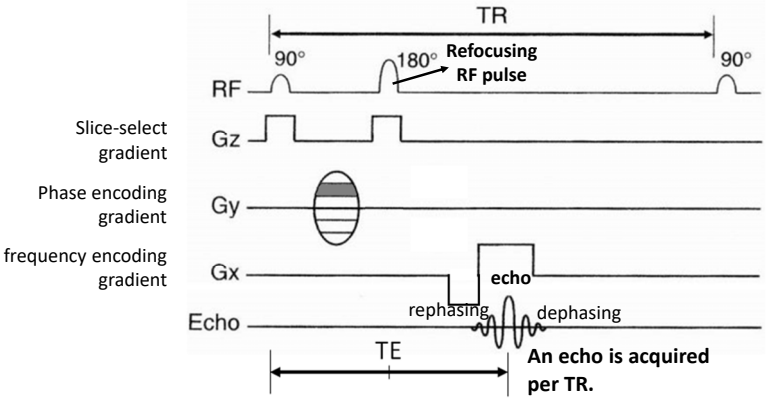
- T2* decay depends on both
  - External magnetic field
  - Spin-spin interactions
- T2 decay depends only on
  - Spin-spin interactions

Eliminate the effects of ΔB_{ext}



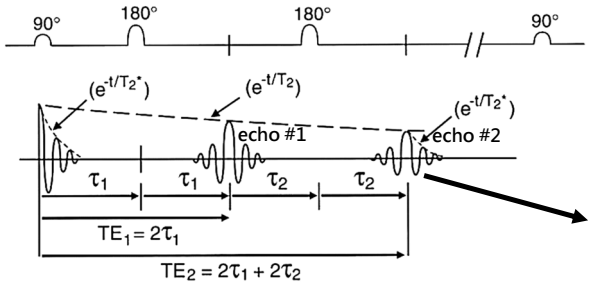


Spin-echo pulse sequence diagram



Dual-echo spin echo

- A second 180° pulse applied at time τ_2 after the first echo will allow the spins to rephase again at time $2\tau_2$ after the first echo and a second echo is obtained.

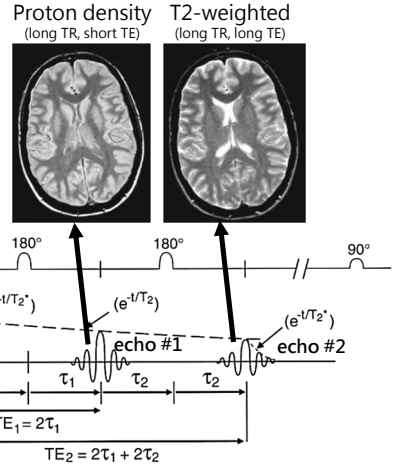


T2>>T2*

Increase T2 weighting
But lower SNR

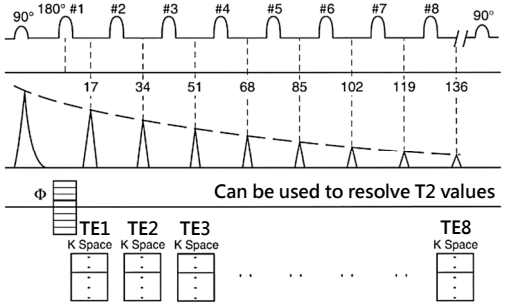
Dual-echo spin echo

- The proton density images can be acquired with T2-weighted images without using another sequence.



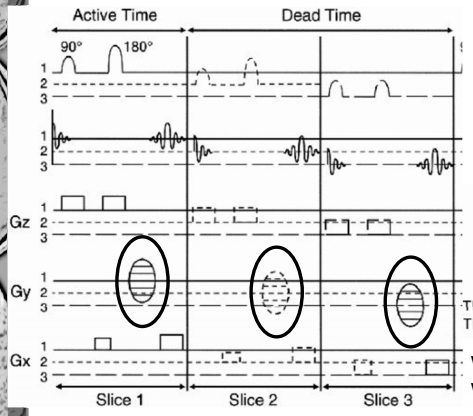
Multi-echo spin echo

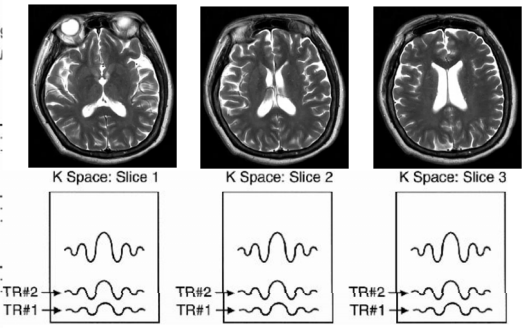
- Fill each echo into the distinct k-space.
- For an eight-echo train, we get eight different images.



Only with a single phase-encoding step

Multi-slice Acquisition in a TR





We excite different slices in each TR;
We use the same magnitude of G_y in each TR

Multi-slice & multi-echo spin echo

(C) 5.磁振造影傳統自旋回聲（conventional spin echo）脈衝序列中，若在一個 TR 內選擇 4 個切面，每個切面有 2 個回聲（echo），則在一個 TR 內，有幾個相位編碼梯度？
A.1
B.2
C.4
D.8

(A) 2.磁振造影傳統自旋回聲（conventional spin echo）脈衝序列中，若在一個 TR 內選擇單一切面，4 個回聲（echo），則在一個 TR 內，有幾個相位編碼梯度？
A.1
B.2
C.4
D.8

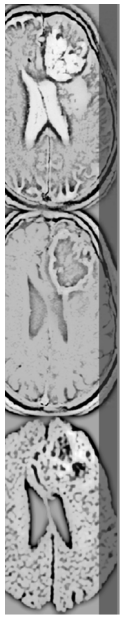
(B) 1.磁振造影傳統自旋回聲（conventional spin echo）脈衝序列中，若在一個 TR 內選擇 2 個切面，4 個回聲（echo），則在一個 TR 內，開啟幾次相位編碼梯度？
A.1
B.2
C.4
D.8

(103 年第二次放射線器材學第 45 題)

Multi-echo procedure doesn't increase the phase-encoding steps.

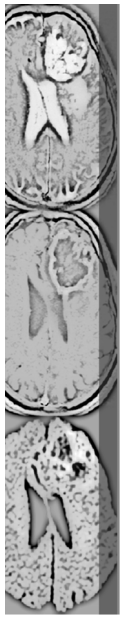
快速自旋回音

Fast spin echo (FSE)



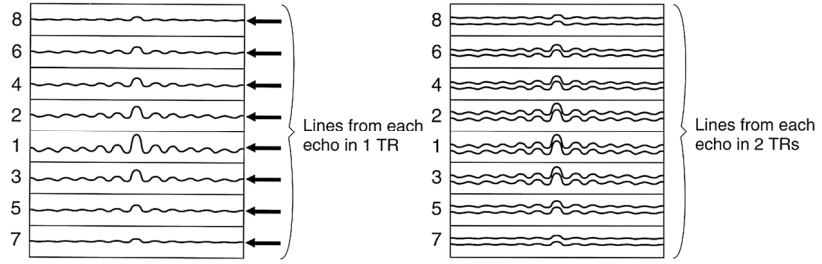
Terminology of FSE

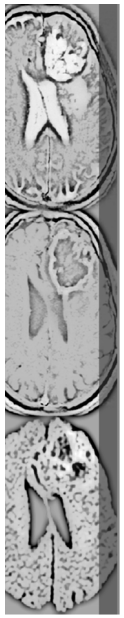
Manufacturer	Name
Bruker	Rapid acquisition with relaxation enhancement (**RARE**)
GE, Hitachi, Toshiba	Fast spin echo (**FSE**)
Siemens, Philips	Turbo spin echo (**TSE**)



Fast spin echo (FSE)

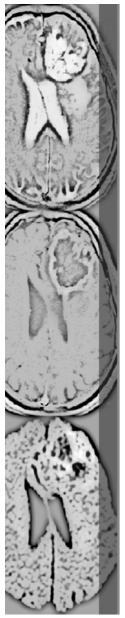
- FSE is a very elegant way of manipulating the CSE technique to save time.
- We will only have one k-space. We'll fill this k-space eight lines (eight-echo train) at a time.





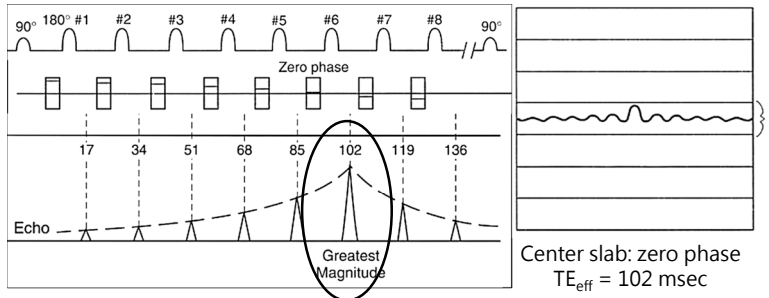
Echo Train Length (ETL)

- ETL refers to the number of echoes used in FSE.
- The time interval between successive echoes (or between 180° pulses) is called the echo spacing (ESP).
- A typical ESP is on the order of 16 to 20 msec.



Fast spin echo

- In FSE, before each 180° pulse, we place a different value of the phase-encoding gradient.
- For the 180° pulse before the echo we choose as the TE_{eff} (in this case, 102 msec), we use a phase-encoding gradient with the lowest strength.



Center slab: zero phase
TE_{eff} = 102 msec

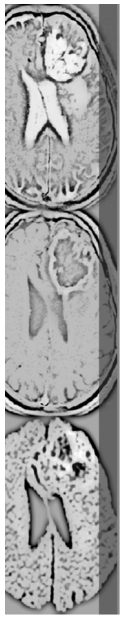
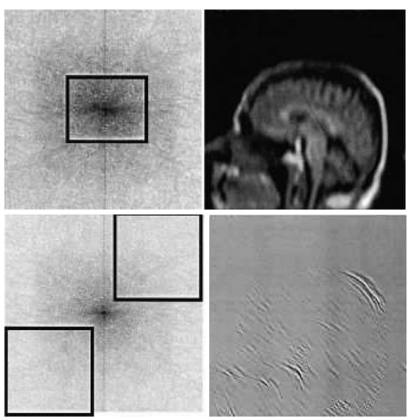
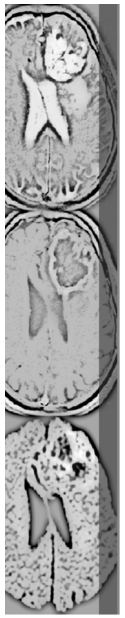


Image of K-Space

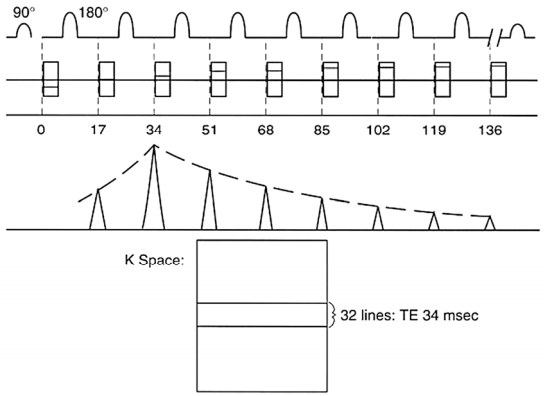
- The center of k-space contributes to the primary information of image (e.g. **contrast**).
- The periphery of k-space provides information regarding fitness of the image and clarity at sharp interfaces

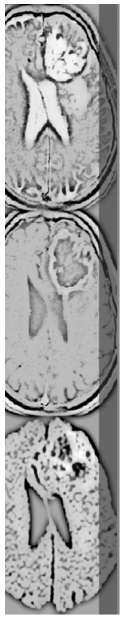




Change TE_{eff} to adjust T2 weighting

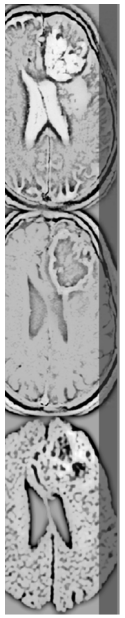
- Long TR, short TE
  ➔ Proton density
- Long TR, long TE
  ➔ T2-weighted





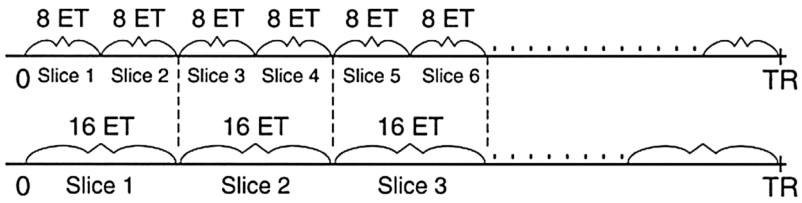
Scan Time

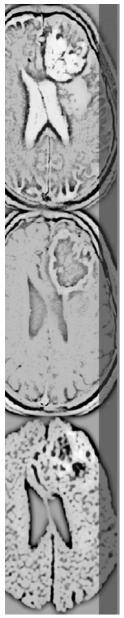
- $Scan\ time\ (CSE) = (TR)(Ny)(NEX)$
- $Scan\ time\ (FSE) = \frac{(TR)(Ny)(NEX)}{ETL}$



Trade-off: slice coverage

- Increasing the ETL causes a reduction in coverage (number of slices) within a TR.
- ETL ↑ → speed ↑ → slice coverage ↓





Phase-encoding step

- Please compare to the conventional spin echo.
- Depends on both ETL and slice number in a TR.

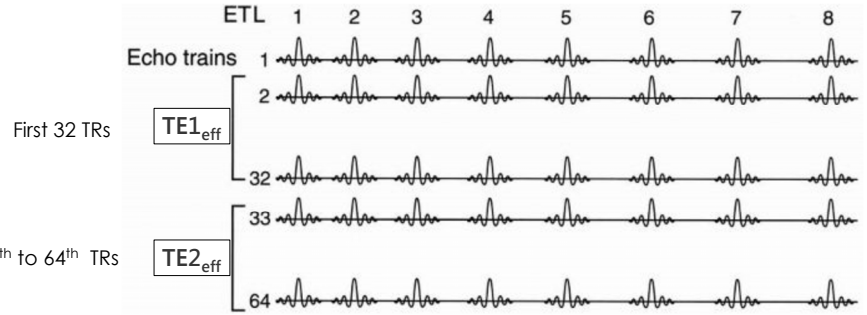
(D) 4.磁振造影快速自旋回聲（fast spin echo）脈衝序列中，若在一個 TR 內選擇單一切面且回聲列長度（echo train length）為 8，則在一個 TR 內，有幾個相位編碼梯度？

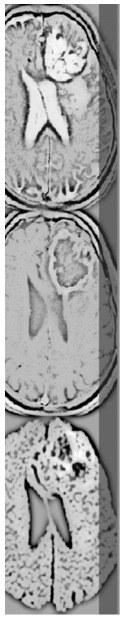
A.1
B.2
C.4
D.8

(98 年第一次放射線器材學第 48 題)

Multi-echo FSE

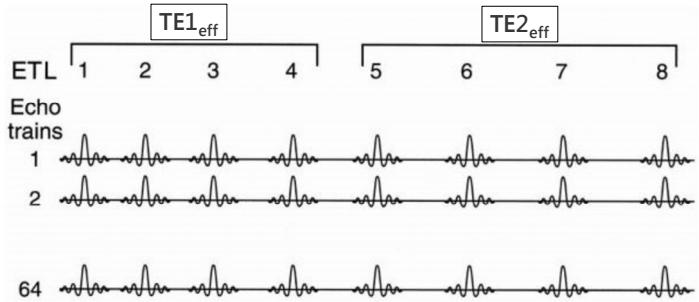
- Full echo trains: the entire echo train is completed for a TE_{eff}.

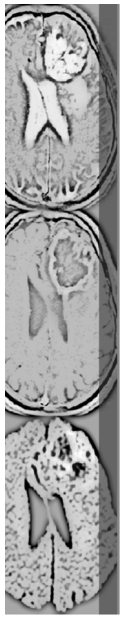




Multi-echo FSE

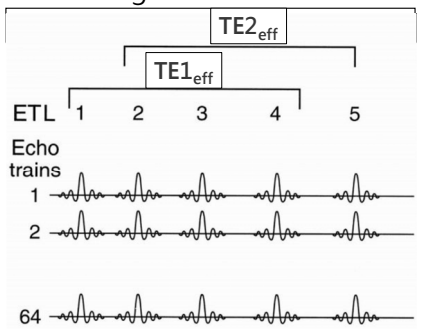
- Split echo trains: the first half of the echo train contributes to the image with $TE1_{eff}$ and the second half to $TE2_{eff}$ (thus, two k-spaces are created).



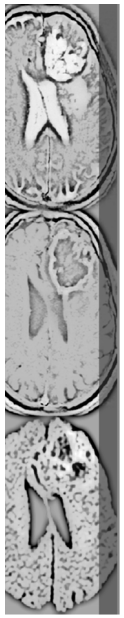


Multi-echo FSE

- Shared echo trains: the first and last echoes in the train are emphasized for $TE1_{eff}$ and $TE2_{eff}$, respectively, and the echoes in between are shared for both images.

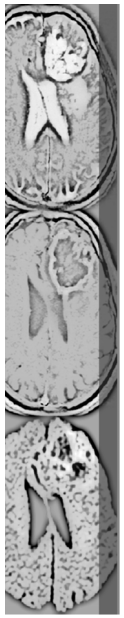


Can save more time for multi-slice.



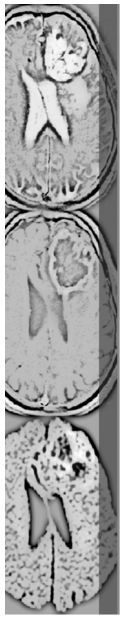
Properties of FSE

- Advantages
  - The scan time is decreased (which allows faster scanning).
  - The signal-to-noise ratio (SNR) is maintained because we still have 256 phase-encoding steps.
  - The increased speed allows for high resolution imaging in a reasonable amount of time.
  - Motion artifacts will be less severe. Because the 180° pulses are evenly spaced, there is a natural even-echo rephasing effect. For instance, cerebrospinal fluid (CSF) motion artifacts are much less severe on FSE than on CSE images.
  - The rephasing from the multiple 180° pulses leads to less distortion from metallic objects (magnetic susceptibility) on FSE images.
  - Similarly, FSE images are much more tolerant of a poorly shimmed magnet than are CSE images.



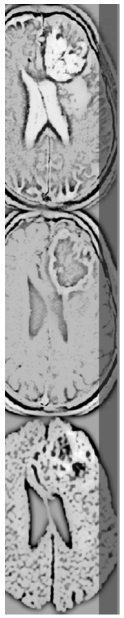
Properties of FSE

- Disadvantages
  - Reduced coverage, that is, decreased number of slices.
  - Contrast averaging (k-space averaging) so that
    - CSF is brighter on proton density-weighted FSE images.
    - To alleviate this problem, either use a shorter ETL (to exclude longer TEs) or a higher BW (to decrease ESP and the minimum TE_{eff}).
  - Magnetization transfer (MT or MTC) effect in FSE. MTC is inadvertently present in FSE. This is caused by the presence of multiple, rapid 180° pulses containing off-resonant frequencies.

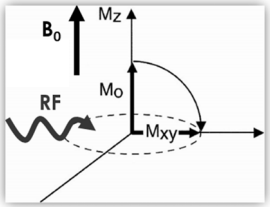


Properties of FSE

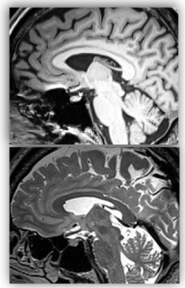
- Disadvantages (continue~)
  - Magnetic susceptibility effects will be less than with CSE. Therefore, T2-weighted FSE images are less sensitive to magnetic susceptibility effects such as metal or hemorrhage (e.g., deoxyhemoglobin and hemosiderin) than are T2-weighted CSE images (Fig. 18-47).
  - Fat is bright on T2-weighted FSE images. This is due to suppression of diffusion-mediated susceptibility dephasing caused by the closely spaced 180° pulses. You could do a fat-saturated FSE to decrease the intensity of fat.



Procedure of MRI



- ☑ Alignment (magnetization) B_0
- ☑ Precession $\omega_0 = \gamma B_0$
- ☑ Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
  - The most effective resonance is produced when $\omega_0 = \omega_2$
- ☑ MR signal (EMF, relaxation time)
- ☐ Imaging (Pulse sequencing: SE, GRE, EPI)
  - ☑ Tissue Contrast: Image weighting
  - ☑ Spatial localization: Slice selection & Spatial Encoding
  - ☑ Data space/K space



THE END

alvin4016@nycu.edu.tw