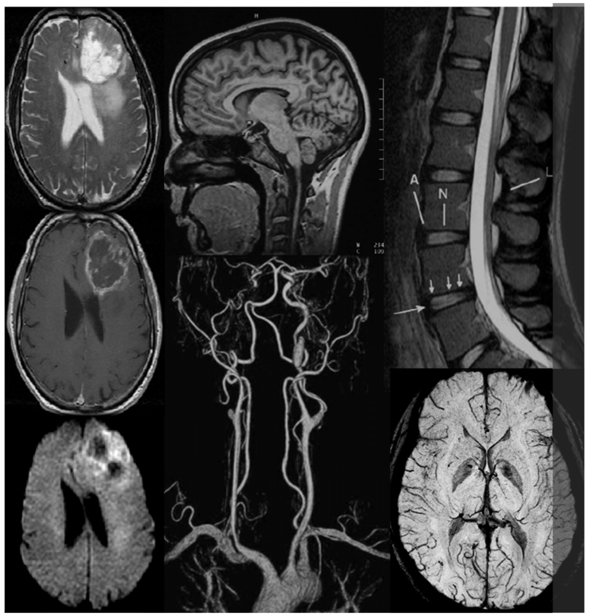

磁振影像學MRI
資料空間(K space)

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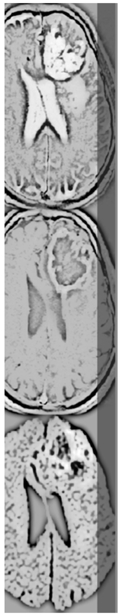
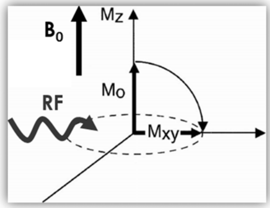
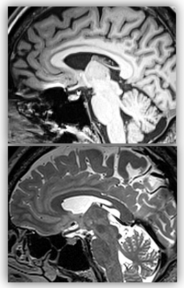
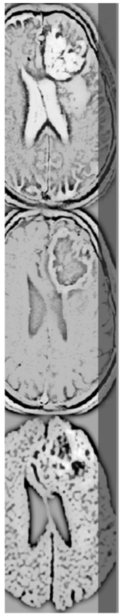


Procedure of MRI



- ☑ 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)
  - ☑ Tissue Contrast: Image weighting
  - ☑ Spatial localization: Slice selection & Spatial Encoding
  - ☐ Data space

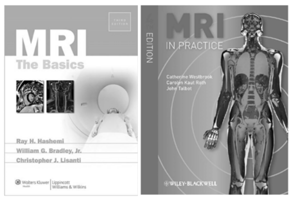




本週課程內容 http://cflu.lab.nycu.edu.tw

- **資料空間 (K space)**

- **MRI The Basics (3rd edition)**
  - Chapter 13: Data Space
- **MRI in Practice, (4th edition)**
  - Chapter 3: Encoding and image formation



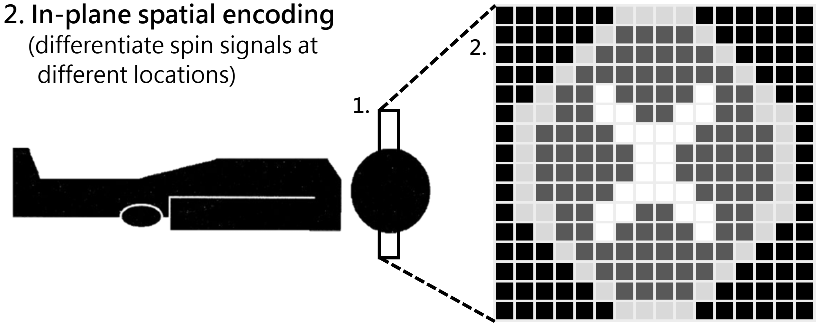
資料空間

Data space/ K space

Image Construction

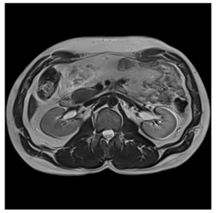
1. Slice selection
(only excite spins on a specific slice location)

2. In-plane spatial encoding
(differentiate spin signals at different locations)

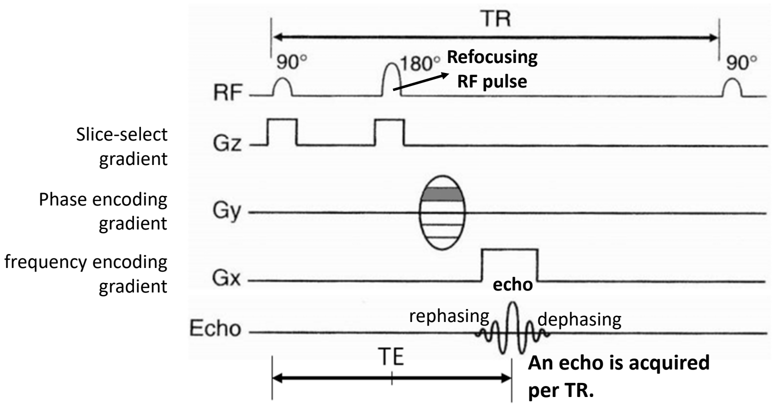


In-plane Spatial Encoding

- Extract the spatial information regarding each slice
  - Frequency encoding or readout gradient
    - Usually apply to the long axis of image
  - Phase encoding gradient
    - Usually apply to the short axis of image or less motion direction

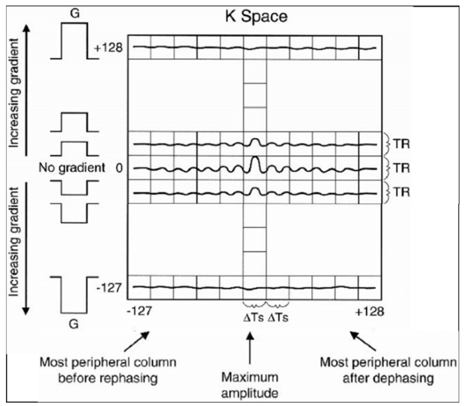


Spin-echo pulse sequence diagram



Properties of K-Space

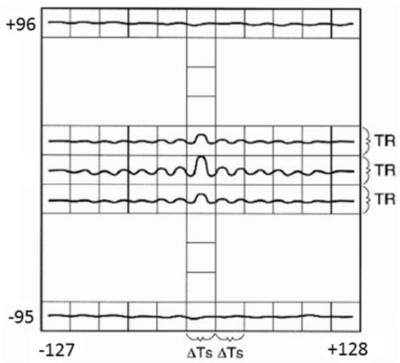
- Each of the signals has its maximum signal amplitude in the center column.
- The maximum amplitude occurs in the center row because this line is obtained without additional dephasing.



K Space

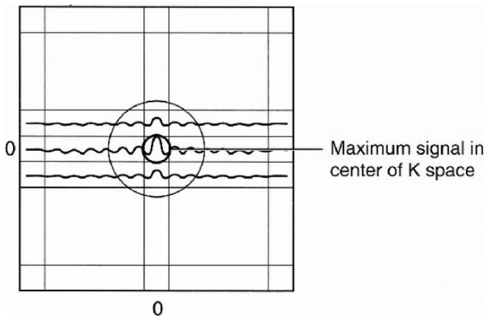
- K space is a digitized (sampled) version of the data space.
- A 192 x 256 k-space matrix
  - The first number refers to the number of phase encoding steps.
  - The second number represents the different number of frequencies we used.

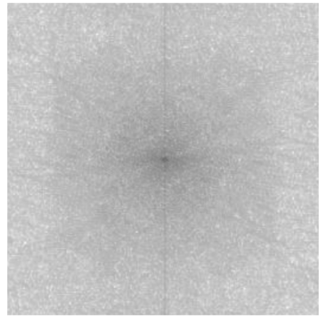
Sampling time
$Ts = \Delta Ts \cdot N$



Properties of K Space

- The center point of the data space contains maximum amplitude, i.e., maximum SNR.





Properties of K space

- Each slice has its own data space.
- Each of received signals (echos) with different phase-encoding gradient fills one line in a set of rows referred to as the data space.
- Each signal in each row of the data space is the sum of all the signals from individual pixels in the slice.
- The center of the data space does not represent the center of image.

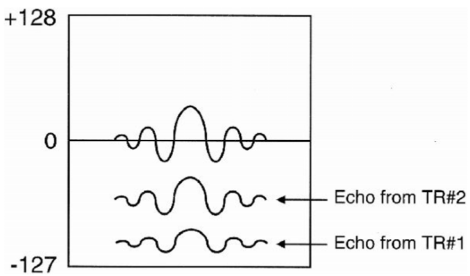


Image of K-Space

- The center of k-space contributes to the primary information of image.
- The periphery of k-space provides information regarding fitness of the image and clarity at sharp interfaces

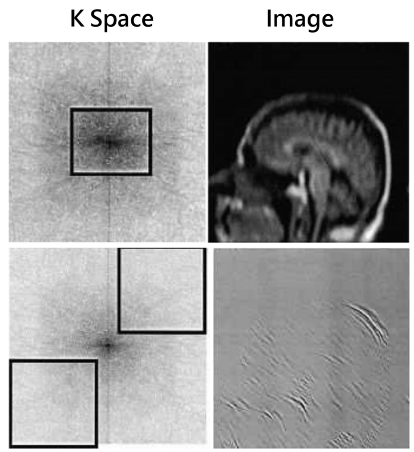
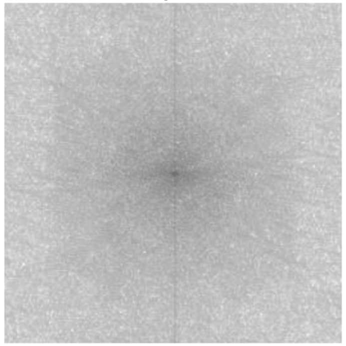


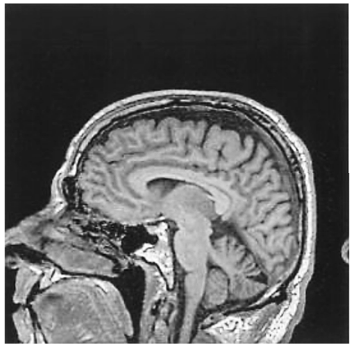
Image of K-Space

K Space



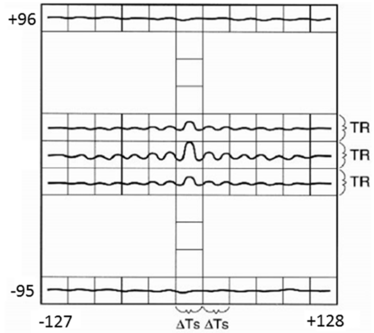
2D FFT ➔

Reconstructed Image



Motion Artifacts

- It takes much more longer to gather the signal in the phase-encoding direction than in the frequency-encoding direction.
- Motion artifacts propagates along the phase-encoding direction.

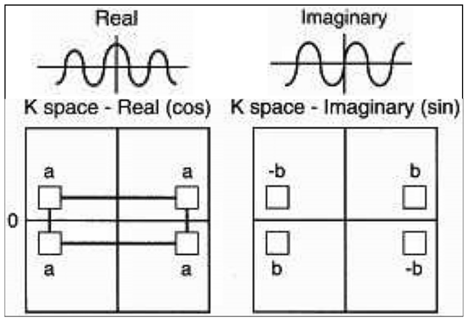


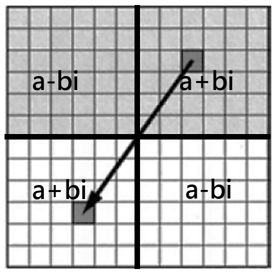
$TR \cdot Ny$

$\Delta Ts \cdot Nx$

K space symmetry

- Conjugate (Hermitian) Symmetry
- We preliminarily decompose the signal into its real and imaginary components ➔ a real and an imaginary k space.



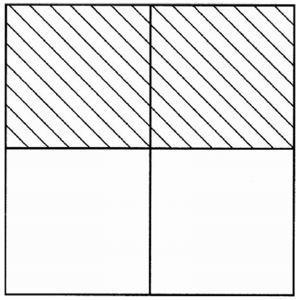


Magnitude and Phase Image

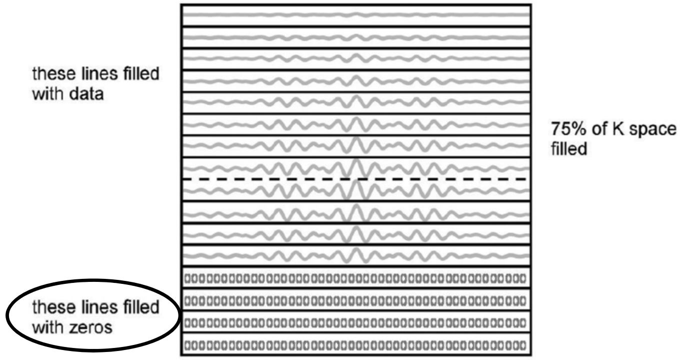
- Magnitude (modulus) image
  - $\boldsymbol{Magnitude} = \sqrt{\boldsymbol{a^2 + b^2}}$
  - It is what we commonly used in MR imaging.
- Phase (angle) image
  - $\boldsymbol{tan\theta = b/a}$
  - It is used in cases in which the direction is important.
  - ex: phase contrast MR angiography
    susceptibility weighted imaging

Half-Fourier Technique

- We acquire the data from the upper half of k-space and construct the lower part mathematically, thus reducing the scan time.
- The trade-off is a reduced SNR by a factor of $\sqrt{2}$.
- Overscanning: we sample half of the phase-encoding steps plus a few lines below the 0 line to compensate the phase errors.

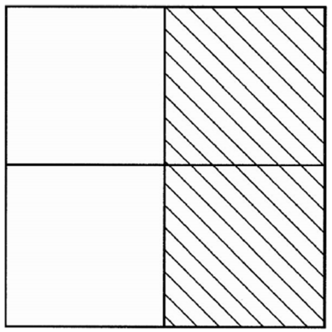


75% K space filling



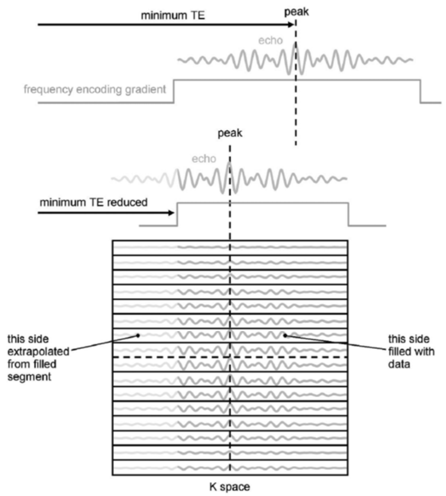
Fractional (Partial) Echo

- Only a half of the echo is sampled, and another half is constructed based on the acquired half.
- It allows TE to be shorter.
- The dephasing in the frequency direction is reduced.
- Give better SNR at a given TE when a smaller FOV or thinner slices are selected.
- Gradient echo sequences (FLASH, Fast SPGR)



Partial echo

- Reduce minimal TE



Signal-to-Noise Ratio (SNR)

- $\mathbf{SNR} \propto (\mathbf{pixel\ volume})\sqrt{\frac{\mathbf{Ny \times NEX}}{\mathbf{BW}}}$
  - BW (receiver bandwidth) = $1/\Delta Ts$
  - Ny is the number of phase-encoding steps
  - NEX is the number of times we repeat the whole sequence (number of excitations)

  - Pixel volume ↑, spatial resolution ↓
  - Ny ↑, spatial resolution ↑, scanning time ↑
  - NEX ↑, scanning time ↑
  - BW ↓, ΔTs ↑, Ts ↑, TE ↑, T2W ↑, # of slice ↓

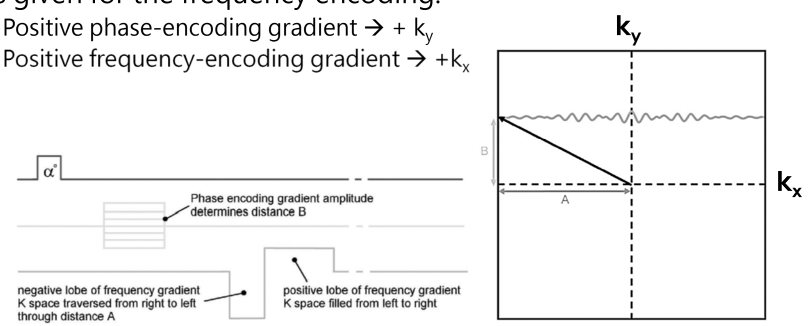
Acquisition Time

- The acquisition time depends on
  - TR (the time to do one line of the data space)
  - Ny (the number of phase-encoding steps)
  - NEX (the number of times we repeat the whole sequence to increase SNR)

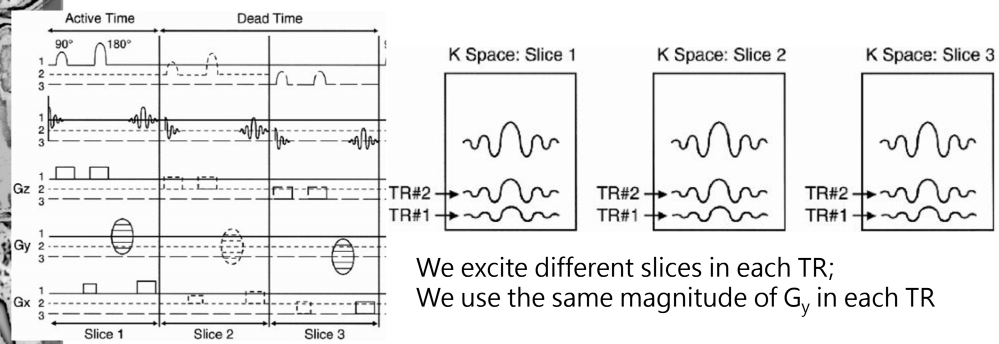
- $acquisition\ time \propto TR \cdot Ny \cdot NEX$

How gradients transverse K space

- A negative lobe with ½ area of the subsequent positive lobe is given for the frequency encoding.
  - Positive phase-encoding gradient → + k_y
  - Positive frequency-encoding gradient → + k_x

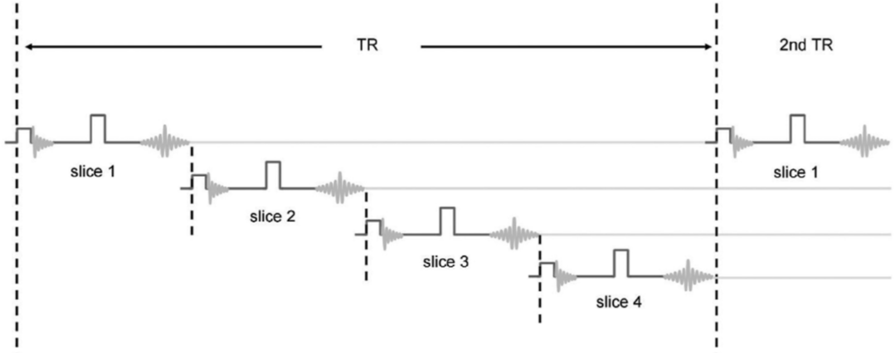


Multislice Acquisition in a TR



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

Multislice Acquisition in a TR



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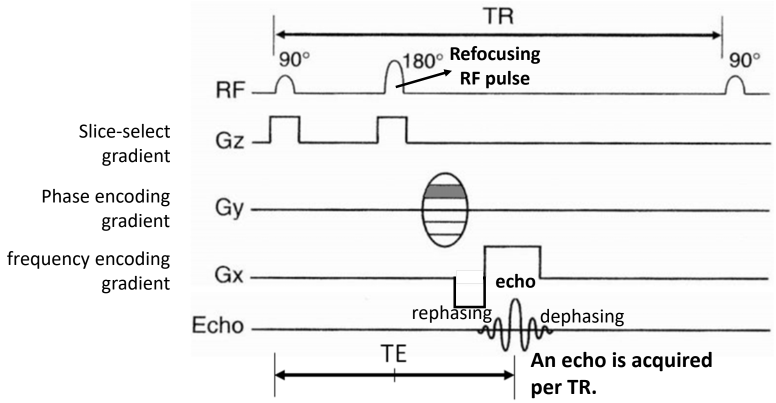

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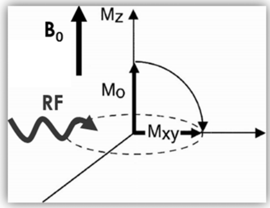

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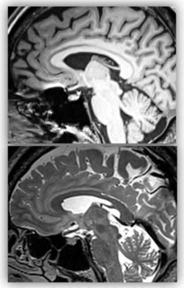

THE END

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