# 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
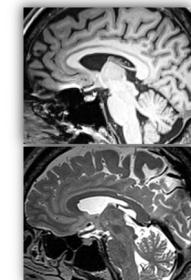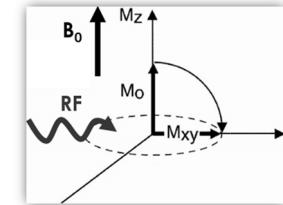
- 資料空間 (K space)

- **MRI The Basics (3rd edition)**
  - Chapter 13: Data Space

- **MRI in Practice, (4th edition)**
  - Chapter 3: Encoding and image formation
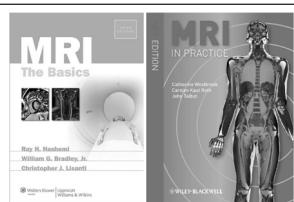
資料空間

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)
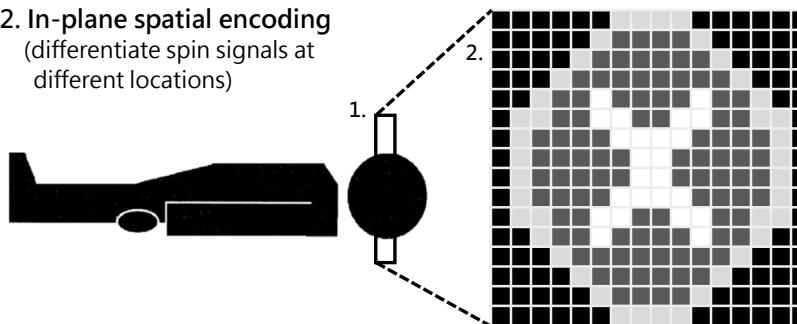
Gradients

- An MR image = slice selection + in-plane spatial encoding

- A gradient is simply a magnetic field that changes from point to point – usually in a *linear* fashion.
  - The slice-select gradient
  - The readout or frequency-encoding gradient
 - The phase-encoding gradient

Pulse sequence diagram

An echo is acquired per TR.
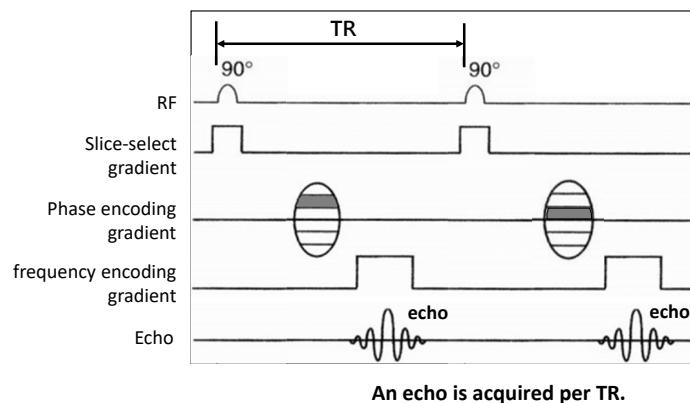
Properties of K-Space

- 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.
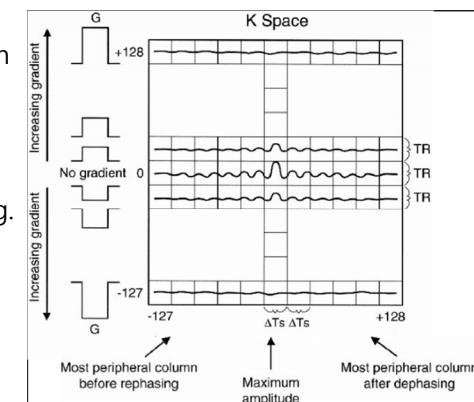
K Space

- 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
$Ts = \Delta Ts \cdot N$
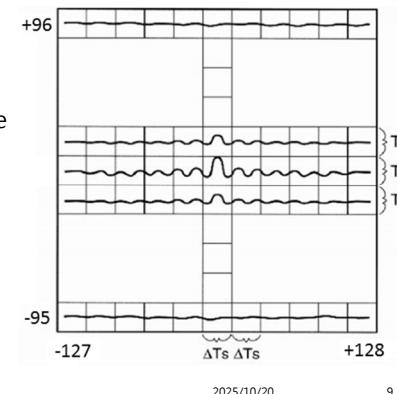
Properties of K Space

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

Maximum signal in center of K space
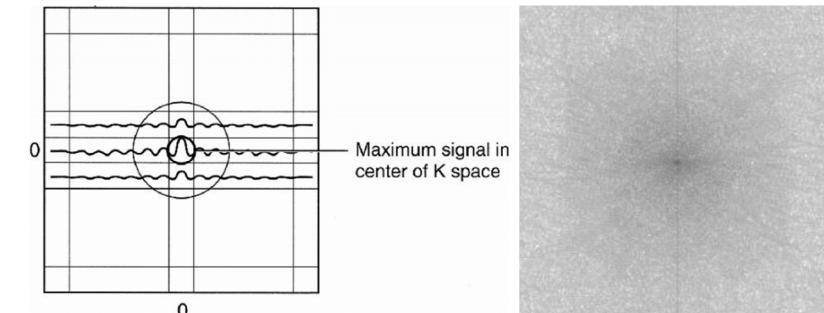
Properties of K space

- 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.


Echo from TR#2

Echo from TR#1
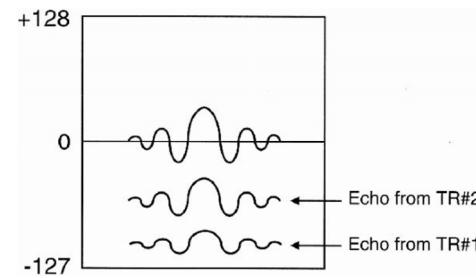
Image of K-Space

K Space　　　Image

- 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
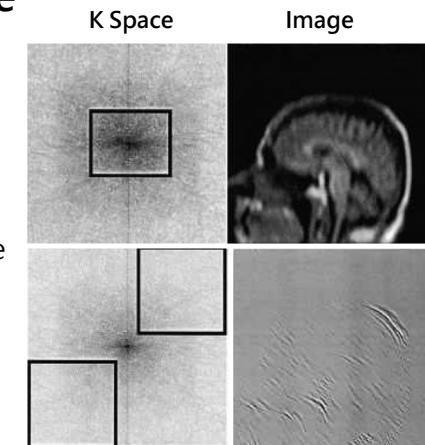
Image of K-Space

K Space

Reconstructed Image

2D FFT ➜
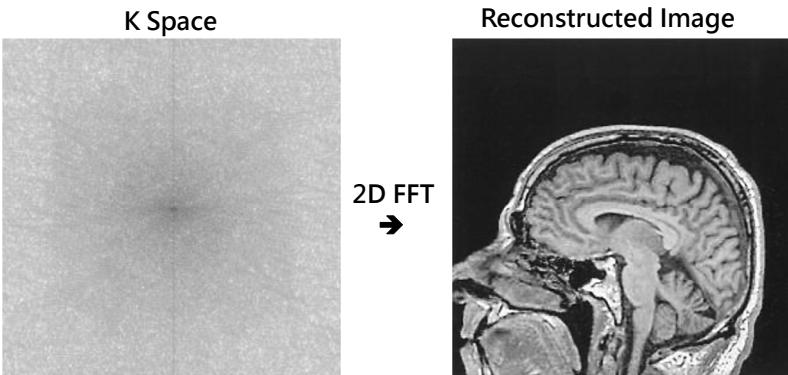
Motion Artifacts

- 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.

$TR \cdot Ny$

$\Delta Ts \cdot Nx$
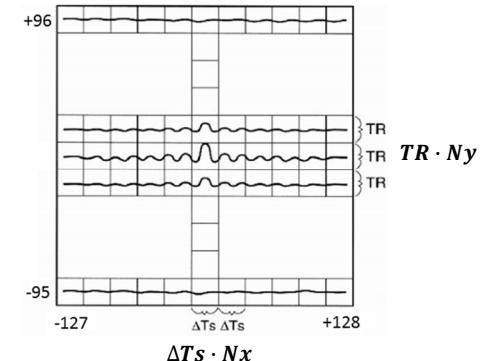
K space symmetry

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

Real

Imaginary

K space - Real (cos)   K space - Imaginary (sin)

a+bi   a+bi

a+bi   a-bi
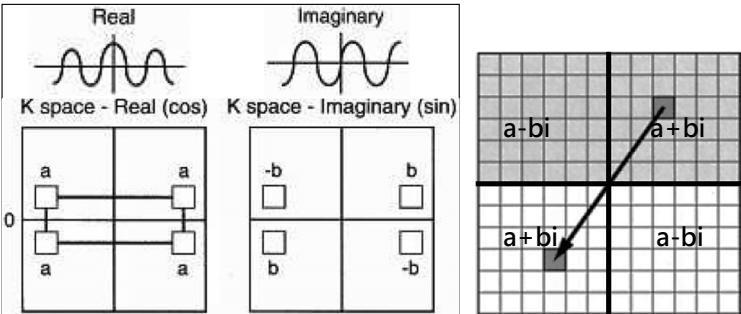
Magnitude and Phase Image

- Magnitude (modulus) image
  - $Magnitude = \sqrt{a^2 + b^2}$
  - It is what we commonly used in MR imaging.

- Phase (angle) image
  - $tan\theta = b/a$
  - It is used in cases in which the direction is important.
 - ex: phase contrast MR angiography
   susceptibility weighted imaging
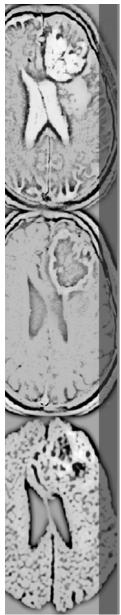
Half-Fourier Technique

- 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.
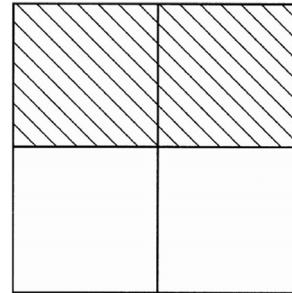
75% K space filling

these lines filled with data
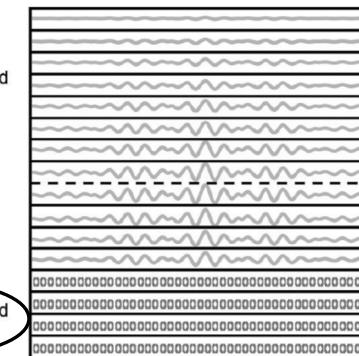
75% of K space filled

these lines filled with zeros

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)
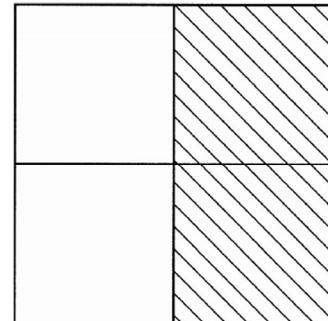
Partial echo

- Reduce minimal TE

minimum TE　peak
echo
frequency encoding gradient

peak
echo
minimum TE reduced

this side extrapolated from filled segment

this side filled with data

K space
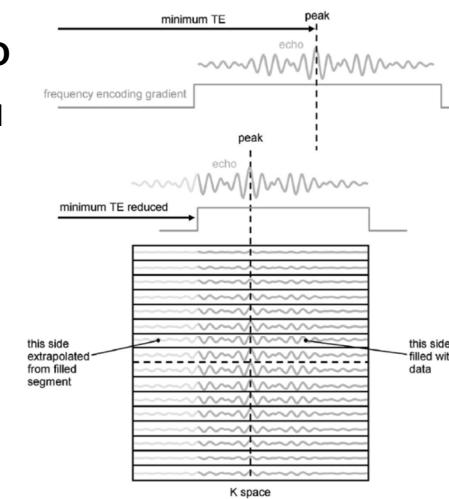
Signal-to-Noise Ratio (SNR)

- $\text{SNR} \propto (\text{pixel volume}) \sqrt{\frac{Ny \times NEX}{BW}}$
  - BW (receiver bandwidth) = 1/ΔTs
  - 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 ↓
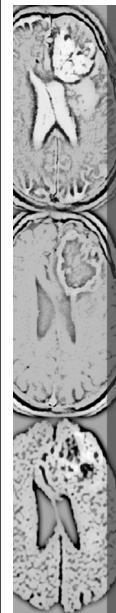
Acquisition Time

- 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
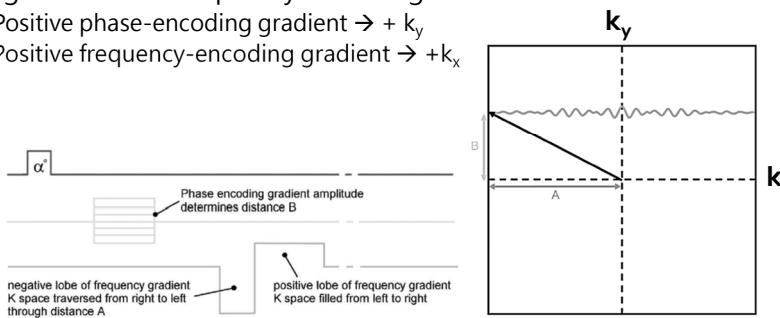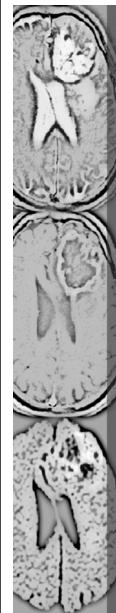
Multislice Acquisition in a TR
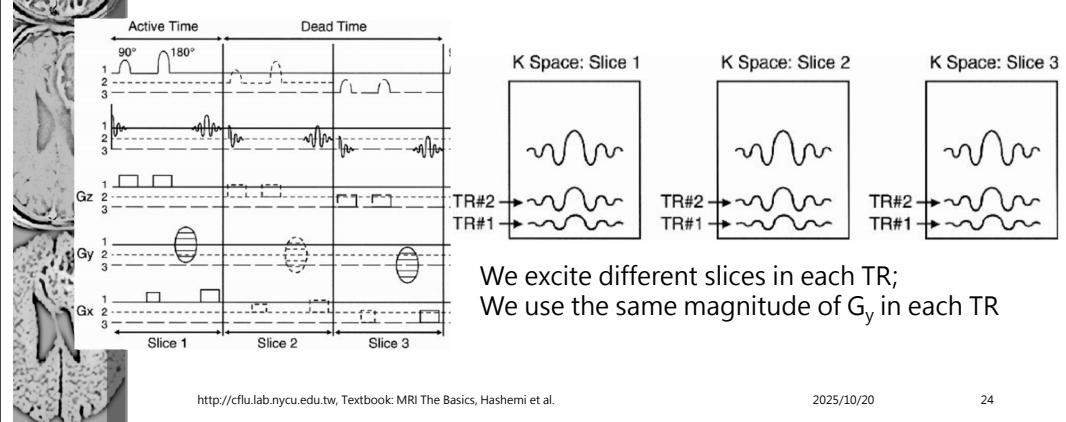
We excite different slices in each TR;
We use the same magnitude of G_y in each TR

Multislice Acquisition in a TR

Pulse sequence diagram

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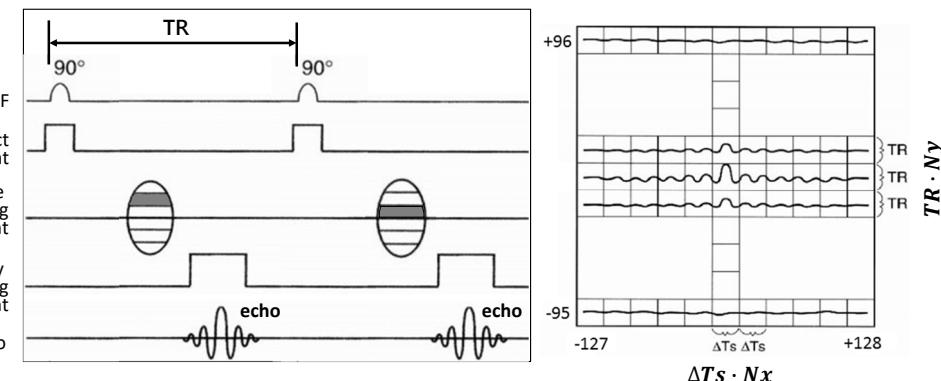
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  - ☑ Data space/K space
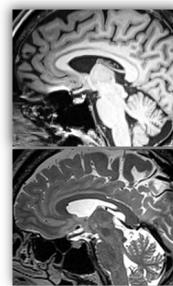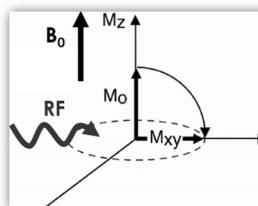
THE END

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