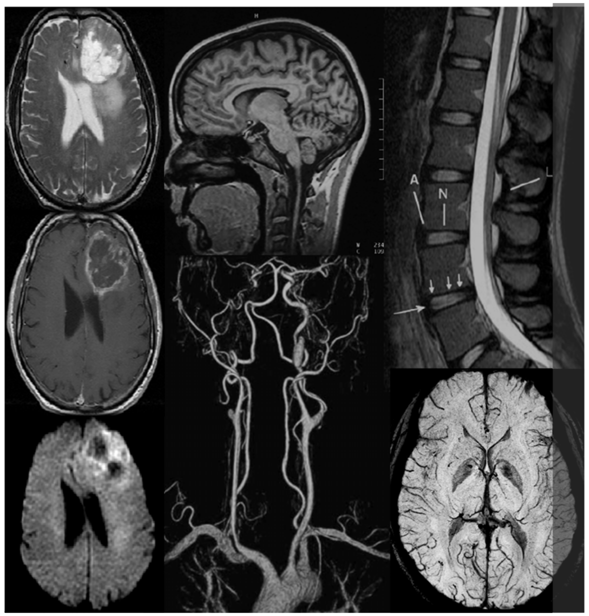

磁振影像學MRI
切面選擇與梯度線圈

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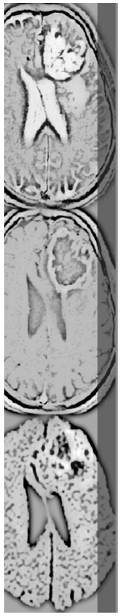
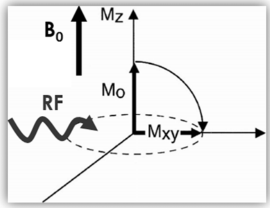
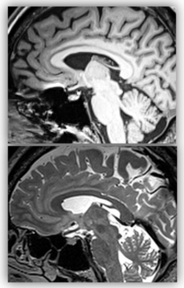
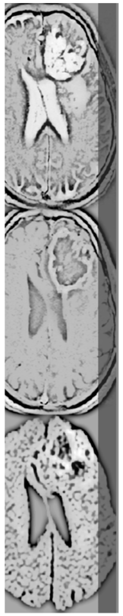


Procedure of MRI



- ☑ 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

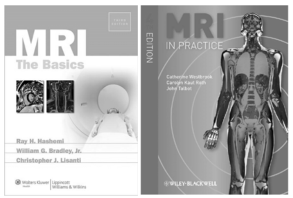




本週課程內容 http://cflu.lab.nycu.edu.tw

- 切面選擇Slice Selection
- 梯度線圈Gradient Coils

- MRI The Basics (3rd edition)
  - Chapter 10: Slice Selection
- MRI in Practice, (4th edition)
  - Chapter 3: Encoding and image formation
  - Chapter 9: Instrumentation and equipment

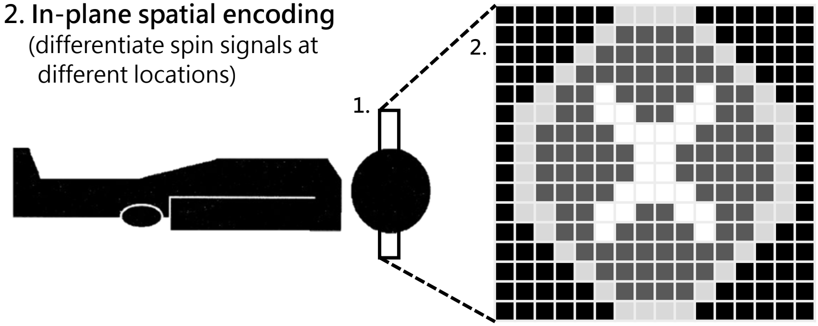


切面選擇

Slice Selection

Image Construction

1. **Slice selection**
   (only excite spins on a specific slice location)
2. **In-plane spatial encoding**
   (differentiate spin signals at different locations)

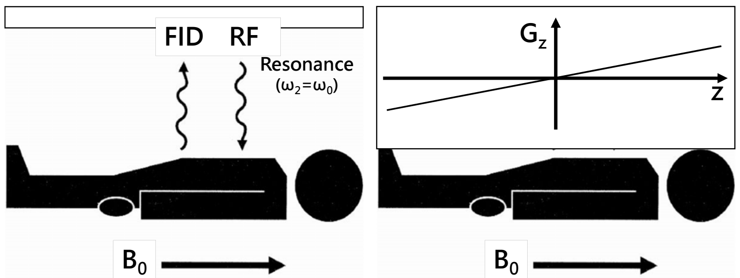


Gradients

- 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

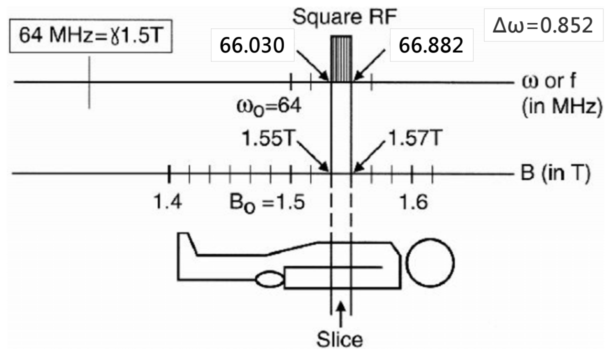
How to Select a Slice

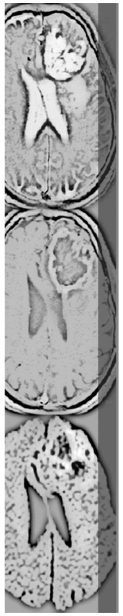
- Create a variation in the field along the z-axis in linearly increasing or decreasing by G_z.



Field Strength and Larmor Frequency

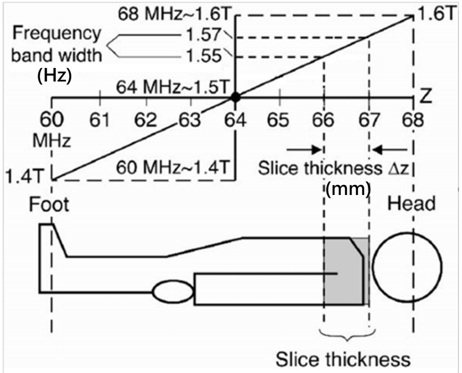
- Larmor frequency: $\boldsymbol{\omega(z)=\gamma(B_0+G_z\cdot z)}$

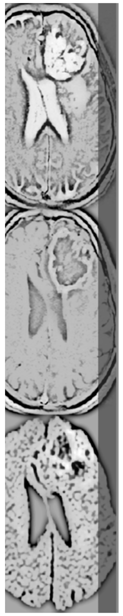




Bandwidth of RF Pulse

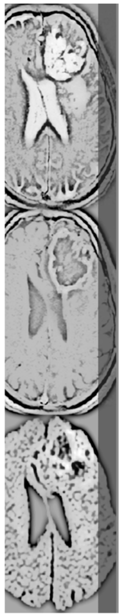
- We can excite one slice by an RF pulse with a specific frequency range.
- This range of frequencies determines the slice thickness and is referred to as the bandwidth.





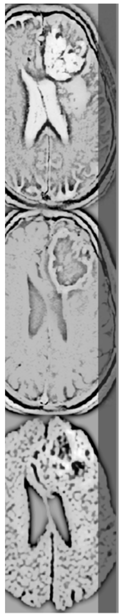
Slice-Select Gradient (G_z)

- We transmit an RF pulse with a bandwidth that has the appropriate **center frequency**.
- This gradient is turned on only when we transmit the RF pulses.
- When we transmit the 180^o pulse (*rephasing pulse*) for the same slice, we activate the same gradient.



Two types of RF pulses

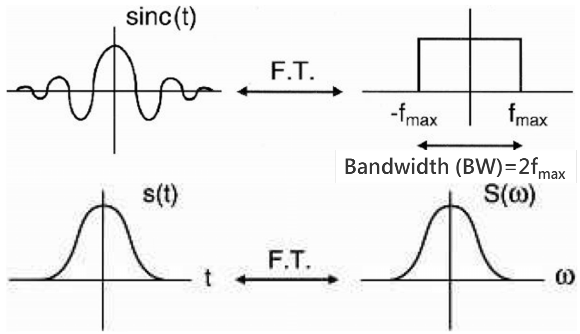
- **Slice-selective**
  - This RF pulse will select only a certain slice of the body.
  - Used in two-dimensional (2D) imaging
- **Non-selective**
  - A non-selective RF pulse excites every part of the body that is in the coil.
  - Used in three-dimensional (3D) imaging



Fourier Transform (FT)

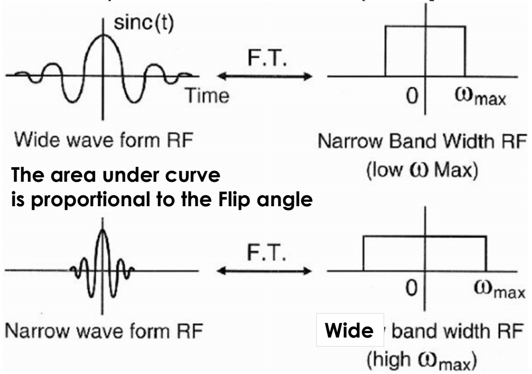
- Time domain ⇔ Frequency domain

sinc(t)=sin(t)/t



Waveform and Bandwidth

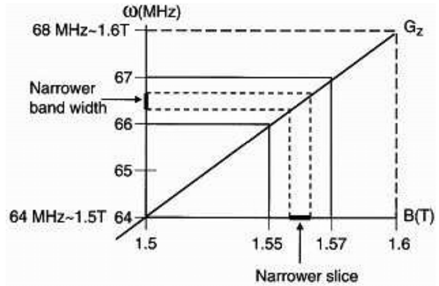
- A narrower RF pulse ➔ a wider frequency bandwidth

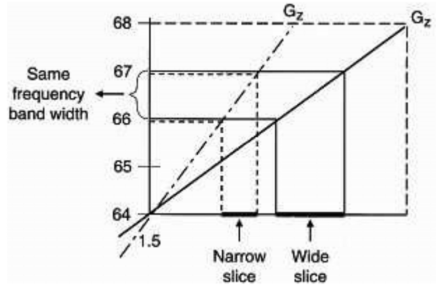


Slice Thickness

Slice thickness ↓ → Excited spins ↓ → SNR ↓

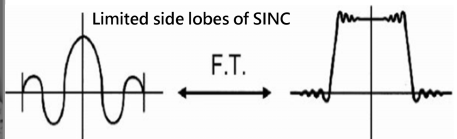
- Two ways to reduce the slice thickness
  - Use a narrow bandwidth
  - Increase the slope of the magnetic field gradient (G_z)

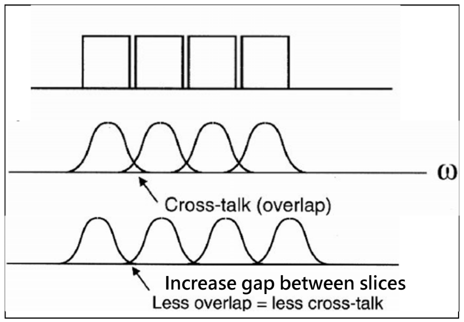




Contiguous Slices Cross Talk

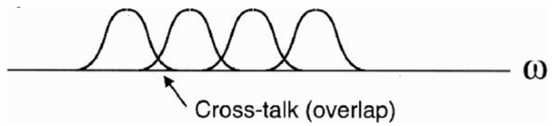
- Ideally, the contiguous slices are right next to each other and the Fourier transform has a rectangular shape.
- In reality, the frequency spectrum of the RF pulse does not have a rectangular shape.





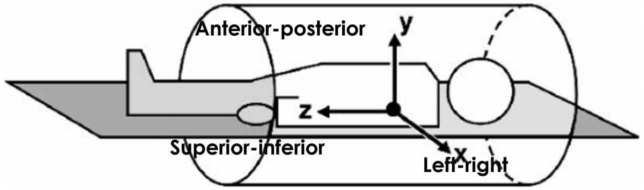
Cross-Talk effects

- Decrease effective TR per slice
  - Due to saturation of protons by the RF signals for adjacent slices
- Cross-talk effects
  - Increase T1 weighting
  - Decrease SNR



Plane of Imaging

	Slice-Select Gradient	In-plane spatial encoding: Phase-Encoding Gradient	Frequency-Encoding Gradient
Axial	z	y ⟺	x
Sagittal	x	y ⟺	z
Coronal	y	x ⟺	z



梯度線圈

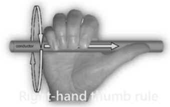
Gradient Coils

Imaging Gradient Coils

- The three components of the gradient set can be activated to create a slope in the static field along x, y, and z axes, respectively.
- Factors that change the strength of an electromagnet
  - The current passing through the windings
  - The number of windings in the coil
  - The diameter of the wire used in the windings
  - The distance or spacing between the windings

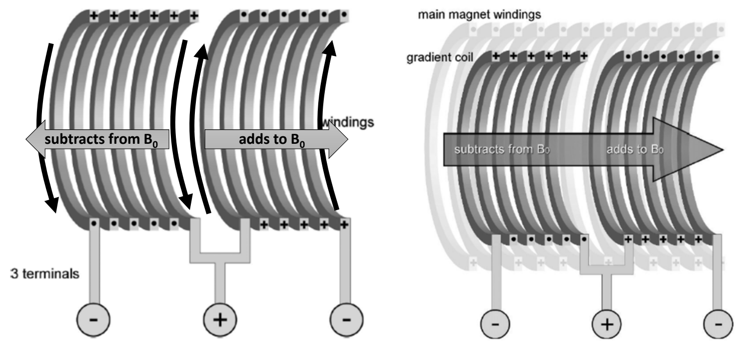
Not superconductive!

Gradient Coils – Z axis

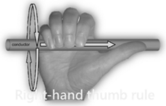


- A three-terminal electromagnet

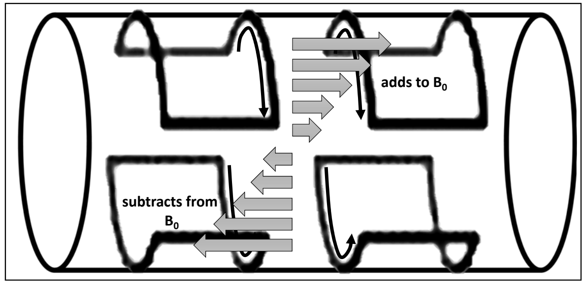
Maxwell Coils



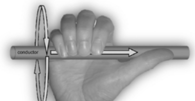
Gradient Coils – Y axis



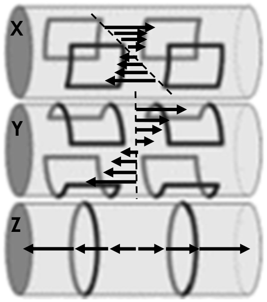
“Double-saddle" coils or Golay coils



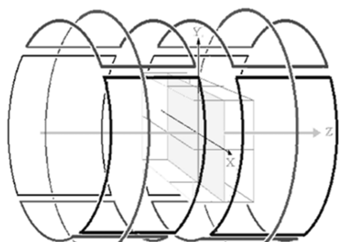
Gradient Coils



- Intentionally create linear perturbation to magnetic field.



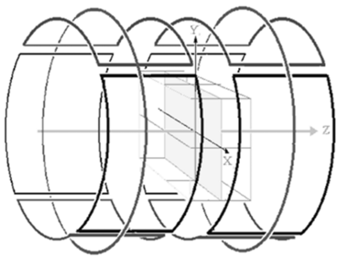
All gradient coils



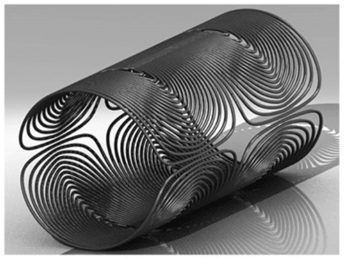
http://www.iomonitoring.org/mri.htm

Gradient Coils

The design for transverse gradients used in cylindrical MR magnets is based on a "double-saddle" coil configuration originally described in 1958 by Marcel Golay.



Advanced Golay design in fingerprint pattern, very typical for modern MR scanners in 2014.



http://mri-q.com/x--and-y--gradients.html

Coil Applications

97. 電阻線圈空氣心式（Resistive Coil Air Core）磁鐵之磁振造影機，該磁鐵之基本設計組態（configuration）為以下何者？

A.Maxwell Pair

B.Helmholtz Pair

C.Goley Pair

D.Gauss Pair

(B, 95 年第二次放射線器材學第 79 題)

Helmholtz coil: create an uniform magnetic field, resistive B0
Maxwell coil: create Gz
Goley coil: (double-saddle coil: create Gx or Gy)
Gauss coil: Gauss rifle, accelerated magnetic gun

Gradient Characteristics

- Gradient strength or gradient amplitude **(mT/m or G/cm)**
  - How steep a particular gradient is.
- Gradient speed or gradient rise time **(μs)**
  - The time it takes for a gradient to reach maximum amplitude.
- Slew rate **(mT/m/s)**
  - The speed and strength of the gradient.
- Duty cycle **(%)**
  - The percentage of time that the gradient is permitted to work.

Acoustic noise

- Caused by the vibration of the gradient set.
- Increased acoustic noise due to
  - Higher amplitude gradient values
  - Rapid gradient activation
- Quiet System

ear plugs

MR-compatible ear phones

> Magn Reson Med. 2016 Jun;75(6):2303-14. doi: 10.1002/mrm.25818. Epub 2015 Jul 16.

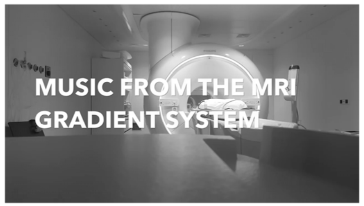
Music-based magnetic resonance fingerprinting to improve patient comfort during MRI examinations

Dan Ma [1], Eric Y Pierre [1], Yun Jiang [1], Mark D Schluchter [2], Kawin Setsompop [3], Vikas Gulani [1] [4], Mark A Griswold [1] [4]

Affiliations + expand

PMID: 26178439 PMCID: PMC4715797 DOI: 10.1002/mrm.25818

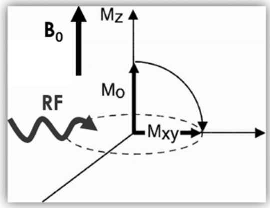
Free PMC article



Abstract

Purpose: Unpleasant acoustic noise is a drawback of almost every MRI scan. Instead of reducing acoustic noise to improve patient comfort, we propose a technique for mitigating the noise problem by producing musical sounds directly from the switching magnetic fields while simultaneously quantifying multiple important tissue properties.

Procedure of MRI



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- ☑ 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
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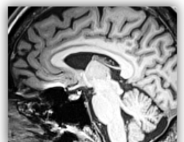

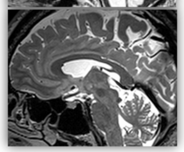

THE END

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