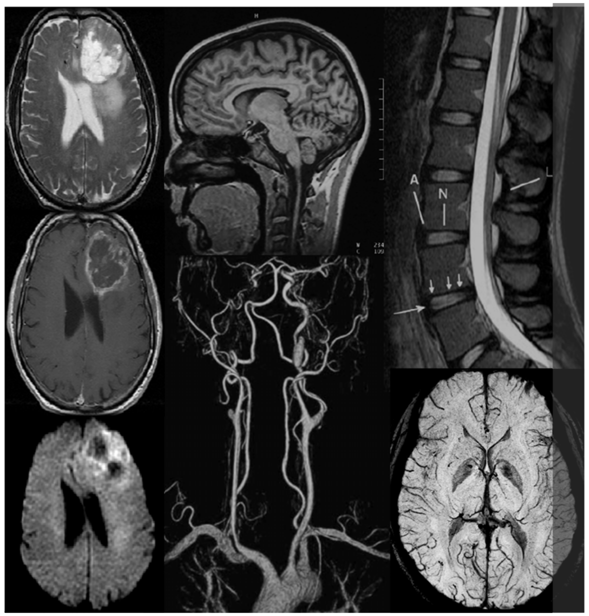

磁振影像學MRI
射頻脈衝與設備

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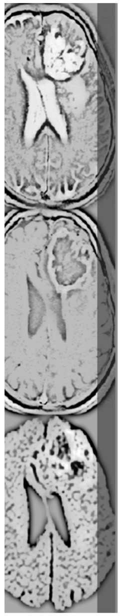
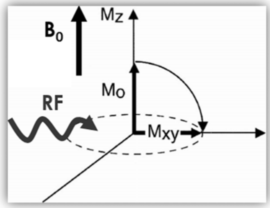
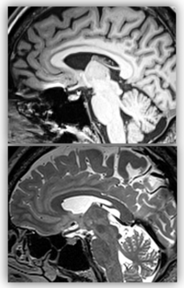
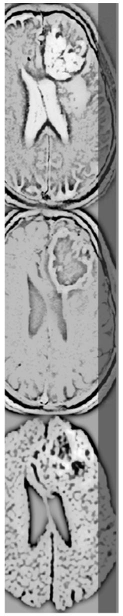


Procedure of MRI



- ☑ 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, electromotive force)
- ☐ Imaging (Pulse sequencing)
  - ☐ Image Contrast: Relaxation time
  - ☐ Spatial localization: Spatial Encoding

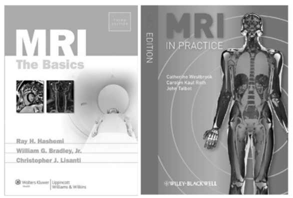




本週課程內容 http://cflu.lab.nycu.edu.tw

- 射頻脈衝
- 射頻線圈

- MRI The Basics (3rd edition)
  - Chapter 3: Radio Frequency Pulse
- MRI in Practice, (4th edition)
  - Chapter 9: Instrumentation and equipment



射頻脈衝

Radio Frequency (RF) Pulse

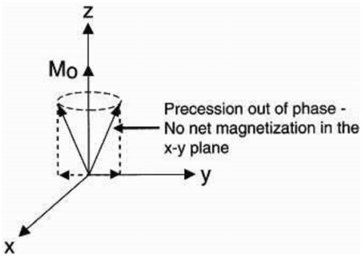
A Readable Signal

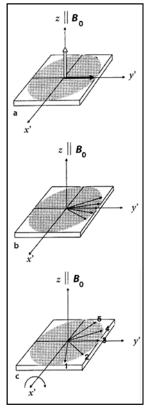
- We can only transmit and receive oscillated signals (like an AC voltage).
- We are only sensitive to oscillations along certain axes.

- The longitudinal magnetization is *not* an oscillating function (like a DC voltage).
- The longitudinal magnetization needs to be "flipped" into the transverse x-y planes (where it can oscillated or precess about z axis) to generate a readable signal.

Magnetization Vector M_0

- The individual spins are precessing along z-axis and "*out of phase*" with each other.
- The x and y components cancel each other out.

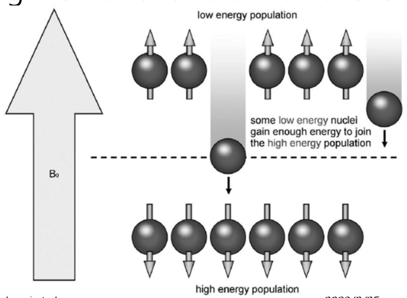




Out of phase

Radio Frequency Pulse

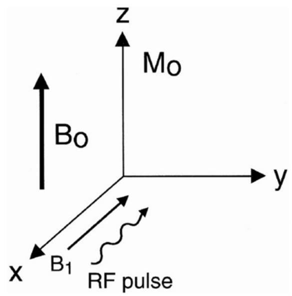
- Create phase coherence
- Flip some of the spins from a low-energy state to a high-energy state
- Transfer the NMV along the Z axis toward the transverse X-Y plane.

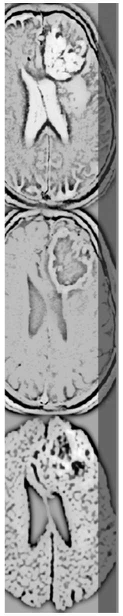


Radio Frequency Pulse B_1

- Two different magnetic fields:
  - B_0 = a very strong external magnetic field (e.g., 1.5T~3.0T)
  - B_1 = a very weak magnetic field generated by the RF pulse (e.g., 0.5~5 mT)
- Two types of precessions
  - **$\omega_0 = \gamma B_0$, along z-axis**
  - **$\omega_1 = \gamma B_1$, along x-axis**
- Since $B_1 \ll B_0$

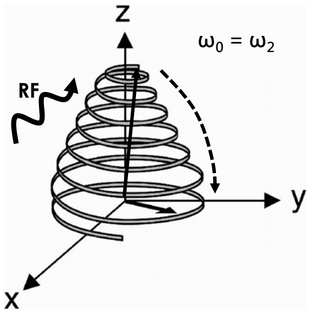
  then $\omega_1 \ll \omega_0$

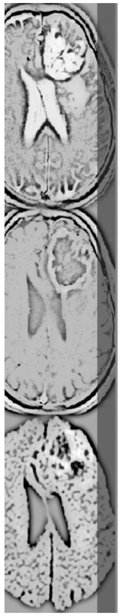




Radio Frequency Pulse B_1

- B_0 is a fixed magnetic field (much like a DC voltage)
- B_1 is an oscillating magnetic field (much like an AC voltage)
  - It is derived from the magnetic component of an oscillating electromagnetic wave.
- The RF pulse has a $\cos(\omega_2 t)$ wave form.
- Precessing along z-axis at frequency ω_0 and x-axis at frequency ω_1 simultaneously. ➔ spiral motion (nutation)



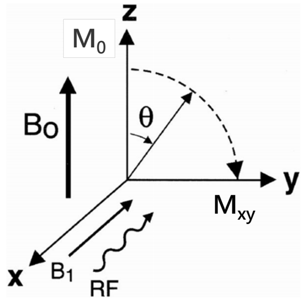


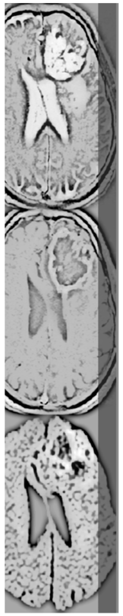
Resonance $\omega_0 = \omega_2$

- By introducing the B1, the spinning protons will then be in phase ➔ creates transverse magnetization
- The B1 field also causes a spiral downward motion of the protons ➔ flipping
- The flip angle is determined by

$$\theta = \gamma B_1 \tau = \omega_1 \tau$$

  - τ is the duration of the RF pulse
  - B_1 is the strength of the RF pulse
  - γ is the gyromagnetic ration of protons

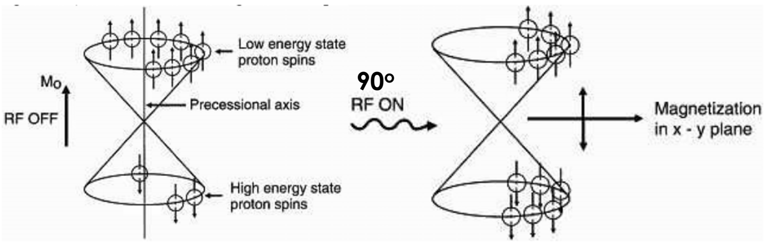


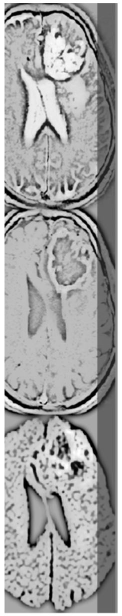


90° RF Pulse

- The pulse that causes the 90° flip is called a 90° RF pulse.
- The entire magnetization vector flips into the x-y plane

  ➔ $M_{xy} = M_0$
- $\tau_{\pi/2} = (\pi/2)/(\gamma B_1)$





180° RF Pulse

- A 180o pulse exactly reverses the equilibrium northward-pointing excess without inducing phase coherece (transverse magnetization).
- $\tau_\pi = \pi/(\gamma B_1)$
- Used in the pulse sequence of inversion recovery

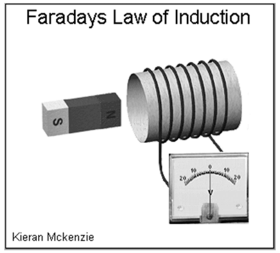
Partial Flip

- A partial flip has a flip less than 90°
- **$M_{xy} = M_0 \cdot \sin\theta < M_0$**
- Commonly used in gradient echo imaging.

Receiver coils

- Faraday's law of induction
- **dB/dt = dv**

where, dB is the changing magnetic field (oscillating magnetic field)
dt is the changing time
dv is the changing voltage (MR signal)



Auto RF

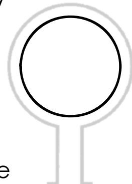
- **Prescan** is the process of preparing the scanner for a specific patient.
- 1. It sets transmit gain.
  - The flip angle is proportional to the square root of the transmit power.
- 2. It sets the receive gain.
- 3. It sets the optimum ω_0.

射頻線圈

RF Coils

Coils

- Gradient coils
  - Shim coil – increase B_0 homogeneities
  - Imaging gradient coil – intentional perturbation for spatial encoding
- Transmit and/or receive RF coils
  - Linear phase or quadrature (receive or transmit)
  - Surface or volume (Helmholtz or solenoid)
  - Single or phased-array



A loop of wire

Solenoid coil

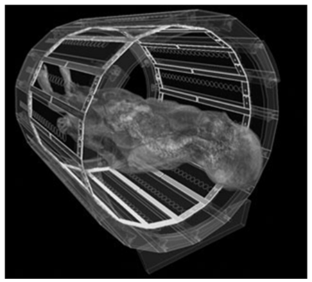
Helmholtz coil

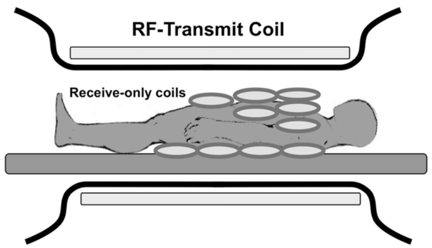
RF Coils

- A transmitter (Tx) coil transmits an RF pulse
- A receiver (Rx) coil receives an RF pulse
- A transceiver (T/R) coil can transmit/receive RF pulses
- Types of coils
  - Body coils: both transmitters and receivers, **a part of magnet. Takes most RF transmit missions.**
  - Head coils: receivers or transceivers, a helmet-like device
  - Surface coils: just receivers, imaging joints/body

Primary RF transceiver

- The closet component to the magnet bore in a closed-bore MRI.
- Known as the body coil.
- Can be used with local receiver.

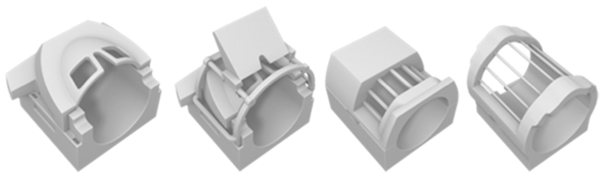




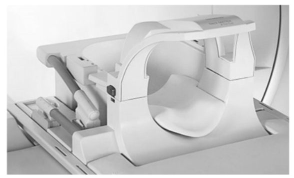
Head Coils

- Saddle shape, or birdcage type configuration.
- Can be multichannel coil (which are generally receivers only)

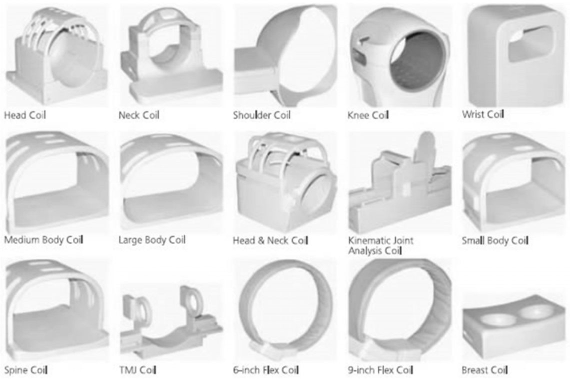
Head Coils

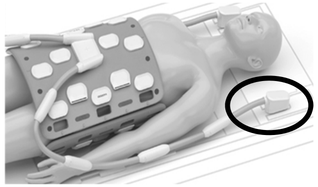


Neck Coil

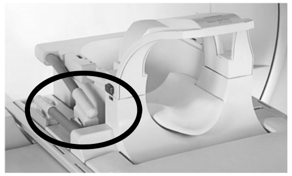


Coil Shapes





RF coils need to be plugin on table!!



medical.neusoft.com

Volume coils

- Generally used to accommodate a "volume" of tissue
  - Body coil (saddle configuration)
  - Birdcage coil (head coils)
  - Solenoid coils (tube shaped)

Higher magnetic homogeneity

Surface (or local) coils

- Generally placed on the surface
  - linear coils (simple surface coil or local coil configuration)
  - quadrature coils (with coils (or electronics) configured perpendicular)
  - Helmholtz pair (two coils combined with B1 fields in the same direction)
  - Maxwell pair (two coils combined with B1 fields in the opposite direction)
  - phased array (multiple coils elements and multiple receivers)
  - Parallel array (multiple elements, multiple receivers for parallel imaging).

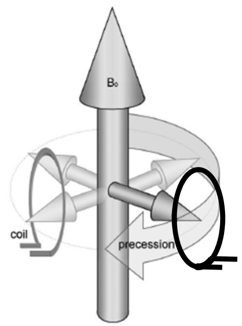
Higher signal-to-noise ratio (SNR)

Linear vs. Quadrature Polarized

- Linear polarized (LP)
- Quadrature (Circular) polarized (CP)
  - **Has higher SNR!**

Body receiver (Flex coil)

Birdcage coil



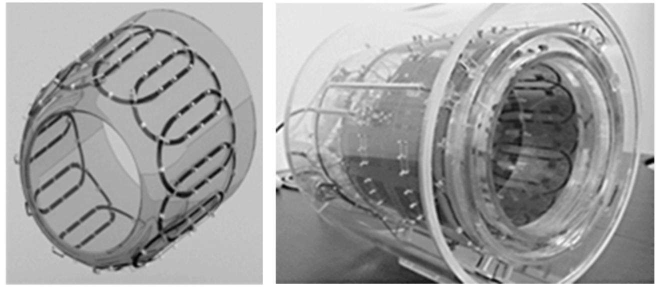
Array Coils - Phased and Parallel

- Array coil systems are collections of small surface coils.
- Small-diameter surface coils near the patient have high sensitivity but limited anatomical coverage.
- By combining multiple small coils into large arrays ➔ high signal-to-noise and large fields of view.

http://mri-q.com/array-coils.html

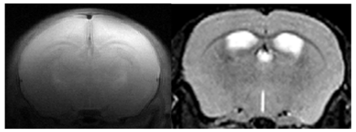
Quadrature-phased array coils

- Multiple elements of coils, larger FOV and better SNR



http://nri.gachon.ac.kr/b_07_e.html

Advantages of coil types

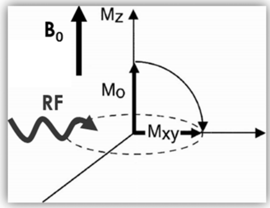


Can increase/achieve…

	Array coils	Volume coils
SNR	higher	higher
Magnetic homogeneity	--	higher
FOV	larger	--

- Generally speaking, the smaller the coil the better the SNR and the more coils used the better the SNR.
- The smaller the coil the smaller chance to produce aliasing artifacts.

Procedure of MRI



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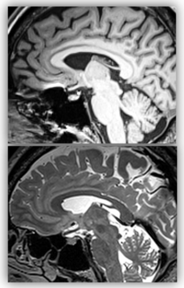

THE END

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