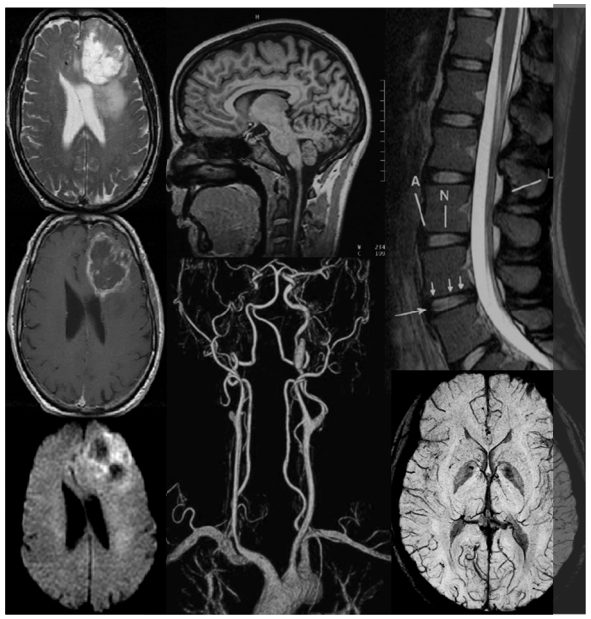
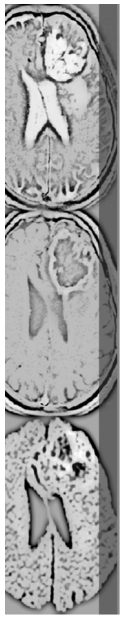


磁振影像學MRI
磁振假影

盧家鋒 教授

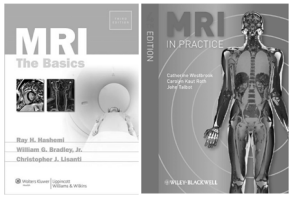
國立陽明交通大學
生物醫學影像暨放射科學系
alvin4016@nycu.edu.tw

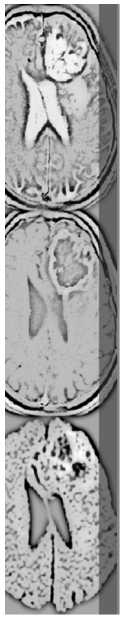


本週課程內容 http://cflu.lab.nycu.edu.tw

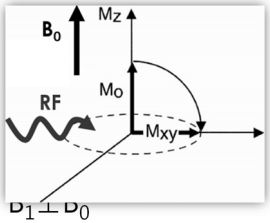
- 磁振假影

- MRI The Basics (3rd edition)
  - Chapter 18: Artifacts in MRI
- MRI in Practice, (4th edition)
  - Chapter 7: Artefacts and their compensation

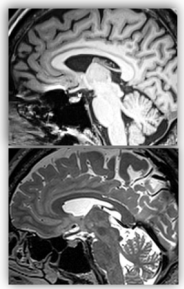




Procedure of MRI

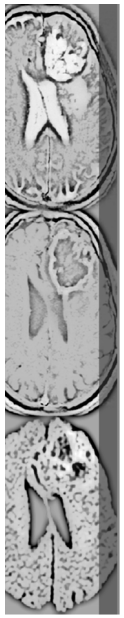


- ☑ Alignment (magnetization) B_0
- ☑ Precession $\omega_0 = \gamma B_0$
- ☑ Resonance (given B_1 by RF with ω_2) $\omega_1 = \gamma B_1$, $B_1 \perp B_0$
  - The most effective resonance is produced when $\omega_0 = \omega_2$
- ☑ MR signal (EMF, relaxation time)
- ☑ Imaging (Pulse sequencing: SE, GRE,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



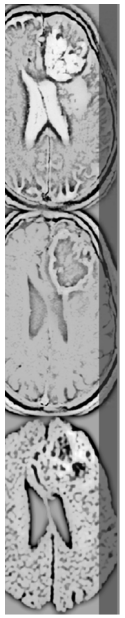
磁振假影

Artifacts in MRI



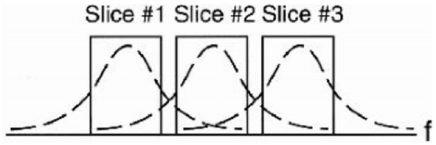
Hardware-related Artifacts

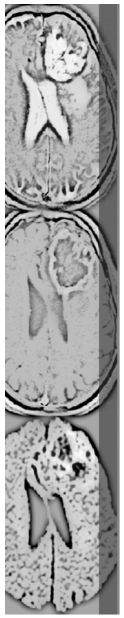
- **Radio frequency (RF)-related artifact**
  - Cross-talk
  - Zipper artifacts
- **External magnetic field artifacts**
  - Magnetic inhomogeneity
- **Gradient-related artifacts**
  - Eddy currents
  - Nonlinearity
  - Geometric distortion



RF-related artifacts: Cross talk

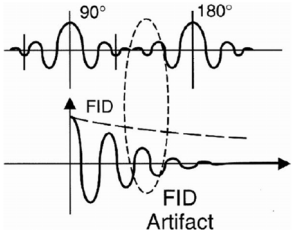
- An imperfect rectangle of the FT of the RF pulse
- Decrease TR due to saturation of protons by the RF for adjacent slices.
- T1 weighting ↑ and SNR ↓
- Remedy: interleaving, increase gap, rectangular wave

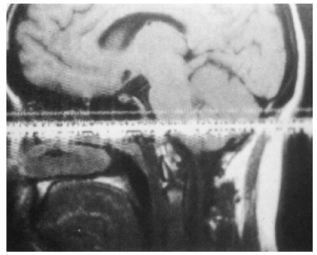




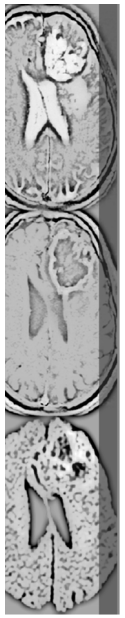
RF-related artifacts: Zipper artifacts

- Along the phase encoding axis at zero frequency
  - Cause 1, RF feed-through: excitation RF pulse → receiver coil
- Along the frequency-encoding axis without phase encoded
  - Cause 2, Stimulated echo: imperfect RF pulses of adjacent slices, imperfect 90°-180°-180° pulses
  - Cause 3, FID artifact: the overlapping of 180° RF pulse with the FID



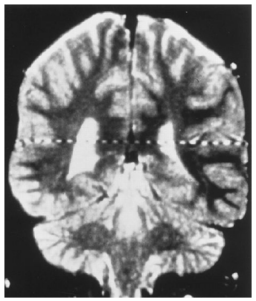


Central artifacts



RF-related artifacts: Zipper artifacts

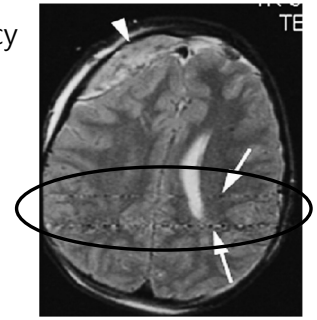
- Remedy to FID artifact:
  - Increase TE (increase the separation between FID and RF pulse)
  - Increase slice thickness (a wide RF BW narrows RF signal in the time domain)
- Remedy to stimulated echo:
  - Use spoiler gradients
  - Adjust the transmitter



Central artifacts

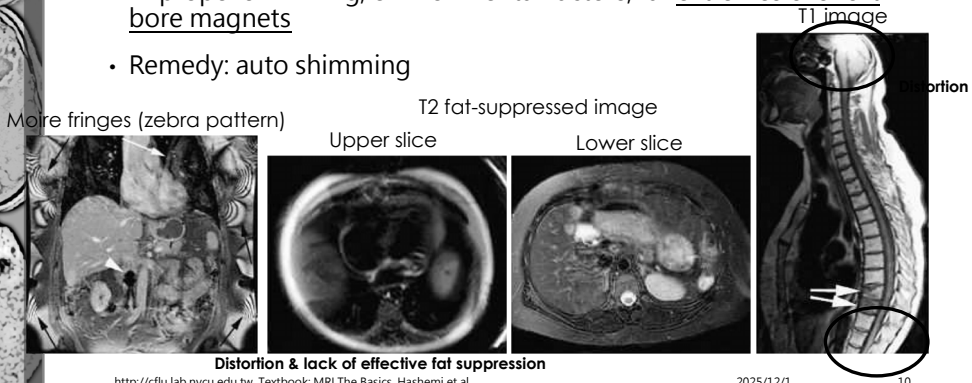
RF-related artifacts: Zipper artifacts

- Unwanted external RF noise (TV, radio station, electronic monitoring equipment)
- Occurs at the specific frequency
- Remedy: improve RF building, shut the door of MR room



External magnetic field artifacts

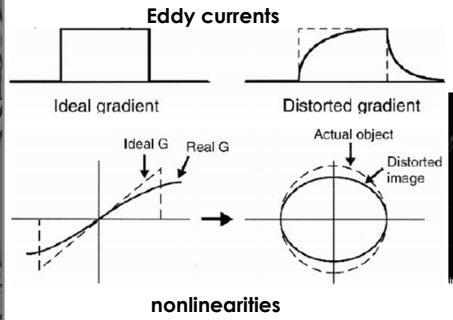
- Improper shimming, environmental factors, far <u>extremes of short bore magnets</u>
- Remedy: auto shimming



Distortion & lack of effective fat suppression

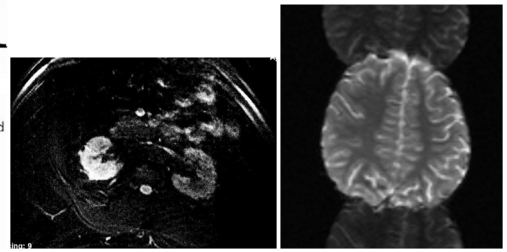
Gradient-related artifacts

- Eddy currents are generated when the gradients are rapidly switched on and off, resulting in a distortion in the gradient profile.



nonlinearities

Nyquist N/2 ghost artifact on EPI images



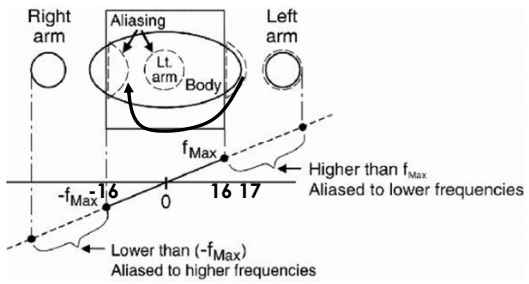
Geometry distortion

Software-related Artifacts

- Image processing artifact
  - Aliasing
  - Chemical shift
  - Truncation
  - Partial volume

Image processing Artifacts: aliasing

- Any frequency higher than the maximum frequency allowed by the gradient cannot be detected correctly.
- f(perceived)= f(true)-2f(max)



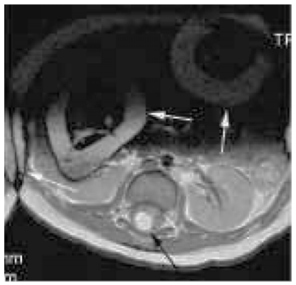
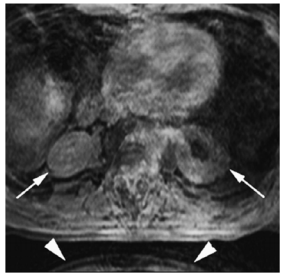


Image processing Artifacts: aliasing

- 2D imaging: along frequency-encoding or phase-encoding directions
- 3D imaging: in all three directions

Kidneys in lungs!

3D axial imaging



3D coronal imaging

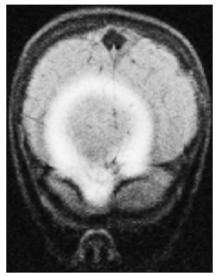


Image processing Artifacts: aliasing

- Remedy
  - Increase FOV (may reduce spatial resolution)
  - Use surface coils that only covers the area within FOV.
  - Frequency or phase oversampling ("No Phase Wrap")
  - Use saturation pulses to saturate the signals outside the FOV.

Image processing Artifacts: chemical shift

- The protons from different molecules precess at slightly different frequencies.
- The protons in H_2O precess slightly faster than those in fat (about 3.4 ppm).

- $\omega_0=\gamma B_0=(42.6\ MHz/T)(1.5T)=64\ MHz$
- $64\ MHz \times 3.4\ ppm = (64 \times 10^6\ Hz)(3.4 \times 10^{-6}) \approx 220\ Hz$
- $B_0 \uparrow$,chemical shift $\uparrow$

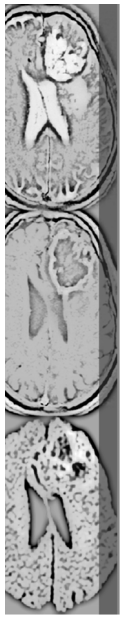


Image processing Artifacts: chemical shift

- BW = Nx/Ts = 256/(8 ms) = 32 kHz
- BW/pixel = 1/Ts = 125 Hz
- Pixel difference (H_2O/fat) = 220 Hz/ 125Hz = 1.76 pixels
- Fat protons are going to be misregistered from H_2O by about 2 pixels (in a 1.5 T magnet using a standard 32kHz bandwidth).
- $chemical\ shift(in\ mm) = \frac{3.5\times10^{-6}\gamma B_0 \times FOV}{BW}$

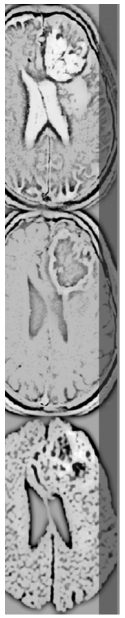
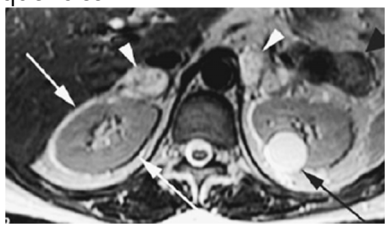
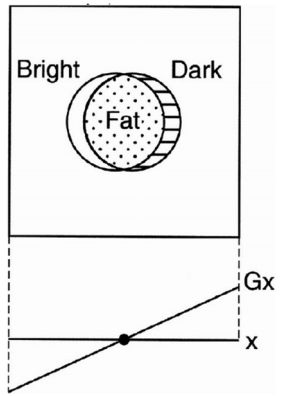


Image processing Artifacts: chemical shift

- Chemical shift artifact only occurs in the frequency-encoding direction.
  - A bright band toward the lower frequencies
  - A dark band toward the higher frequencies



T2 FSE



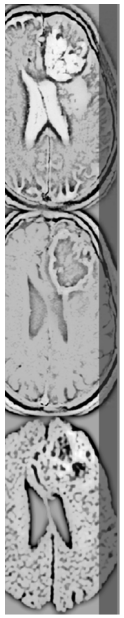
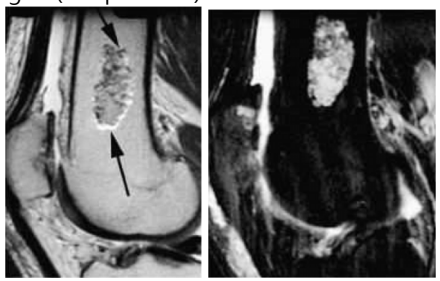
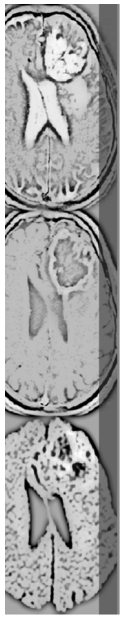


Image processing Artifacts: chemical shift

- Remedy:
  - Fat suppression
  - Increase pixel size by keeping FOV the same and decreasing Nx (spatial resolution ↓)
  - Lower the magnet's field strength (not practical)
  - Increase bandwidth (SNR ↓)
  - Use a long TE (less signal from fat)

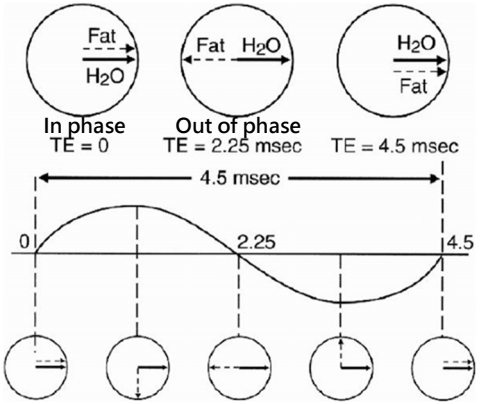


T2 with/without fat saturation



Chemical shift of the second kind

- 220 Hz at 1.5T:
- Fat and water are in phase every 4.5 msec.
- Only exist in GRE (without 180° rephasing pulse).
- Not only in the frequency-encoding direction



Chemical shift of the second kind

- Boundary effect (when out of phase)

In phase

Out of phase

Image processing Artifacts: Truncation

- Truncation artifacts (Gibbs Phenomenon)
- Occurs at high contrast interfaces
  - Skull/brain, spinal cord/CSF, meniscus/fluid in the knee
- Due to insufficient samples for the large signal changes
  - Mostly seen in the phase direction (because fewer samples are usually taken)
- Causes alternating bright and dark bands
  - Pseudo syrinx of the spinal cord
  - Pseudo tear of the knee meniscus

The K-space data is often under-sampled and truncated to shorten the scan time.

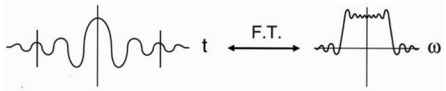
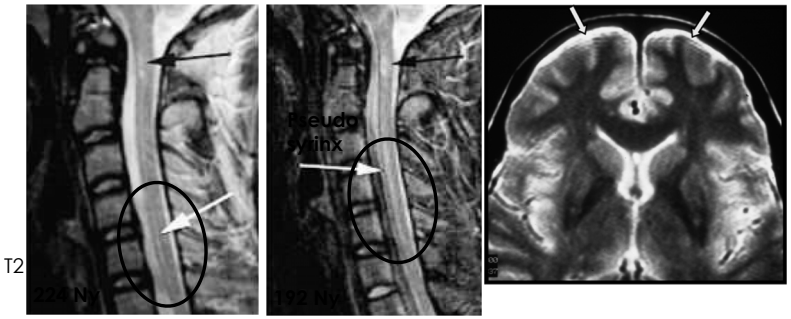


Image processing Artifacts: Truncation

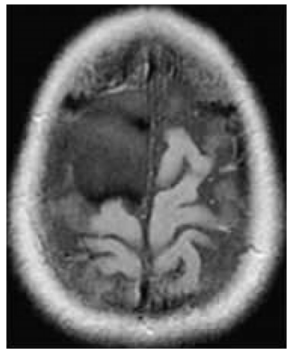
- Remedy:
  - Decrease pixel size (increase phase encoding steps, reduce FOV)
  - Increase sampling time, increase sampling bandwidth



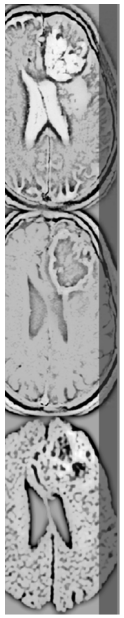
Fat-saturated T2

Image processing Artifacts: Partial volume

- Remedy: decrease the slice thickness

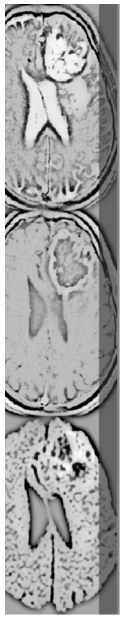


Axial FLAIR image



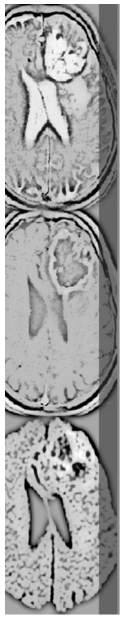
Subject-related Artifacts

- Motion artifacts
- Magnetic susceptibility artifacts
  - Diamagnetic, paramagnetic, ferromagnetic
  - Metal



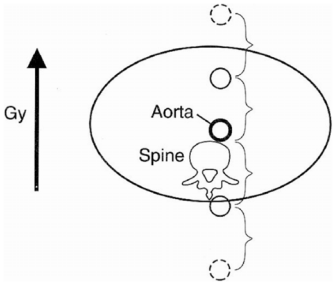
Subject-related Artifacts: Motion

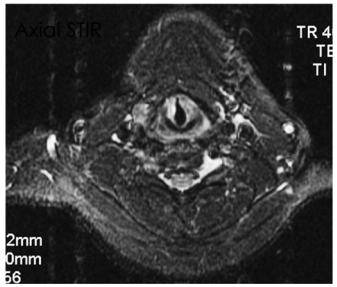
- Random movements, periodic motion (pulsating flow in vessels)
- We only get motion artifacts in the phase-encoding direction (the sampling time for frequency-encoding is short).

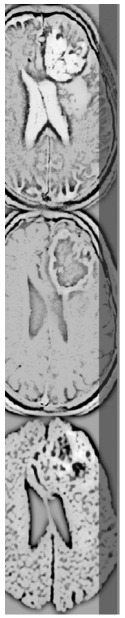


Periodic Motion

- Ghost artifacts of the vessels are equally separated along phase-encoding direction.
- $\boldsymbol{separation\ (SEP\ in\ pixels)} = \frac{\boldsymbol{TR \times Ny \times NEX}}{\boldsymbol{T(motion)}} = \frac{\boldsymbol{acquisition\ time}}{\boldsymbol{T(motion)}}$



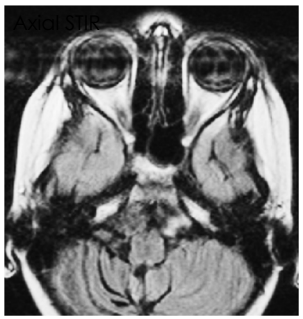


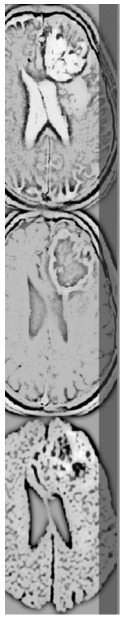


Motion artifacts

- Remedy for Periodic motion
  - Spatial presaturation pulses to saturate inflowing protons
  - Increase separation between ghosts
  - Swap phase and frequency (only change the direction of artifacts)
  - Use cardiac/respiration gating
  - Use flow compensation
- Remedy for random motion
  - Patient instruction: **don't move!**
  - Fast scanning techniques
  - Sedation

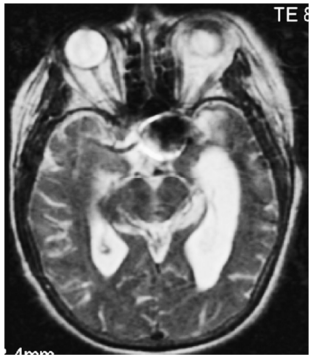
Random eye movements



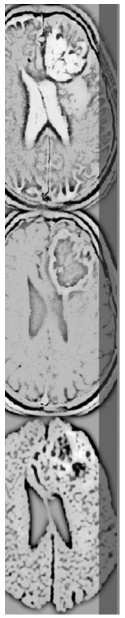


Magnetic susceptibility artifacts

aneurysm clip



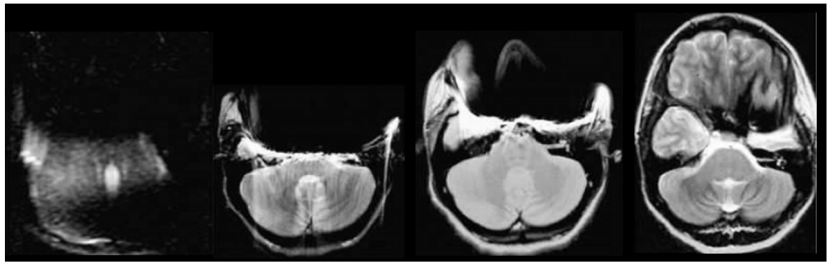
Metallic foreign body



Magnetic susceptibility artifacts

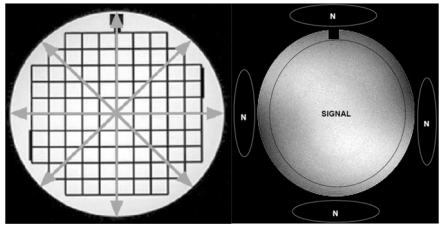
- A patient with dental braces

EPI B0 CSE T2 CSE PD FSE T2



- **請完整練習此部分國考題，很多臨床假影影像實例！**
- **請務必閱讀ACR MRI phantom (11 slices)補充教材！**

< 補充資料 >
ACR phantom overview.pdf
ACR phantom guidance.pdf
ACR 官網連結



- Geometric Distortion
- Spatial Resolution
- Slice thickness and position
- Interslice Gap
- Estimate of Image Bandwidth
- Low Contrast Detectability
- Image Uniformity
- Signal-to-Noise Ratio (SNR)
- Physical and Electronic Slice Offset
- Landmark

THE END

alvin4016@nycu.edu.tw