The Artifacts in MRI

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Introduction

- *All MRI images have artifacts in some degrees.*
- *Why and How ?*
- *How to remedy the artifacts encountered in MRI.*

Introduction

- *Motion artifacts*
  - *patient motion, physiological motion, flow*
- *Inhomogeneity artifacts*
  - *mental artifacts, zipper artifacts, cross talk*
- *Digital imaging artifacts*
  - *aliasing, chemical shift, truncation, herring-bone artifacts, halo artifacts*

Motion Artifacts

- *Patient motion*
  - *voluntary motion, involuntary motion*
- *Physiological motion*
  - *respiration, cardiac motion, peristaltic*
- *Occurring in phase encoding direction*

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But, why are ghosts only produced in the phase-encode direction?

- *Consecutive points in the frequency-encoding direction are measured close together, typically much less than 1 ms apart.*
- *whereas consecutive phase-encoding steps are TR ms apart.*
- *Motion such as respiration and blood flow occurs slowly compared with frequency encoding but much quicker than phase encoding. So between successive phase encodings, the anatomy moves and produces a ghost signal at a different PE position.*

Motion Artifacts

- *Solution of patient motion*
  - *fixed patient, repeat scan, reduce scan time, drug-assisted*
- *Solution of physiological motion*
  - *hold on breath, respiration gating, respiratory compensation, ECG gating, fast scan technology, drug-assisted*

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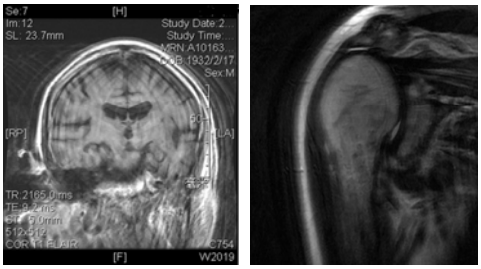
- *Patient motion*



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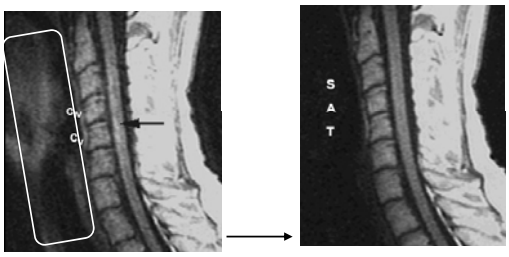
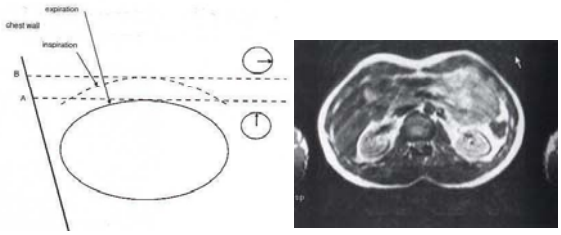
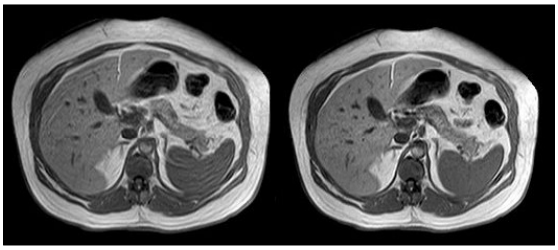


加saturation band

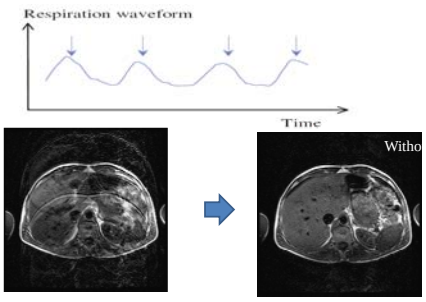
*Motion Artifact(**Respiratory)***





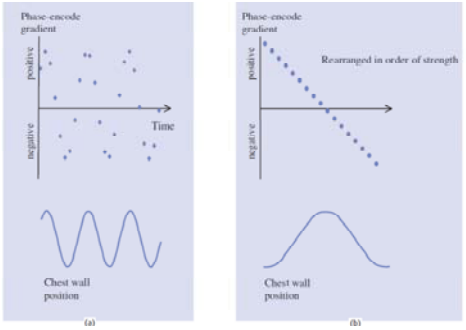
Respiration *Breath-hold*

Respiration Gating

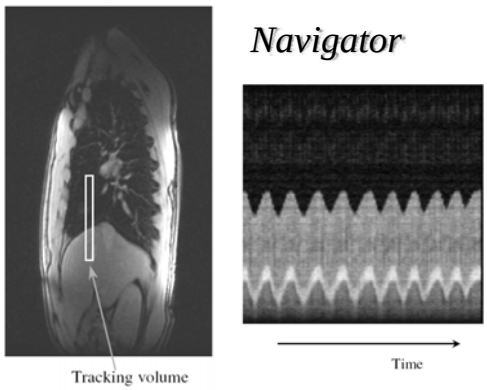


Respiratory Compensation

Respiratory-**O**rdered **P**hase **E**ncoding, ROPE



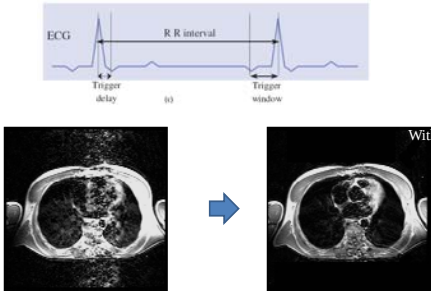
Navigator



Motion Artifact(**Cardiac pulse)**

- *Involuntary motion*
- *ECG trigger or PPU trigger are used to avoid artifacts*
- *MR compatible electrodes use carbon instead of metal to avoid causing artefact on the MR images*
- *Scan time is determined by the heart rate*
- *The TR is controlled by the R–R interval*

ECG Gating



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ECG or peripheral gating?

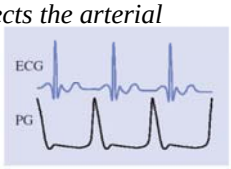
- *ECG gating is a more accurate gating method*

--- peak is usually sharp and easily recognizable

--- all the other ECG peaks can be seen too

--- good for cardiac imaging

- *Peripheral gating only detects the arterial*
- *Pulse peak is much broader wave*
- *Ease of preparing the patie*



Motion Artifact(**Peristaltic motion)**

- *Causes a random continuous motion of the abdominal contents*
- *Acquiring multiple averages can reduce the ghost appearances*
- *Antiperistalsis drug such as hyoscine butylbromide (Buscopan)*
- *Ultrafast pulse sequences*

--- HASTE

*--- single-shot **F**ast**S**pin **E**cho (FSE)*

Flow Motion Artifact

- *Velocity-induced phase effects*
  - *Resonant frequencies are changing continuously*
  - *Incorrect phase angle for their real position*
  - *Artifact on phase encoding direction*

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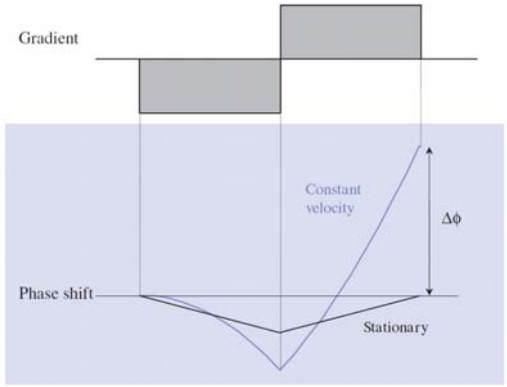
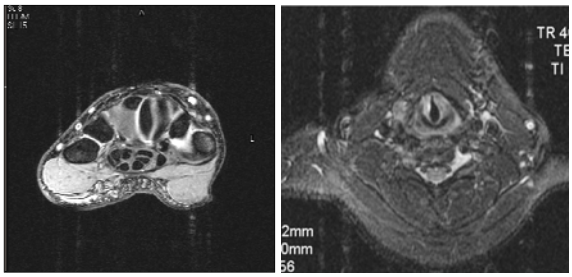


Flow artifact



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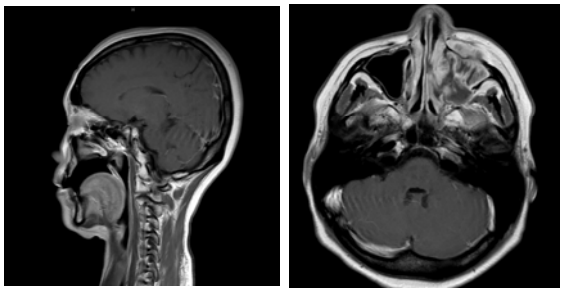
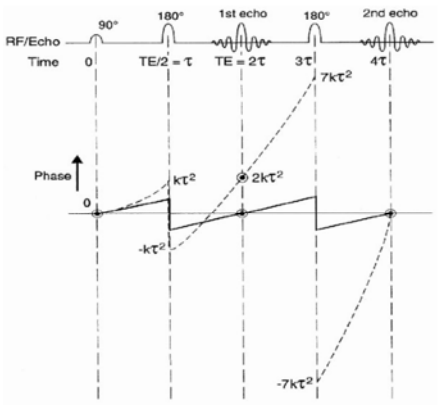
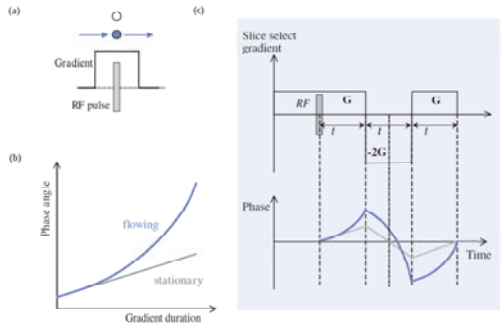


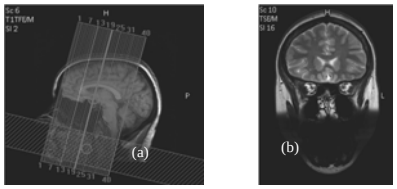


Flow compensation



Avoiding FRE Artifacts

- *Spatial saturation bands, also known as REST slabs or pre-sat bands, are simply slice selections, and can be used in many ways*



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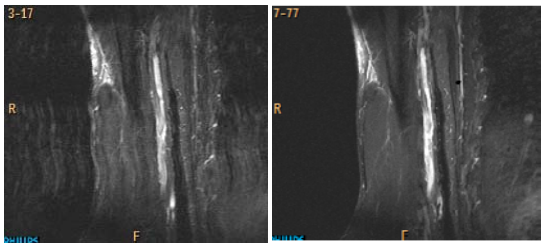


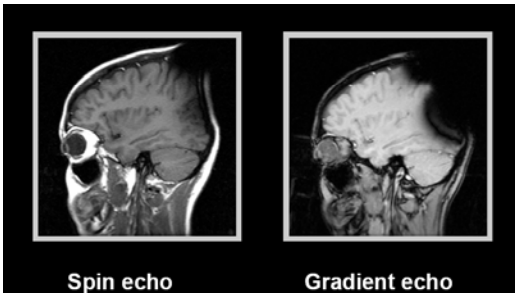
Inhomogeneity artifacts

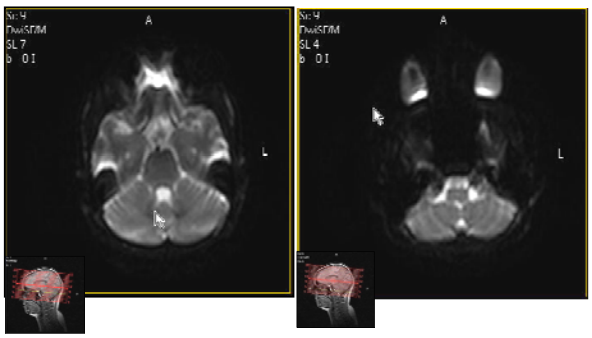
Susceptibility artifacts

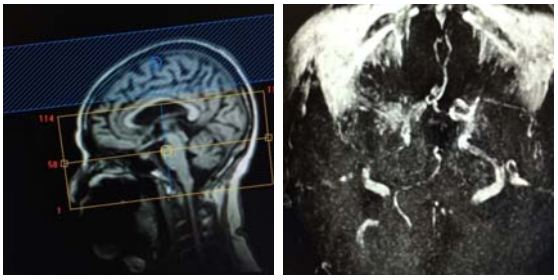
- *Susceptibility artifacts in MRI occur at interfaces of differing magnetic susceptibilities, such as at tissue-air and tissue-fat interfaces (examples include paranasal sinuses, skull base, and sella)*
- *There are caused by inhomogeneities , susceptibility artifacts are generally worse on gradient-echo images than spin-echo images.*

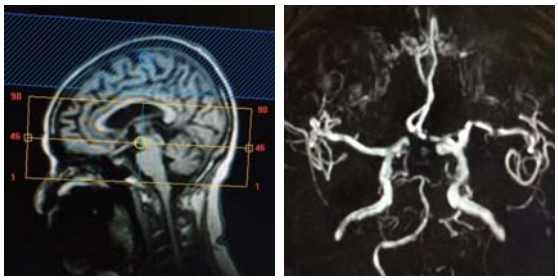
Mental Artifacts

- *Metals caused homogeneity change*









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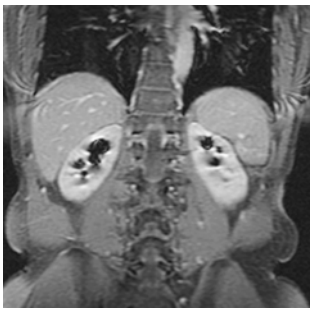


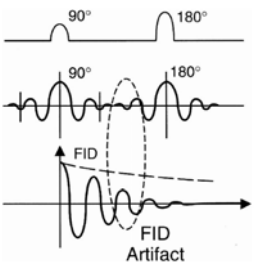
Zipper artifact (RF)

- *This artifact is one form of **central artifacts***
- *Most of zipper artifacts result from inhomogeneities of the magnetic field caused by interferences with radio frequency from various sources.*
- *Software and equipment problems can also cause zipper lines in both directions*

FID Artifacts

- *Free induction decay (FID) artifacts occur due to overlapping of side lobes of the 180^0 pulse with the FID before it has had a chance to completely decay. This overlapping causes a "zipper" artifact*
- *Along the frequency -encode direction.*

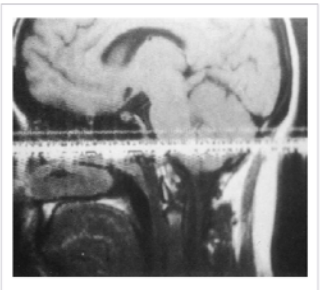
FID Artifacts



Remedy

- *Increase the TE (increases the separation between the FID and the 180^0 RF pulse).*
- *Increase slice thickness. This in effect results from selecting a wide RF BW , which narrows the RF signal in the time domain, thus lowering chances for overlap.*

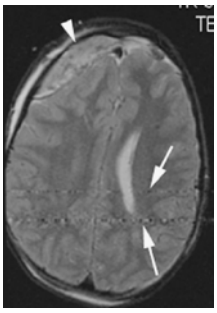
Zipper artifact



RF Feedthrough Zipper Artifact

- *This artifact occurs when the excitation RF pulse is not completely gated off during data acquisition and "feeds" through the receiver coil. It appears as a "zipper" stripe along the phase-encoding axis at zero frequency*

RF Noise

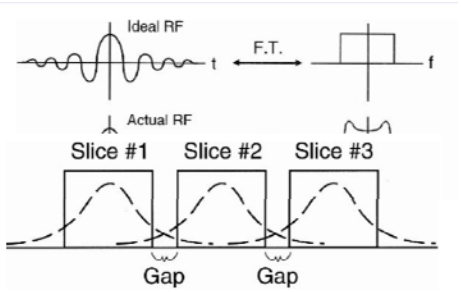


- *RF noise is caused by unwanted external RF noise (e.g., TV channel, a radio station, a flickering fluorescent light, patient electronic monitoring equipment). It is similar to RF feedthrough except that it occurs at the specific frequency (or frequencies) of the unwanted RF pulse(s) rather than at zero frequency*

Remedy for Zipper Artifact

- *Improve RF shielding.*
- *Remove monitoring devices if possible.*
- *Shut the door of the magnet room!*

Cross-talk

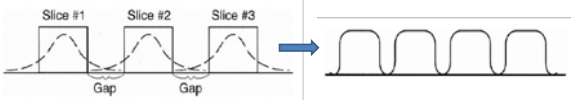


The remedy of cross talk

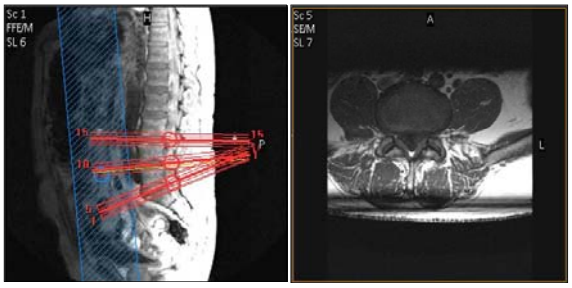
- *At least a 30% gap between the slices.*
- *Excite alternate slices (interleaved) during the acquisition.*

--- First sequence: odd slices 1,3,5,7, …

--- Next sequence: even slices 2,4,6,8,



Multi-stack artifact



Digital imaging artifacts

Aliasing Artifacts

- *Aliasing artifacts, also called wrap-around artifacts*
- *Arises whenever the anatomy bigger than field of view (FOV)*

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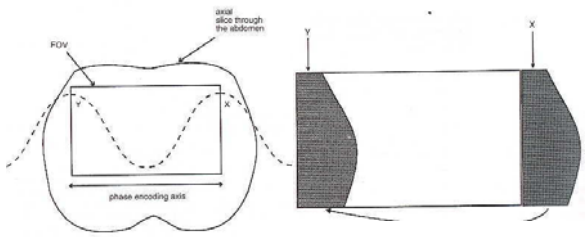
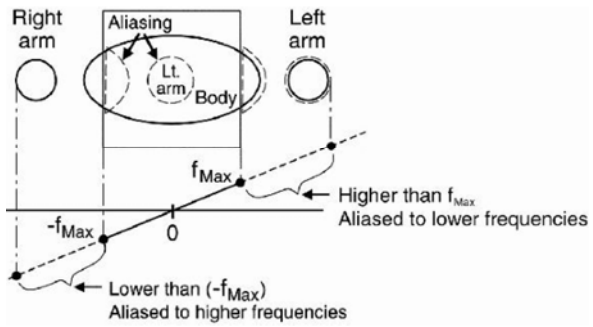
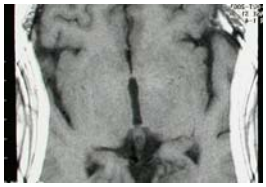
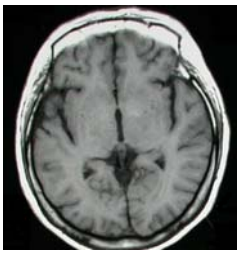




Aliasing Artifacts



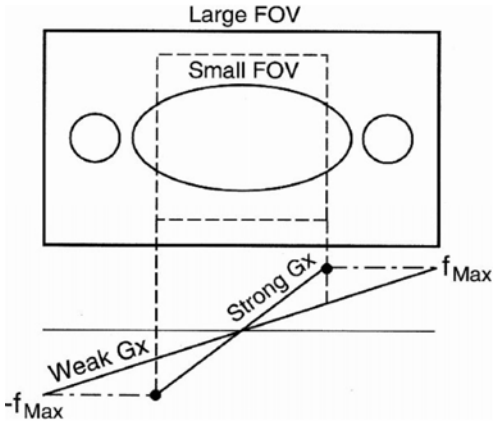


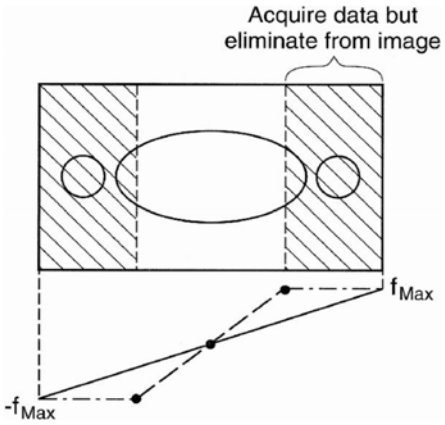
Anti-aliasing along the phase axis

- *Surface coil*
- *Increase FOV*
- *Over samples along the phase encoding axis.*

--- To increasing the number of the phase encoding,the scan time has be prolonged. So, the motion artifact may be more apparent.

- *Saturation pulse*



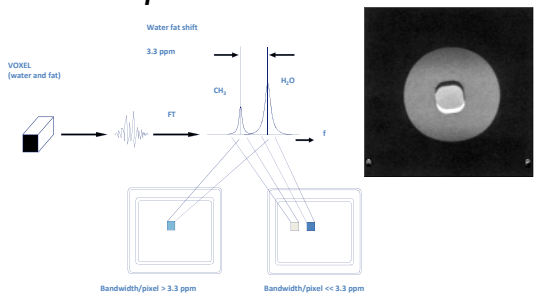


Chemical shift artifact

- *Caused by the different chemical environment of fat and water.*
- *The precessional frequency of fat < water （depend on the main magnetic field strength）*

  ex. At 1.5T the different of precessional frequency is 220 Hz;at 1.0T is 147 Hz.But at lower field strength（o.5T or less）,it is usually insignificant.

Chemical shift



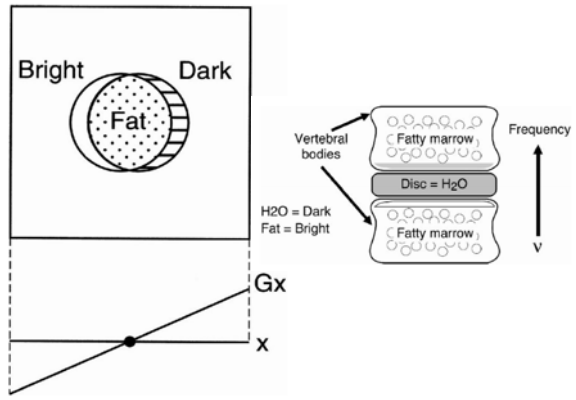
chemical shift artifact

- *For example :*

  The frequency mapped across the FOV is 32000 Hz;256 frequency samples are selected,each pixel has an individual frequency range of 125Hz（32000/256Hz）.At 1.5T,fat and water existing adjacent has a shift about 1.76 pixel which called chemical shift

chemical shift artifact

- *It depend on the size of FOV as this determines the size of each pixel.*
- *Causes a dark edge at the interface between fat and water.*
- *It occurs along the frequency encoding axis only.*



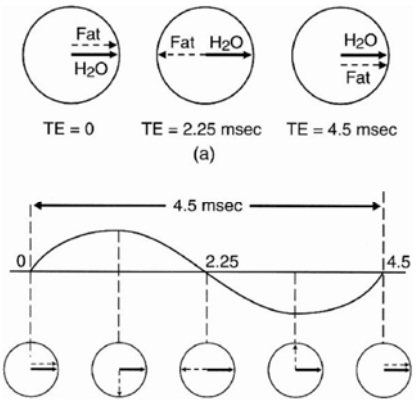
The remedy of chemical shift artifact

- *Using fat suppression.*
- *Scanning at lower filed strengths.*
- *Increase bandwidth (trade-off: lowers SNR)*
- *Switch phase and frequency directions.*
- *Use a long TE (causes more dephasing and less signal from fat).*

Chemical misregistration

Chemical Shift of the "Second Kind"

- *Also produced as a result of the precessional frequency different between fat and water.*
- *Caused because fat and water are in phase at certain times and out of phase at others.*



- *When fat & water are in phase:*
  ⟹ *signals add constructively.*
- *When fat & water are out phase:*
  ⟹ *signals cancel each other out.*

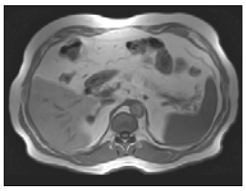
Which called ---- Chemical misregistration

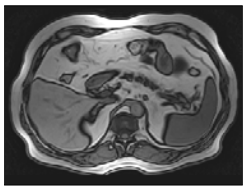
- *Cause a ring of dark signal around certain organs where fat and water interfaces occur within the same voxel.*

The remedy of Chemical misregistration

- *Use a spin echo sequence to reduce the artifact.*
- *Select a TE generates an echo when fat and water are in phase. (at 1.5T the TE is a multiple of 4.2ms)*

Chemical shift for in-out phase





FIELD STRENGTH	In	Out	In	Out	In	Out	In
0.5 T	0	6.8 ms	13.6 ms	20.4 ms	27.2 ms	34 ms	40.8 ms
1.0 T	0	3.4 ms	6.8 ms	10.2 ms	13.6 ms	17 ms	20.4 ms
1.5 T	0	2.2 ms	4.4 ms	6.8 ms	9 ms	11.2 ms	13.4 ms
3.0 T	0	1.1 ms	2.2 ms	3.4 ms	4.5 ms	5.6 ms	6.7 ms

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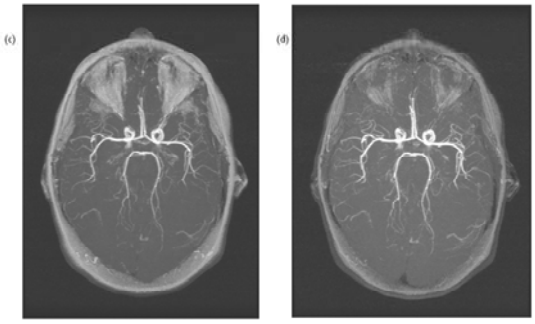
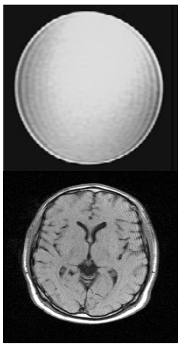
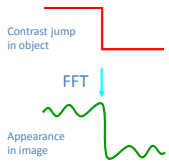


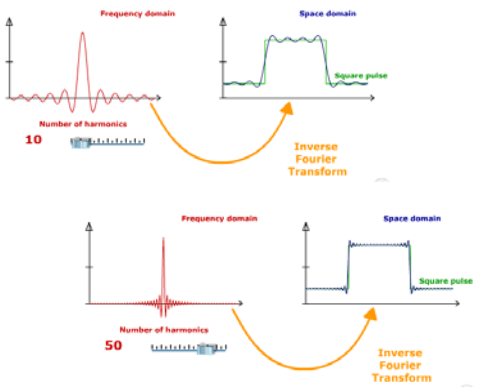
Truncation artifact

- *Caused by under sampling of data so that interfaces of high and low signal are incorrectly represented on the image.*
- *Occurs in the phase direction only.*
- *Produces a low intensity band running through a high intensity area.*

- ***Also called:***
  - ***Gibbs artefact***
  - ***Ringing***
  - ***Spectral leakage***
- ***Predominant in case of***
  - ***low matrix***
  - ***scan percentage << 100%***







The remedy of truncation artifact

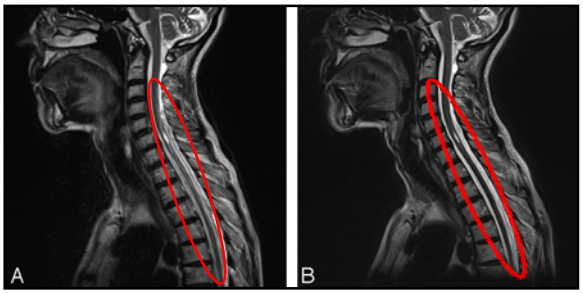
- *Increase sampling time (BW)*
- *Decrease pixel size:*

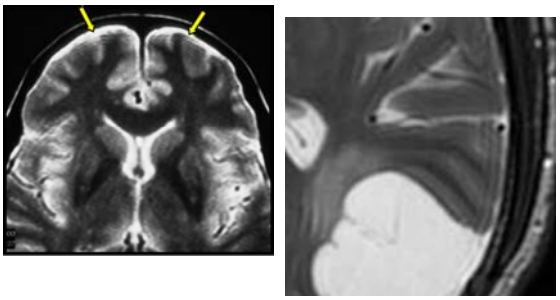
---The under sampling of data must be avoided.

⇒ *increase the number of phase encoding steps.*

---Decreasing the FOV

Gibbs' artifact(truncation artifacts)

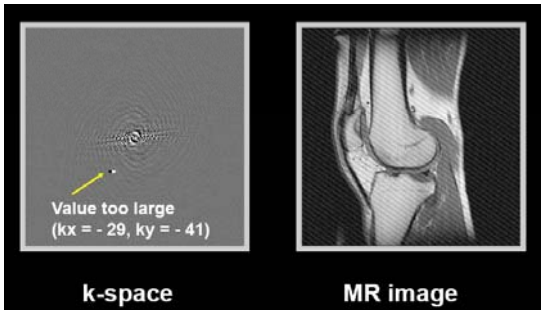


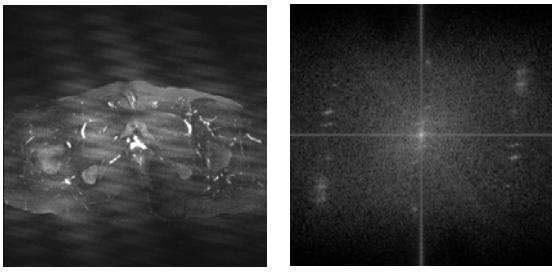


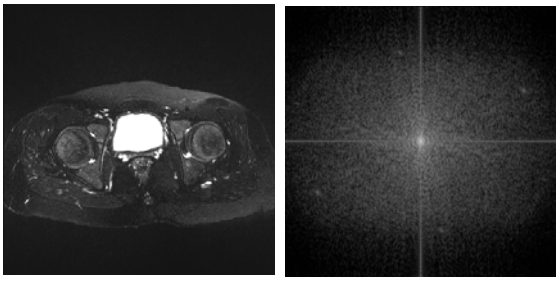
Herring-bone artifact

- *A regular series of high- and low-intensity stripes extending right across the image*
- *It is caused by spike noise in the raw data, whose Fourier transform is then convolved with all the image information*

Herring-bone artifact



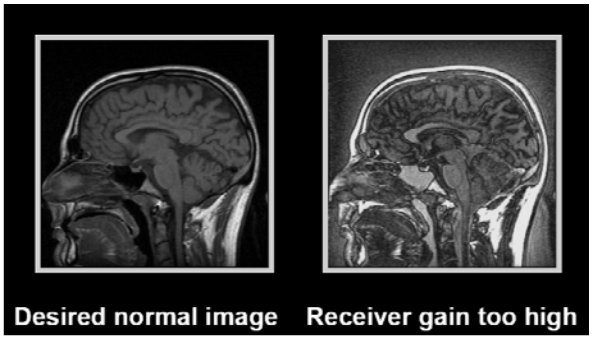




Halo artifact

- *A halo effect can be produced if the receiver gains are incorrectly set.*
- *When this happens the signal is too large for the range of the digitizer and information in the center of k-space is lost*
- *It is a rare artifact with modern automatic pre-scan systems, and is more likely to occur when receiver gains are manually set*

Halo artifact



感謝您的聆聽，再會！！

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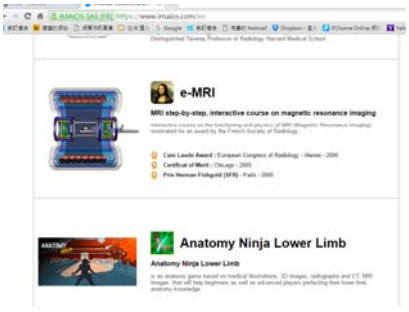

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