Bioengineering 278  
Magnetic Resonance Imaging  

Winter 2010  
Lecture 5  

• MRI Artifacts  
  – Noise spikes  
  – Clipping  
  – Gibbs Ringing  
  – Quadrature ghost  
  – Wraparound  
  – Motion  
  – Chemical Shift  

• SNR in MRI  
  – RF Coil  
  – Magnetization  
  – Sampling time  

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Normal Image  

K-space  

Image space
Noise Spike

- Localized in K-space
- Extends outside object in image space
- Come from arcing, loose connections, ground spikes

More Noise Spikes

- Multiple spikes create multiple sinusoids and generate ‘herringbone’ patterns
Data clipping

- Center of K-space over-ranges ADC and clips
- Image is (correct image) - (low frequency image)

• Here is the data that was clipped
Gibbs Ringing

- Data is truncated before it decays into the noise
- Result is an image convolved with FT of the window in k-space

Quadrature Ghost

- K-space data is a superposition of good_data and good_data*
  => Image space is a superposition of good_image(x,y) and good_image(-x,-y)
**Phase Encode**
- K-space sampled discretely
- Susceptible to aliasing
- FOV = \(2\pi/\Delta k\)

**Frequency Encode**
- K-space traveled continuously, but data is digitized
- Wraparound can be prevented by either analog or digital bandpass filter

**Motion Artifact**
- Motion between TR periods generates inconsistency between lines of K-space
- Ghosts propagate in the phase encode direction
- Periodic motion generates structured ghosts (analogous to the EPI Nyquist Ghosts). One oscillation every N points in K space gives a ghost with spacing FOV/N
Chemical Shift

- Magnetic field of electron clouds shields nucleus from external magnetic field
- => Actual magnetic field experienced by nucleus is smaller than applied field
- Differences in local field are called chemical shift, and are measured in PPM
- Water and fat differ in chemical shift by 3.5 PPM = 440Hz at 3T
- Chemical shift causes phase twist across readout
- Fourier shift theorem tells you how far things are shifted

Fourier Shift Theorem

\[ FT(f(x)) = F(k) = \int_{-\infty}^{\infty} f(x)e^{ikx} \, dx \]

\[ FT(f(x-a)) = \int_{-\infty}^{\infty} f(x-a)e^{ikx} \, dx \]

\[ = \int_{-\infty}^{\infty} f(x')e^{i(kx'+ka)} \, dx' \]

\[ = e^{ika} \int_{-\infty}^{\infty} f(x')e^{ikx'} \, dx' \]

\[ = e^{ika} F(k) \]
CONVENTIONAL IMAGING

1 / 0ms = ∞ Hz / pixel

1 / 8ms = 125 Hz / pixel

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EPI

1 / 40ms = 25 Hz / pixel

1 / 0.5ms = 2000 Hz / pixel

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Signal to Noise Ratio in MRI

\[ SNR \propto (\text{coil \_ factor}) \times (\text{magnetization \_ factor}) \times (\text{sampling \_ factor}) \]

- Proportional to local B1
- Sample noise increases with coil size
- Depends on coil geometry, coil quality (internal coil losses)

- Proportional to \( M_{xy} \) at time of readout
- Depends on \( B_0 \), pulse sequence, TR, TE, PD, T1, T2, T2*, voxel volume

- Proportional to \( \sqrt{\text{total \_ readout \_ time}} \)

\[ SNR \propto (\text{voxel \_ volume})^{\sqrt{\text{total \_ readout \_ time}}} \]