Bioengineering 208
Magnetic Resonance Imaging

Winter 2007
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)

Data clipping

- 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)
**Wraparound**

**Phase Encode**
- K-space sampled discretely
- Susceptible to aliasing

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

**No Phase Wrap**

**Motion Artifact**

- Motion between TR periods generates inconsistency between lines of K-space
- Ghosts propagate in the phase encode direction
- Period motion generates structured ghosts (analogous to EPI Nyquist Ghosts)

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http://www.fmrib.ox.ac.uk/~peterj/lectures/kspace/img034.GIF

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http://www.rad.pulmonary.ubc.ca
Chemical Shift

- Magnetic field of electron clouds shields nucleus from external magnetic field
- \( \Rightarrow \) 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

CONVENTIONAL IMAGING

\[
\begin{array}{c}
0ms \\
\uparrow \\
1 / 0ms = \infty \text{ Hz / pixel} \\
\downarrow \\
\downarrow 8ms \\
\downarrow 1 / 8ms = 125 \text{ Hz / pixel}
\end{array}
\]

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Off Resonance Behavior: EPI

\[ 0.5\text{ms} \rightarrow 40\text{ms} \rightarrow 1 / 40\text{ms} = 25 \text{Hz/pixel} \]
\[ 1 / 0.5\text{ms} = 2000 \text{Hz/pixel} \]

Signal to Noise Ratio in MRI

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

- Proportional to local B1
- Sample noise increases with coil size
- Depends on coil geometry, coil quality (internal coil losses)
- Proportional to \( M_{\text{xy}} \) at time of readout
- Depends on \( B_0 \), pulse sequence, TR, TE, PD, \( T_1 \), \( T_2 \), \( T_2^* \), voxel volume

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