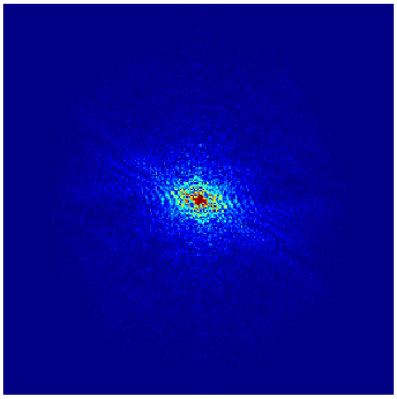
Bioengineering 278
Magnetic Resonance Imaging

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

Normal Image



K-space

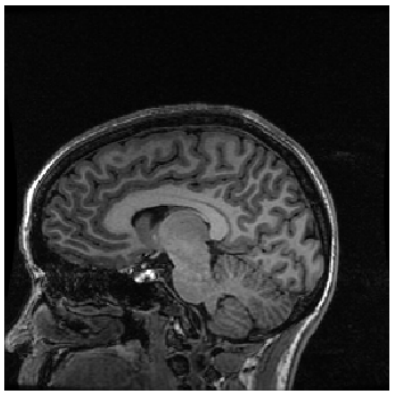
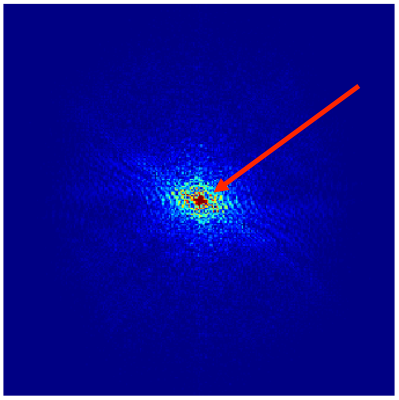


Image space

Noise Spike



K-space

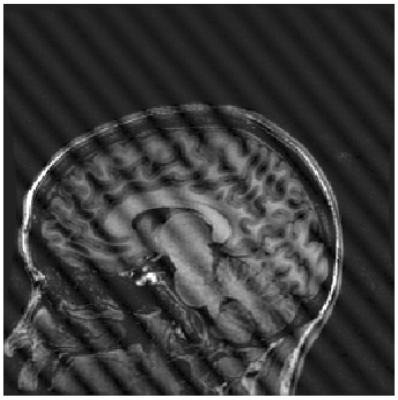
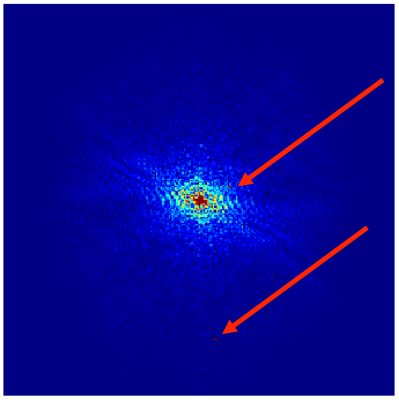


Image space

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

More Noise Spikes



K-space

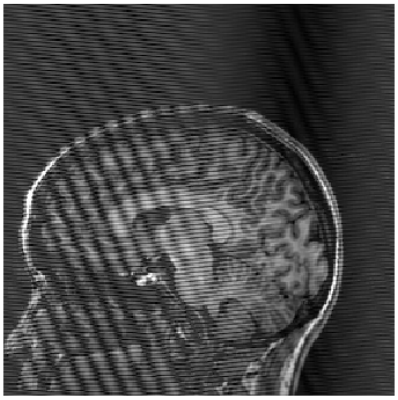
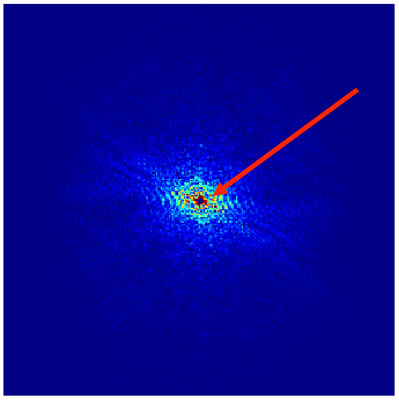


Image space

- Multiple spikes create multiple sinusoids and generate 'herringbone' patterns

Data clipping



K-space

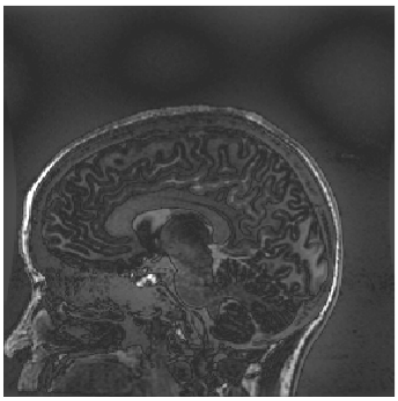
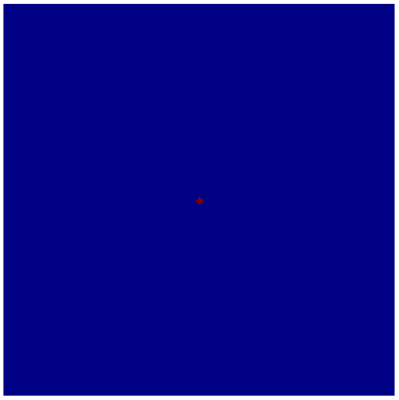


Image space

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

Data clipping



K-space

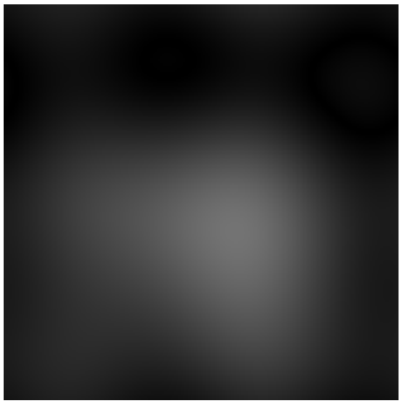
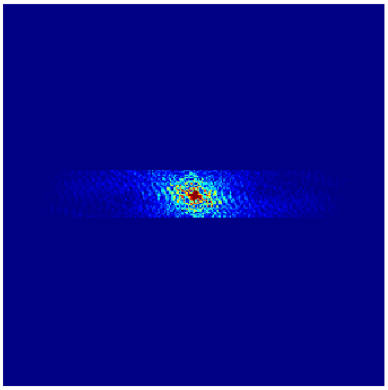


Image space

- Here is the data that was clipped

Gibbs Ringing



K-space

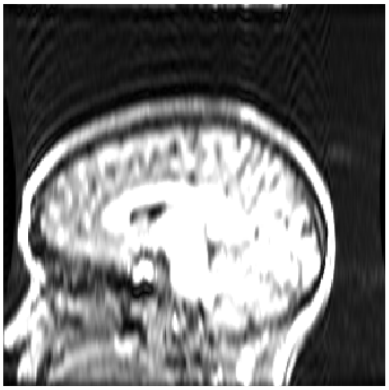
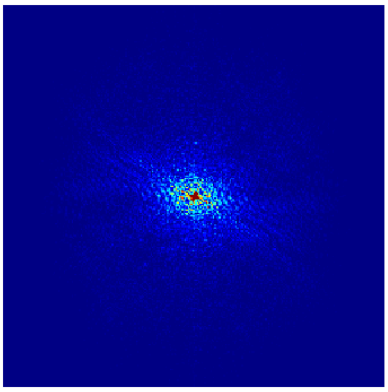


Image space

•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

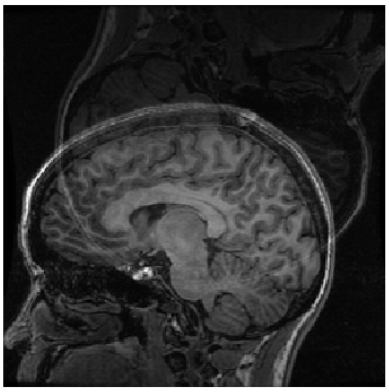
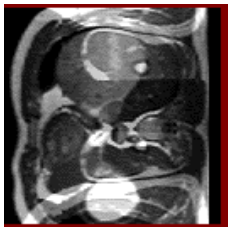


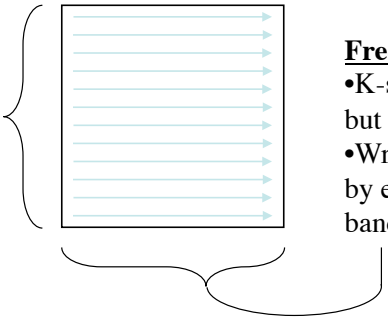
Image space

•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
- FOV = $2\pi/\Delta k$

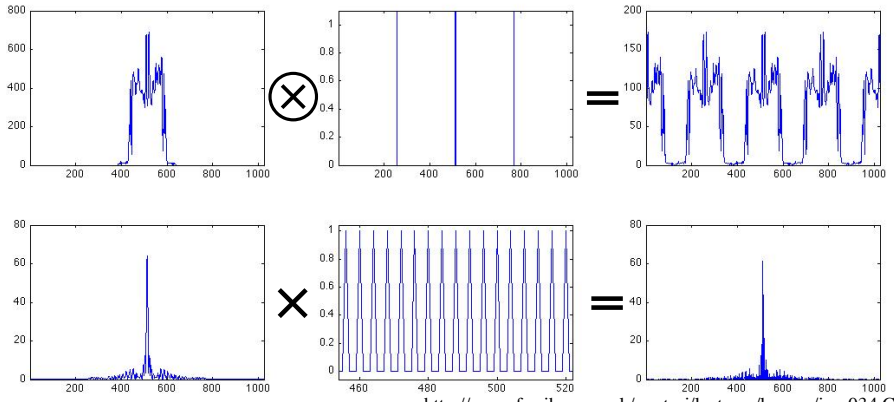




Frequency Encode
- K-space traveled continuously, but data is digitized
- Wraparound can be prevented by either analog or digital bandpass filter

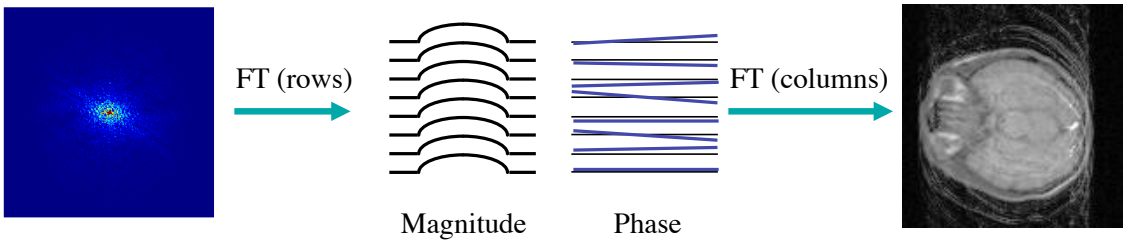
Image Space

K-Space

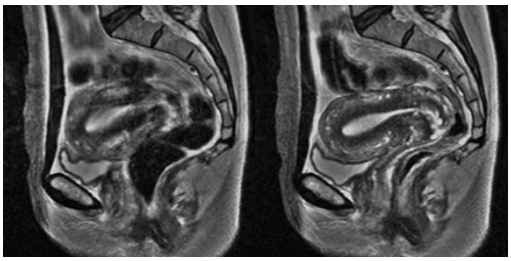


http://www.fmrib.ox.ac.uk/~peterj/lectures/kspace/img034.GIF

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

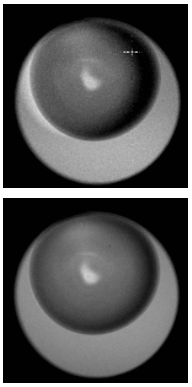


Normal Peristalsis Paralyzed Bowel

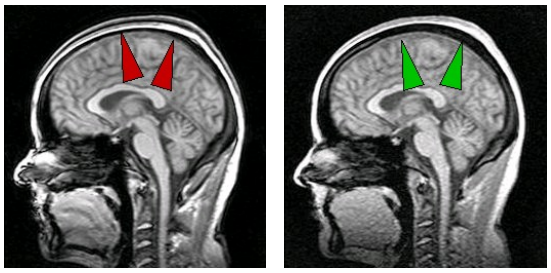
http://wwwrad.pulmonary.ubc.ca

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



http://chickscope.beckman.uiuc.edu/roosts/carl/artifact/cs_a001.gif



http://www.mr-tip.com/serv1.php?type=art&sub=Chemical%20Shift%20Artifact

Fourier Shift Theorem

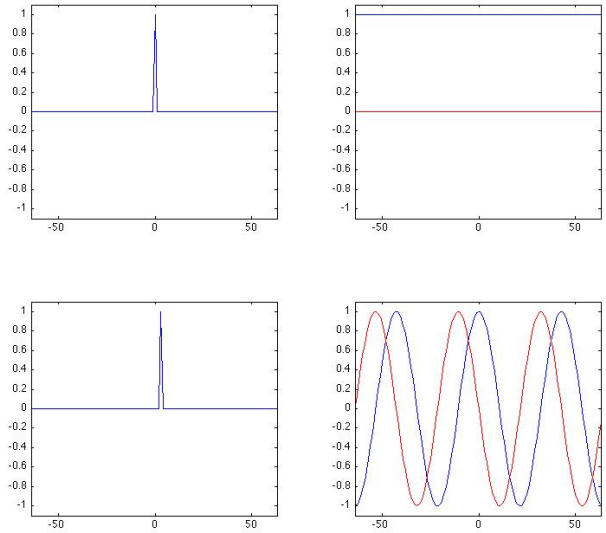
$$FT(f(x)) = F(k) \equiv \int_{-\infty}^{\infty} f(x) e^{ikx} dx$$

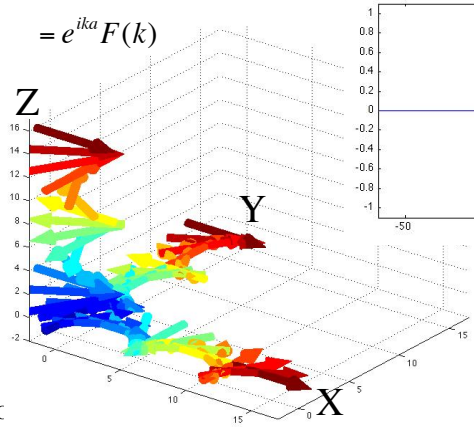
$$FT(f(x-a)) = \int_{-\infty}^{\infty} f(x-a) e^{ikx} dx$$

$$= \int_{-\infty}^{\infty} f(x') e^{ik(x'+a)} dx'$$

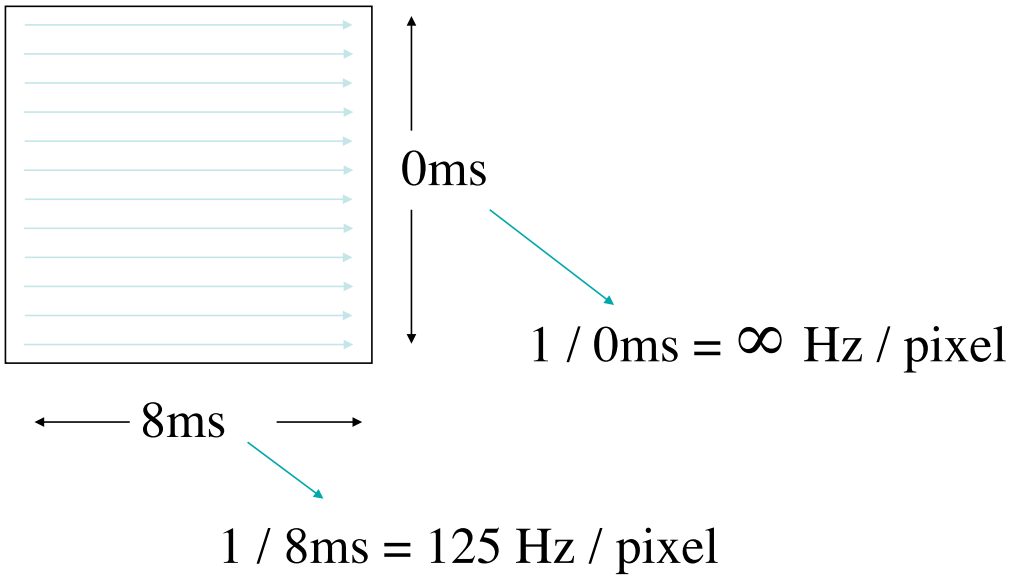
$$= e^{ika} \int_{-\infty}^{\infty} f(x') e^{ikx'} dx'$$

$$= e^{ika} F(k)$$

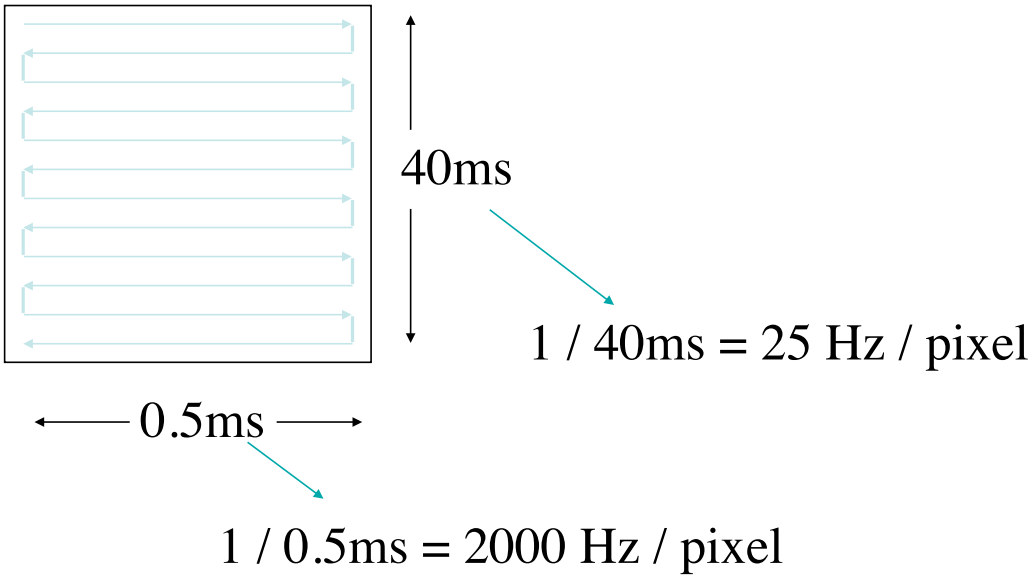




CONVENTIONAL IMAGING



EPI



Signal to Noise Ratio in MRI

$$SNR \propto (coil\_factor) \times (magnetization\_factor) \times (sampling\_factor)$$

- 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, T_1, T_2, T_2*, voxel volume

- Proportional to sqrt(total readout time)

$$SNR \propto (voxel\_volume)\sqrt{total\_readout\_time}$$