

Practical MRI

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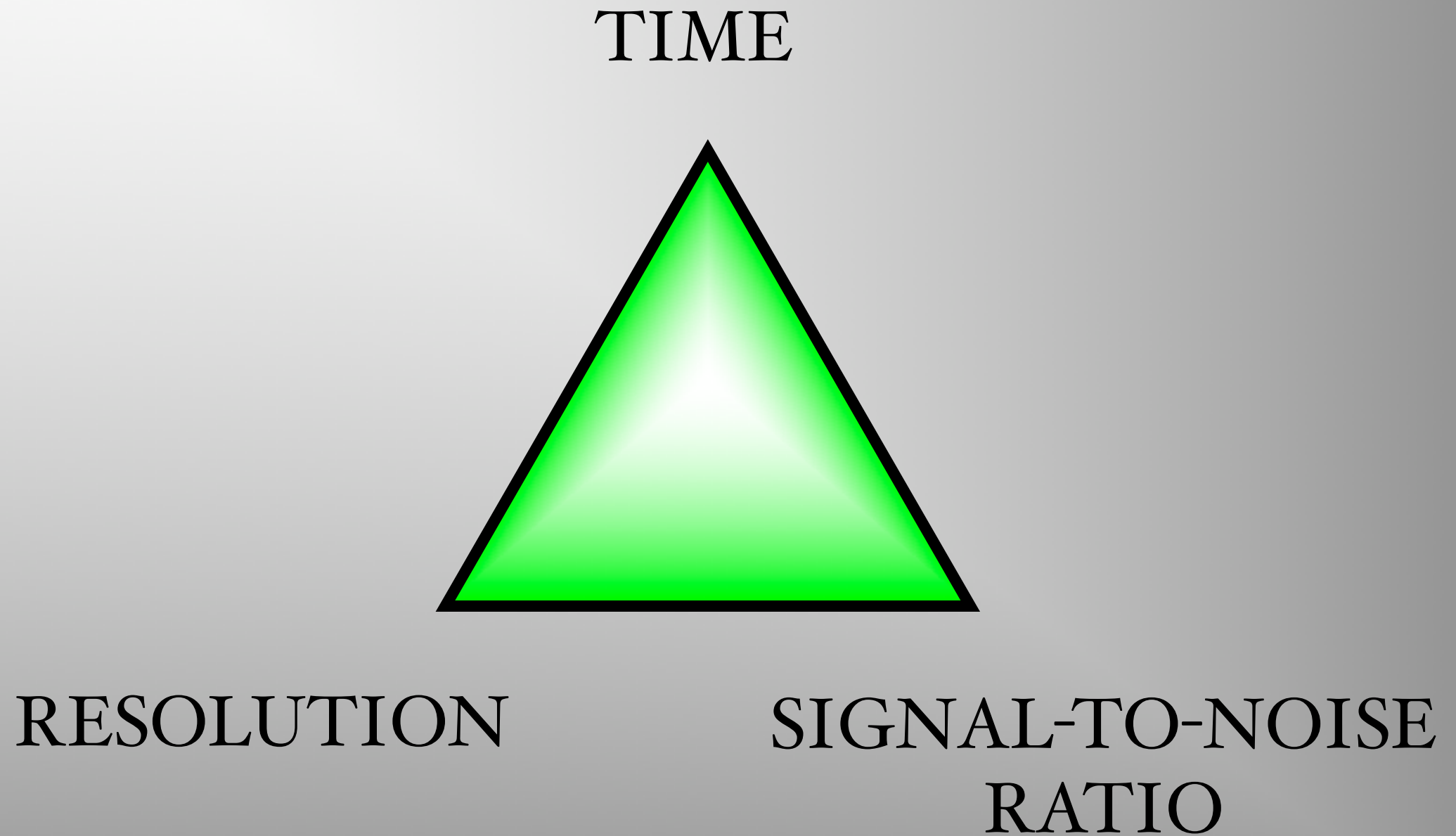


Magnetic Resonance Theory Course 2004

Caltech Brain Imaging Center

California Institute of Technology

The MRI Tradeoff



MRI Optimization

- Start with a low resolution test image
- Optimize contrast in the low res image
- Calculate SNR for the contrast optimized image
- Adjust SNR using voxel volume and signal averaging.
- Use *a priori* knowledge where possible.
- Be prepared to experiment.

Sources of Noise in MRI

- Sample or Subject
 - Important at lower fields/larger subjects
- RF coil
 - Important at higher fields/smaller samples
- RF Preamplifier
- RF Receiver Electronics
- External Sources

Signal and Noise

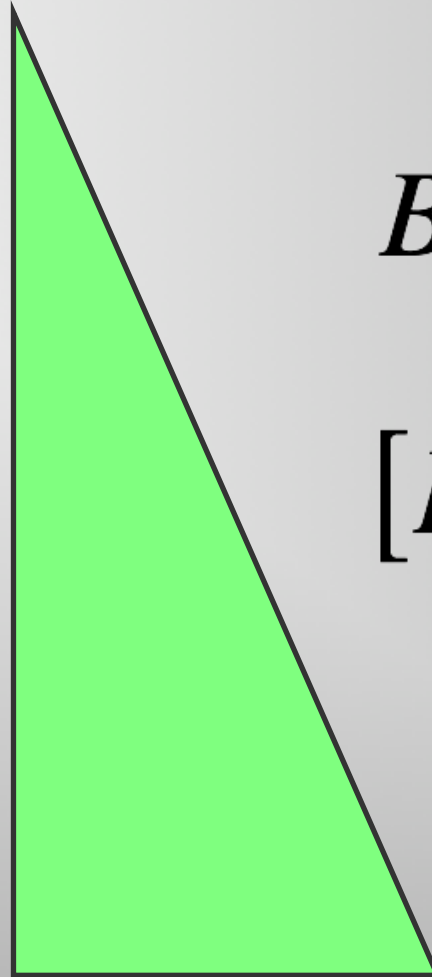
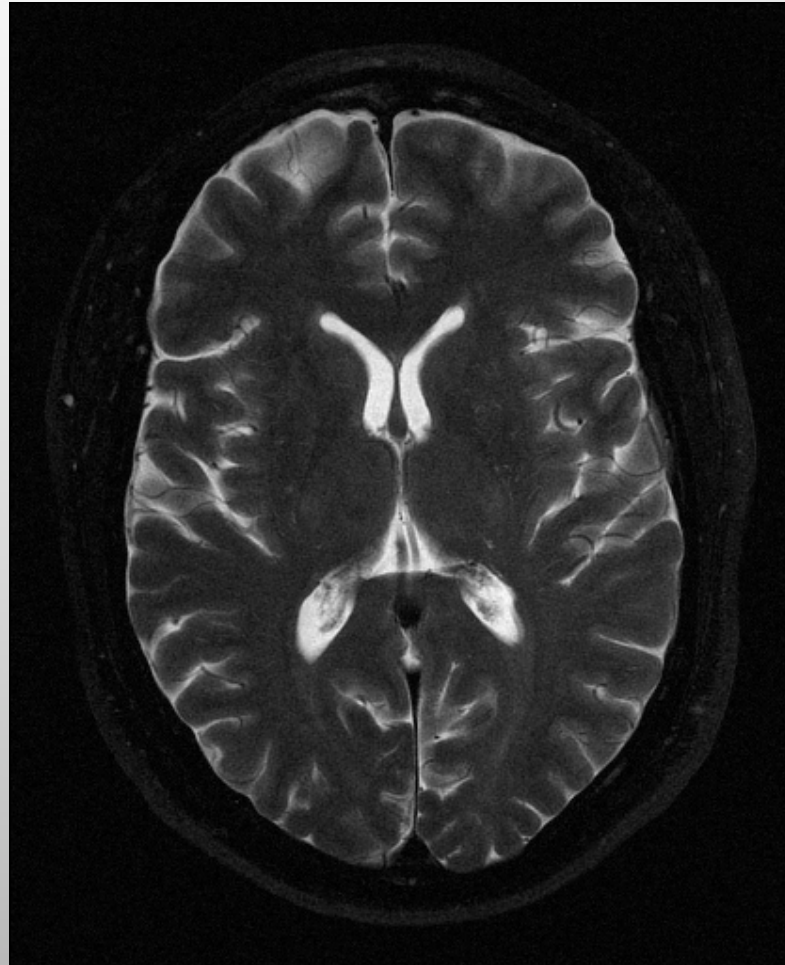
Total signal from a voxel is proportional to the voxel volume:

$$\frac{S}{N} \propto \Delta x^3 \sqrt{N_{av}}$$

$$N_{av} \propto \frac{1}{\Delta x^6}$$

Total imaging time has an inverse sixth power relation to voxel dimension at constant SNR.

Frequency Encoding Bandwidth



$$BW = \gamma G_x FOV_x$$

$$[Hz] = \left[\frac{Hz}{G} \right] \left[\frac{G}{cm} \right] [cm]$$

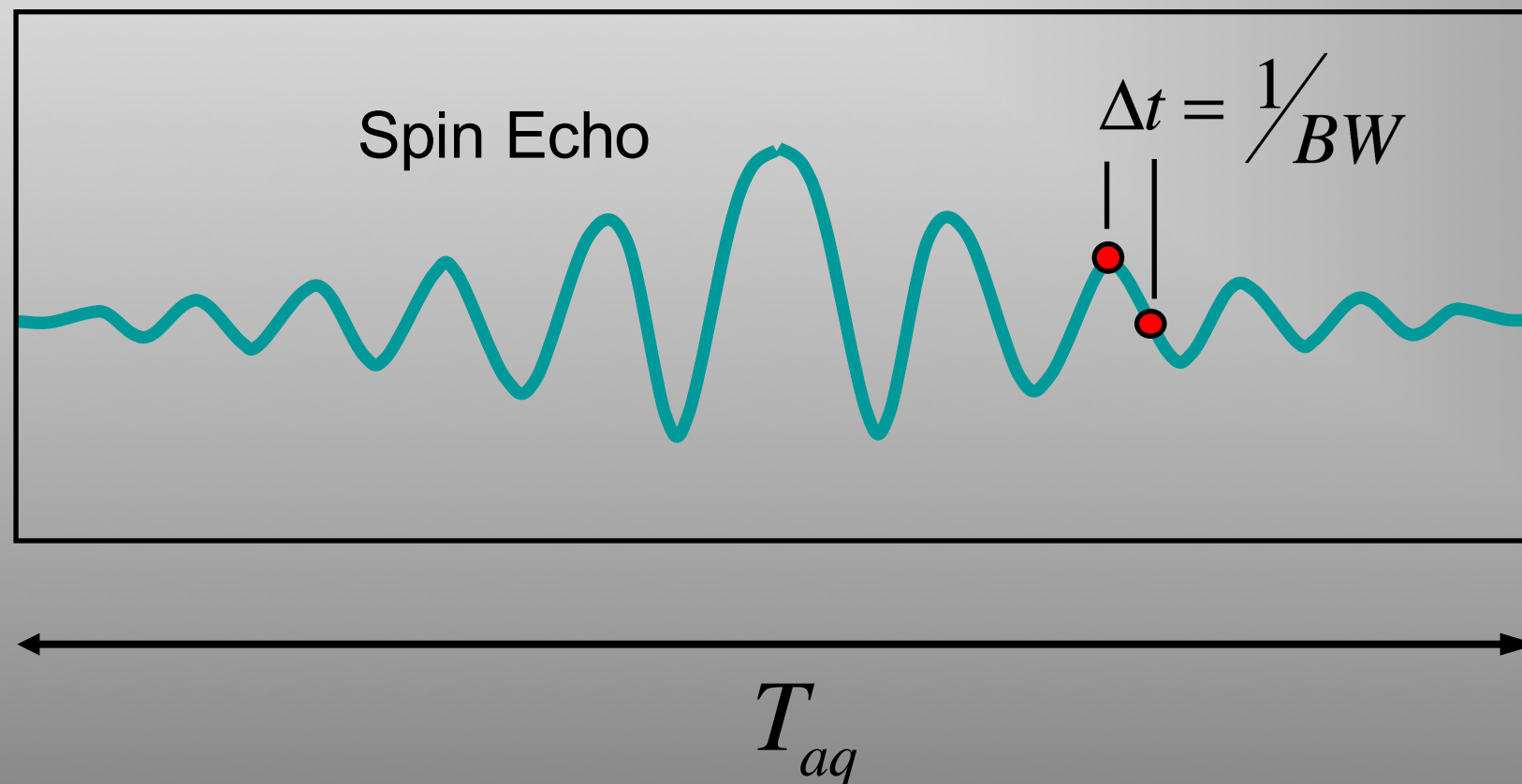
$$B_z = B_0 + G_x x$$

Frequency Encoding Bandwidth and Noise

SNR is proportional to the square-root of the total digitizer acquisition time (c.f. SNR proportional to the square root of the number of signal averages).

$$\frac{S}{N} \propto \sqrt{T_{aq}} = \sqrt{N_x \Delta t} = \sqrt{\frac{N_x}{BW}}$$

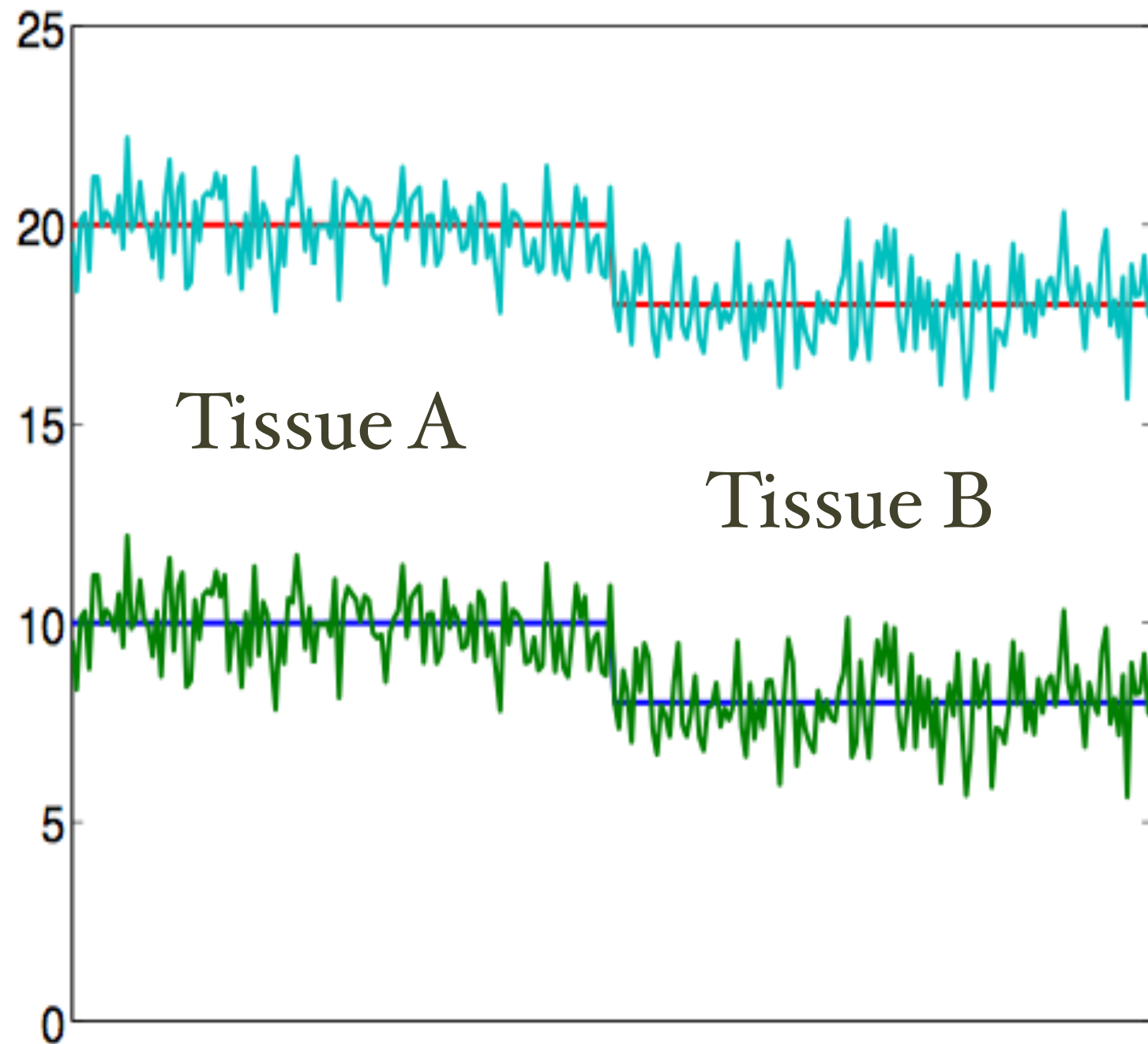
Digitizer acquisition window



SNR and CNR

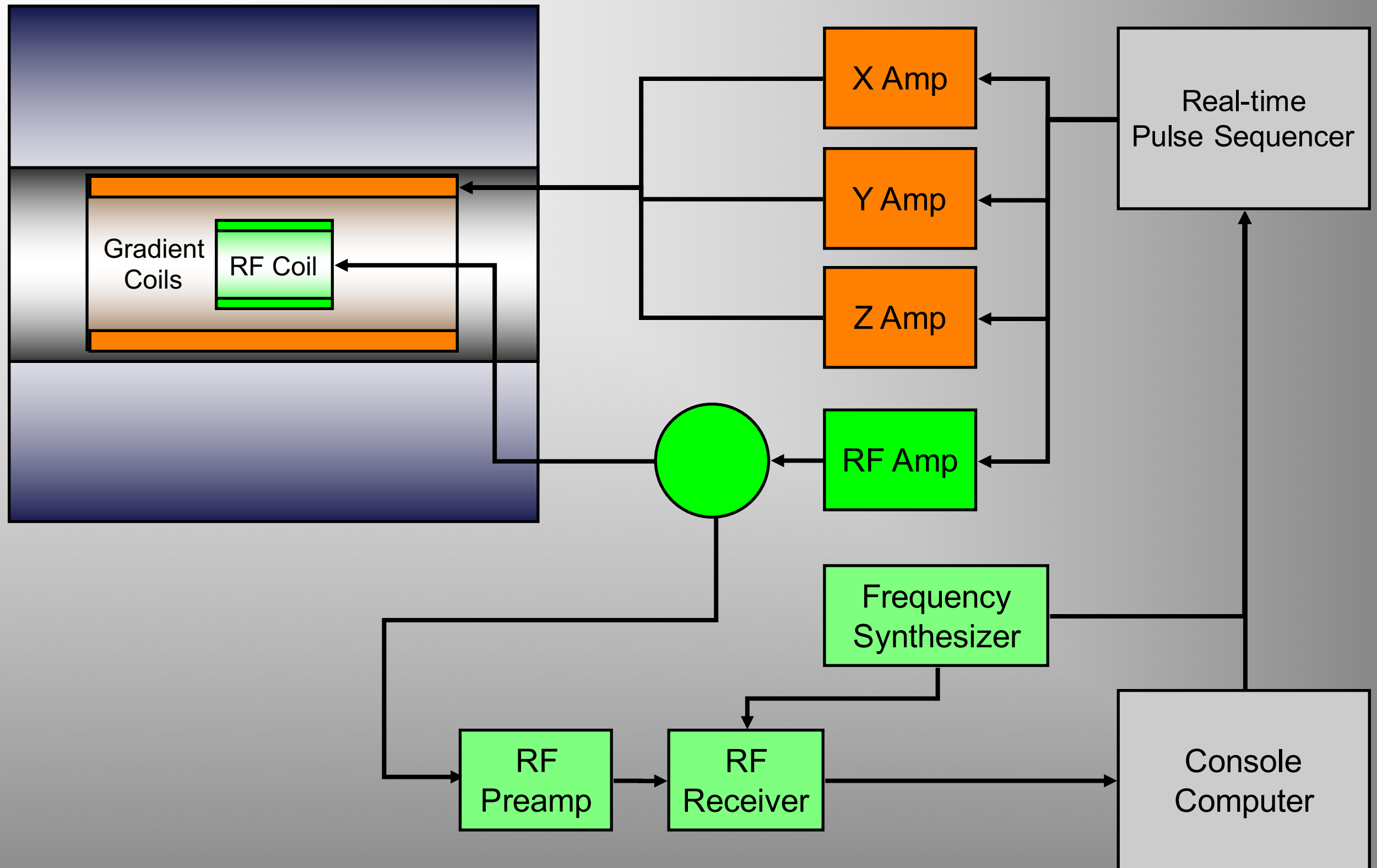
SNR = 20
CNR = 2

SNR = 10
CNR = 2



MRI Hardware

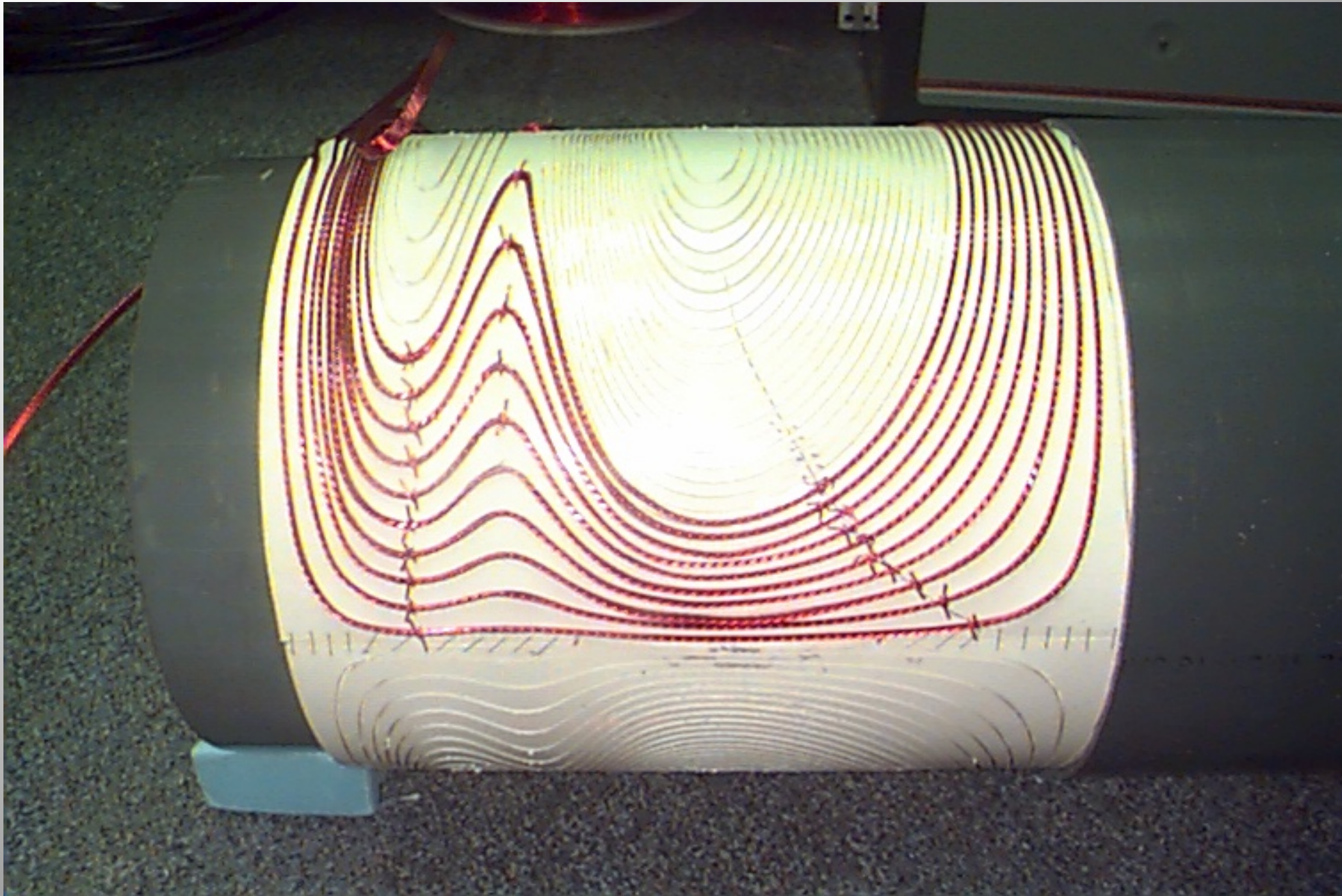
MRI Hardware Schematic



Magnet Solenoid

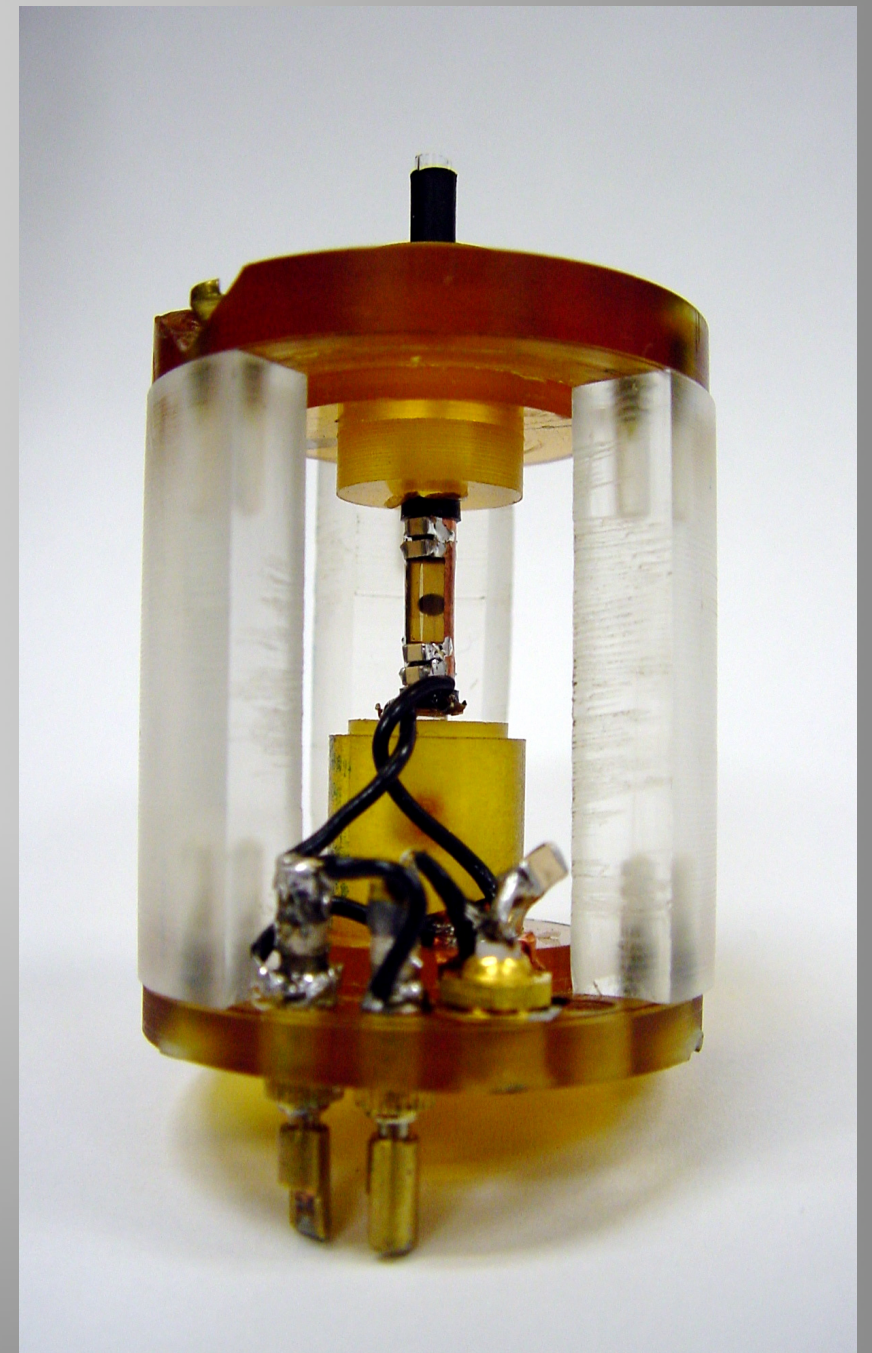
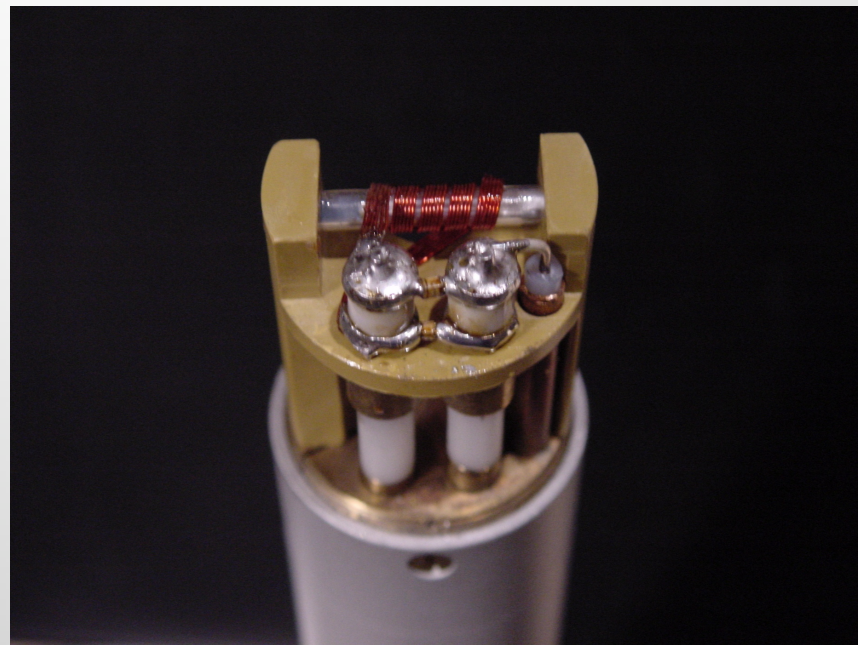


Gradient Coils

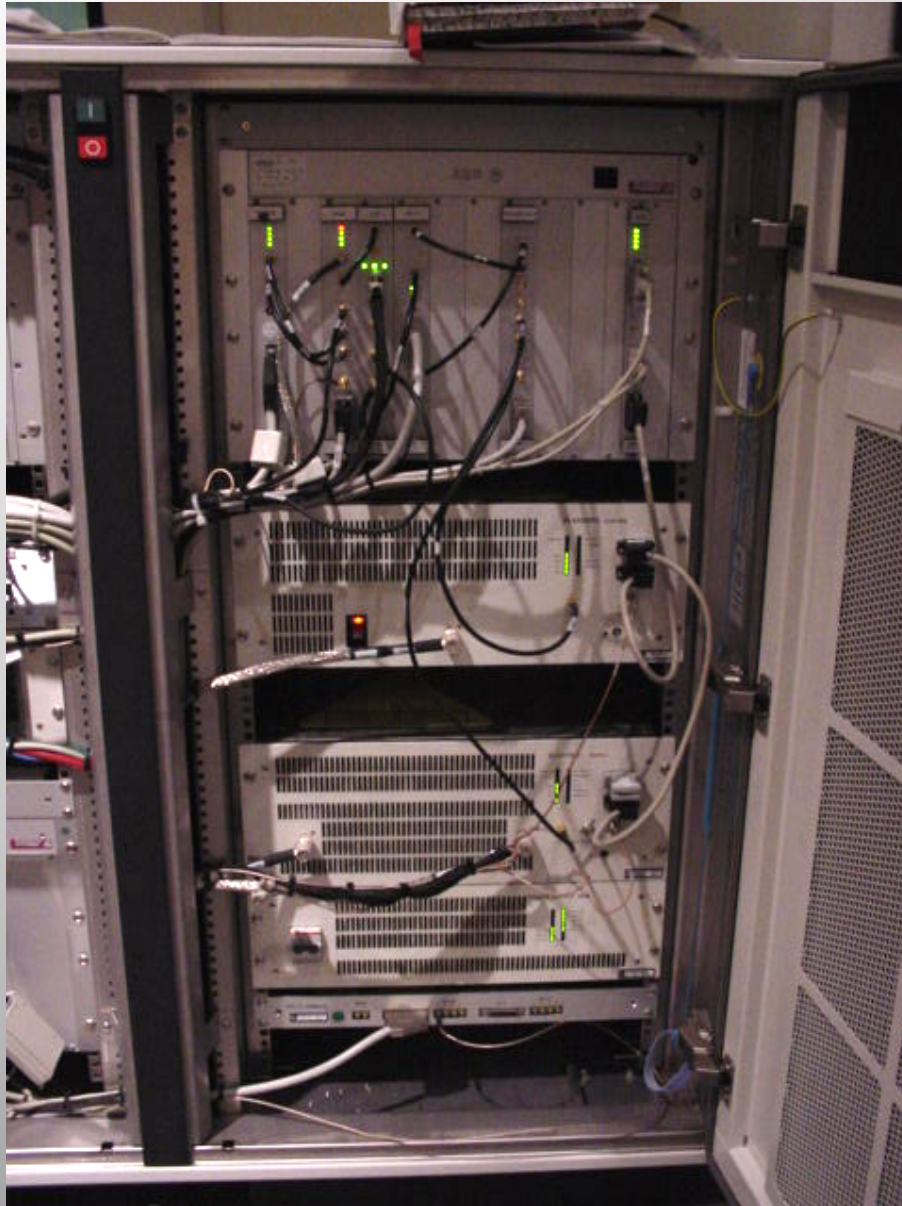


Chronik B, **Rutt BK**: Constrained Length Minimum Inductance Gradient Coil Design. Magnetic Resonance in Medicine. 39 :270-278, 1998

RF Coils



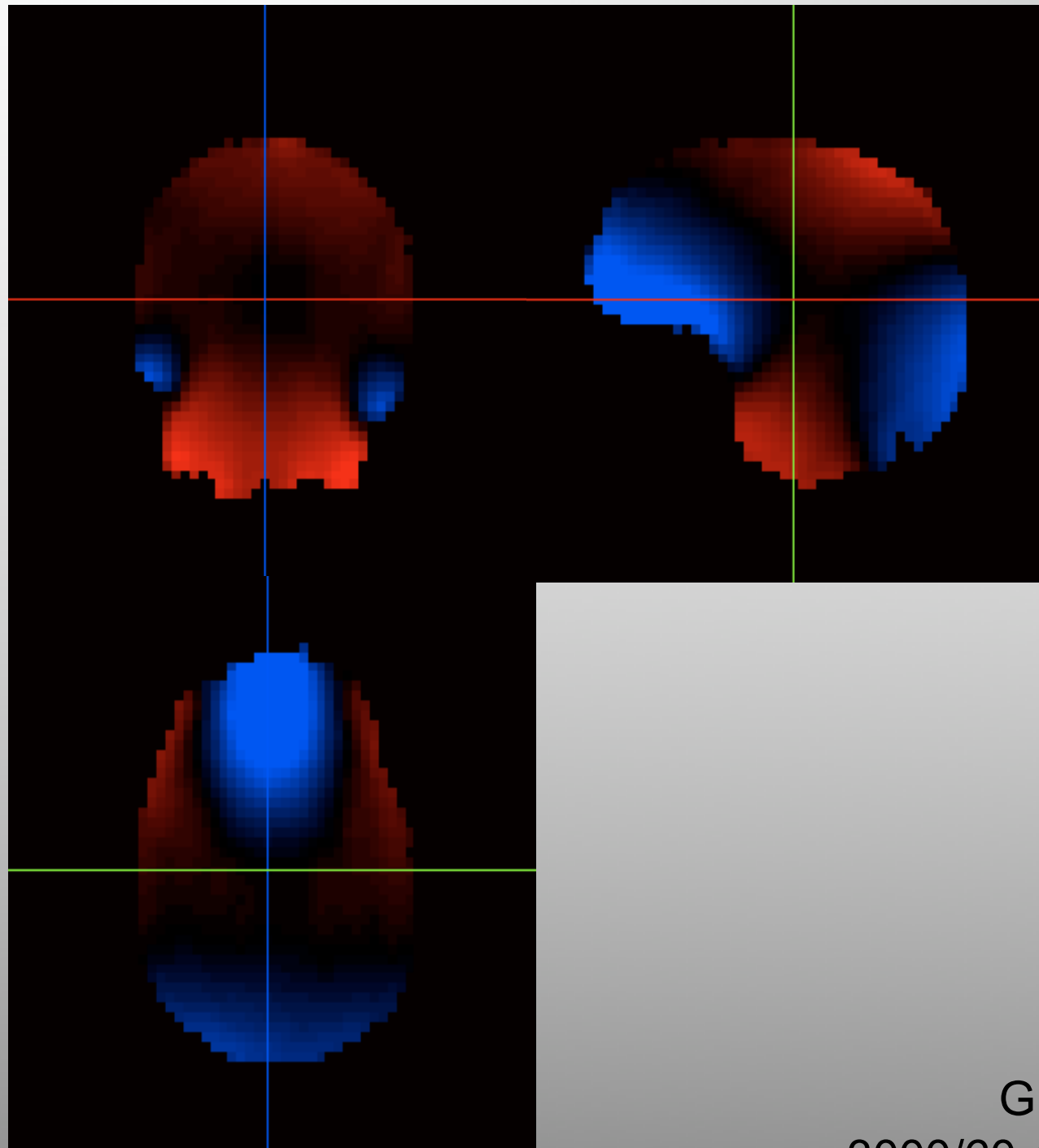
System Electronics



MRI Artifacts

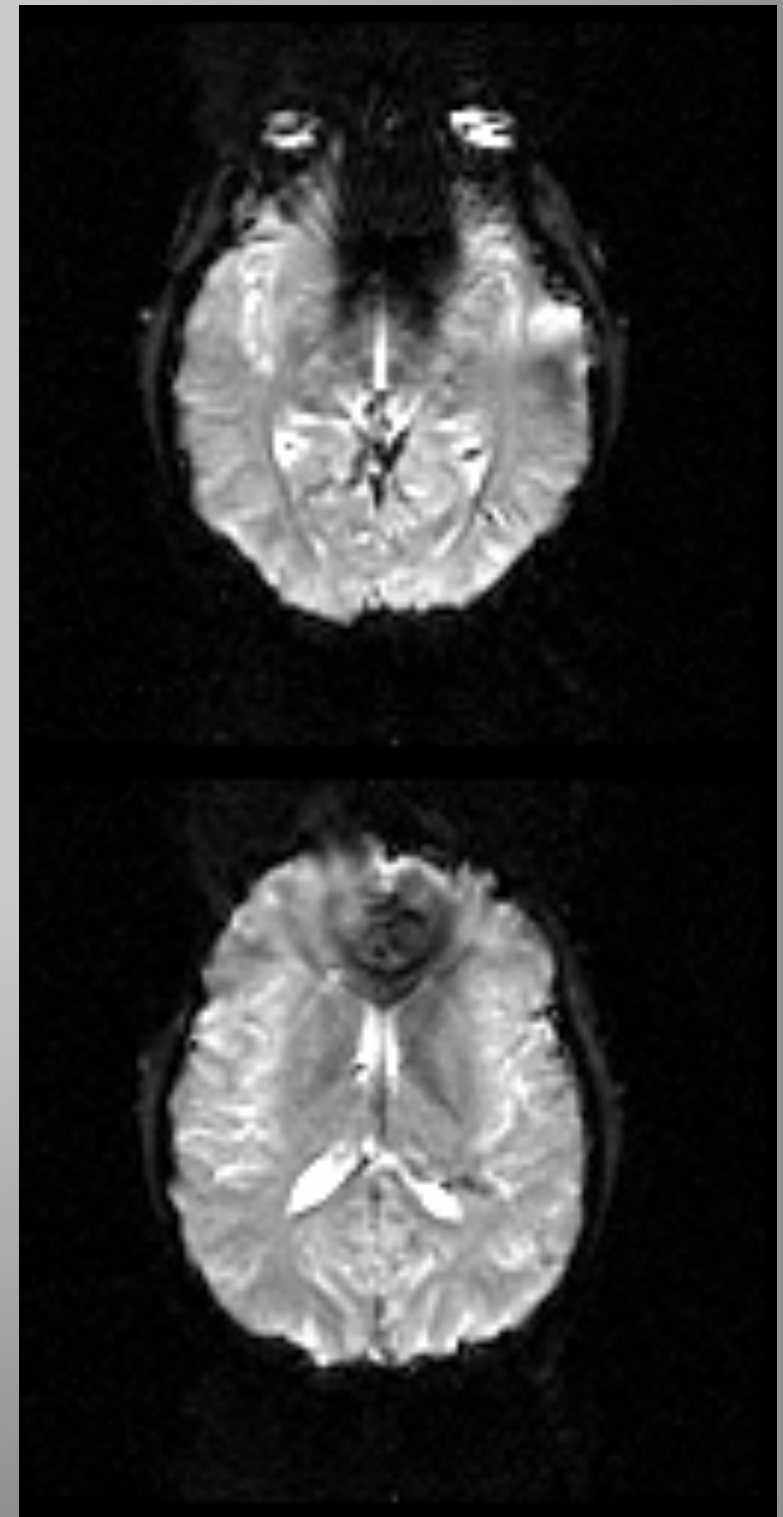
B_0 Inhomogeneity Artifacts

Mean B_0 maps following linear shimming (n=5)

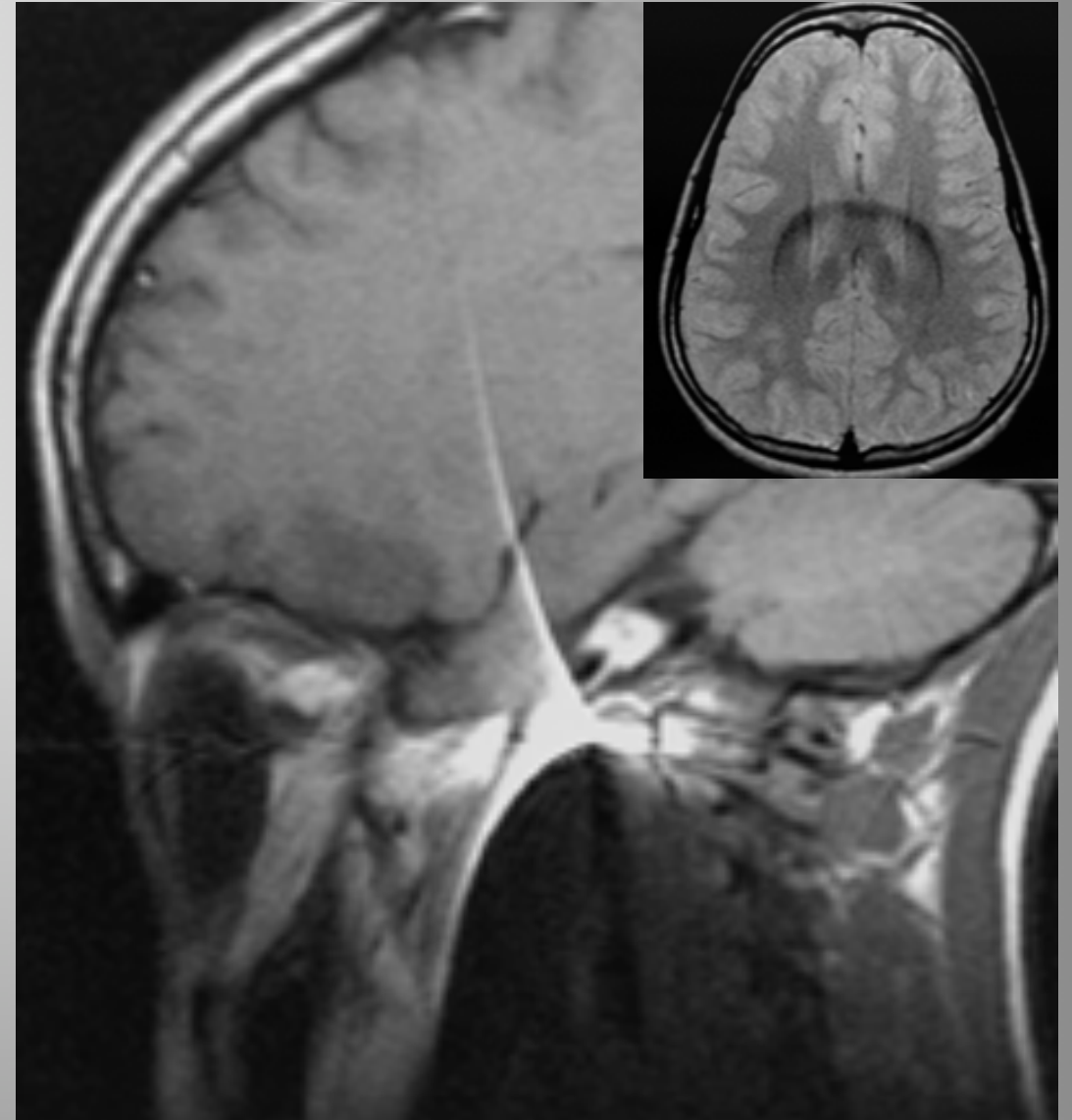
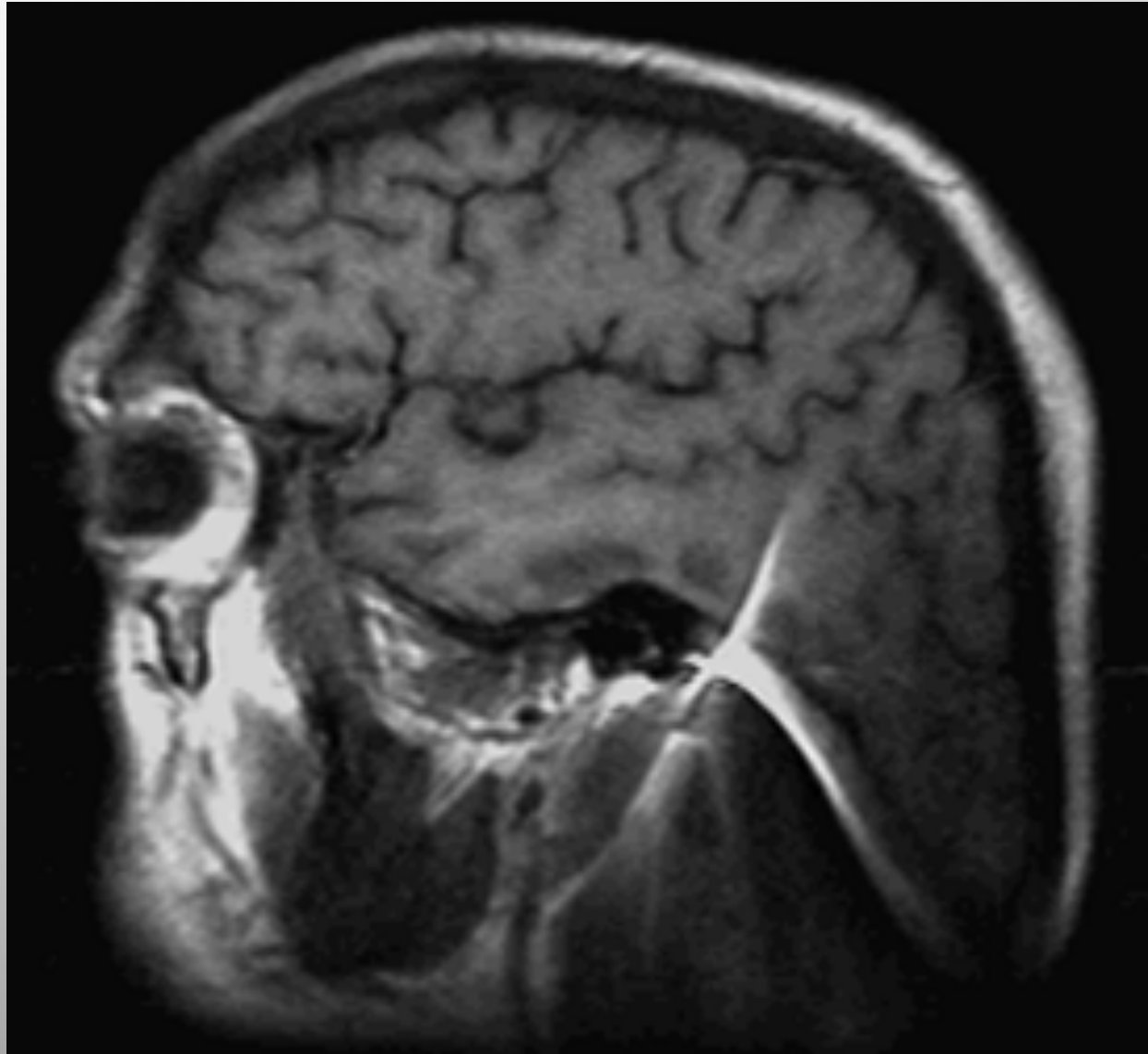


Color range -0.4 to 0.4ppm

GE-EPI
3000/60 1 shot

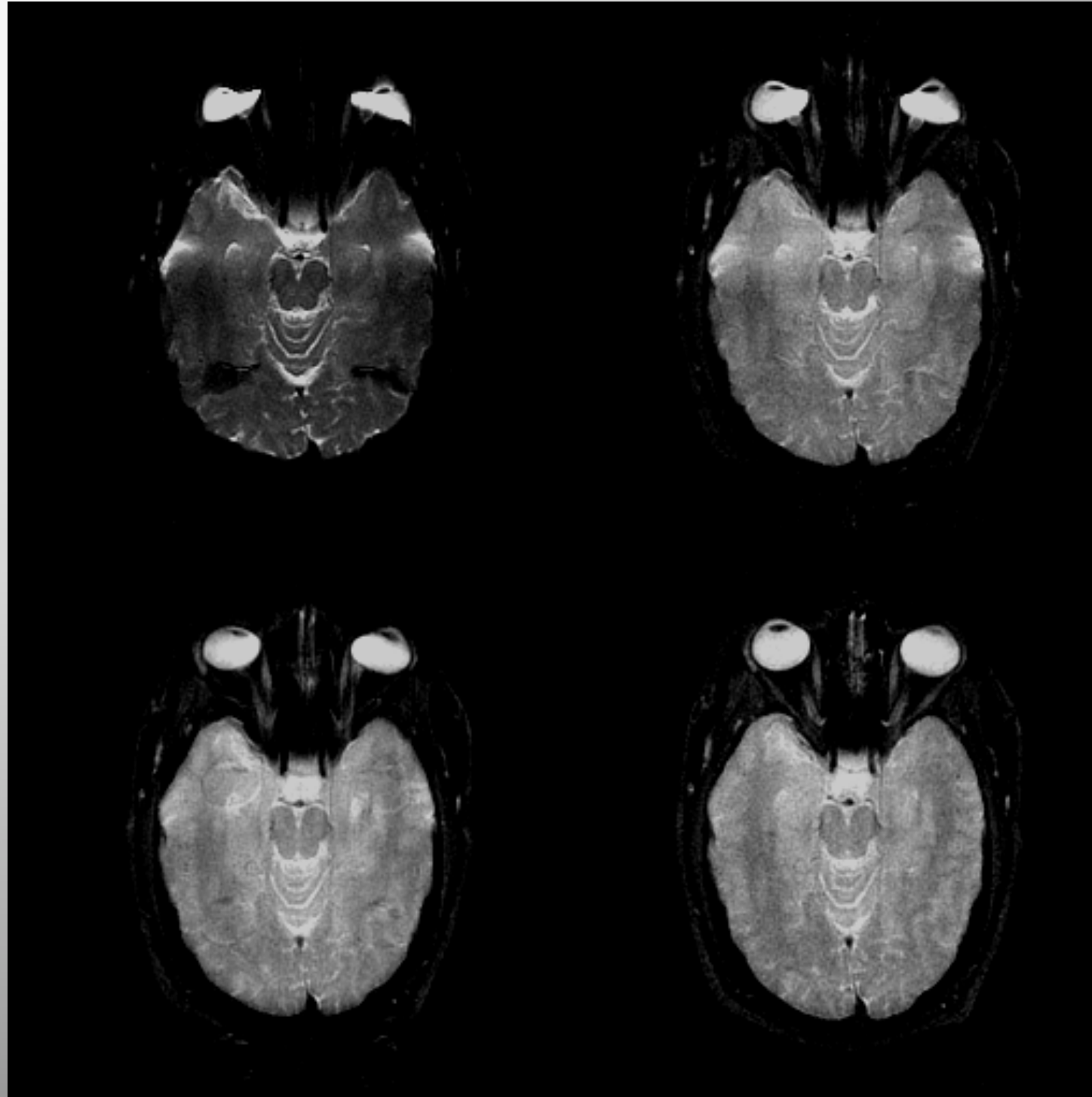


Ferromagnetic Metal Artifacts

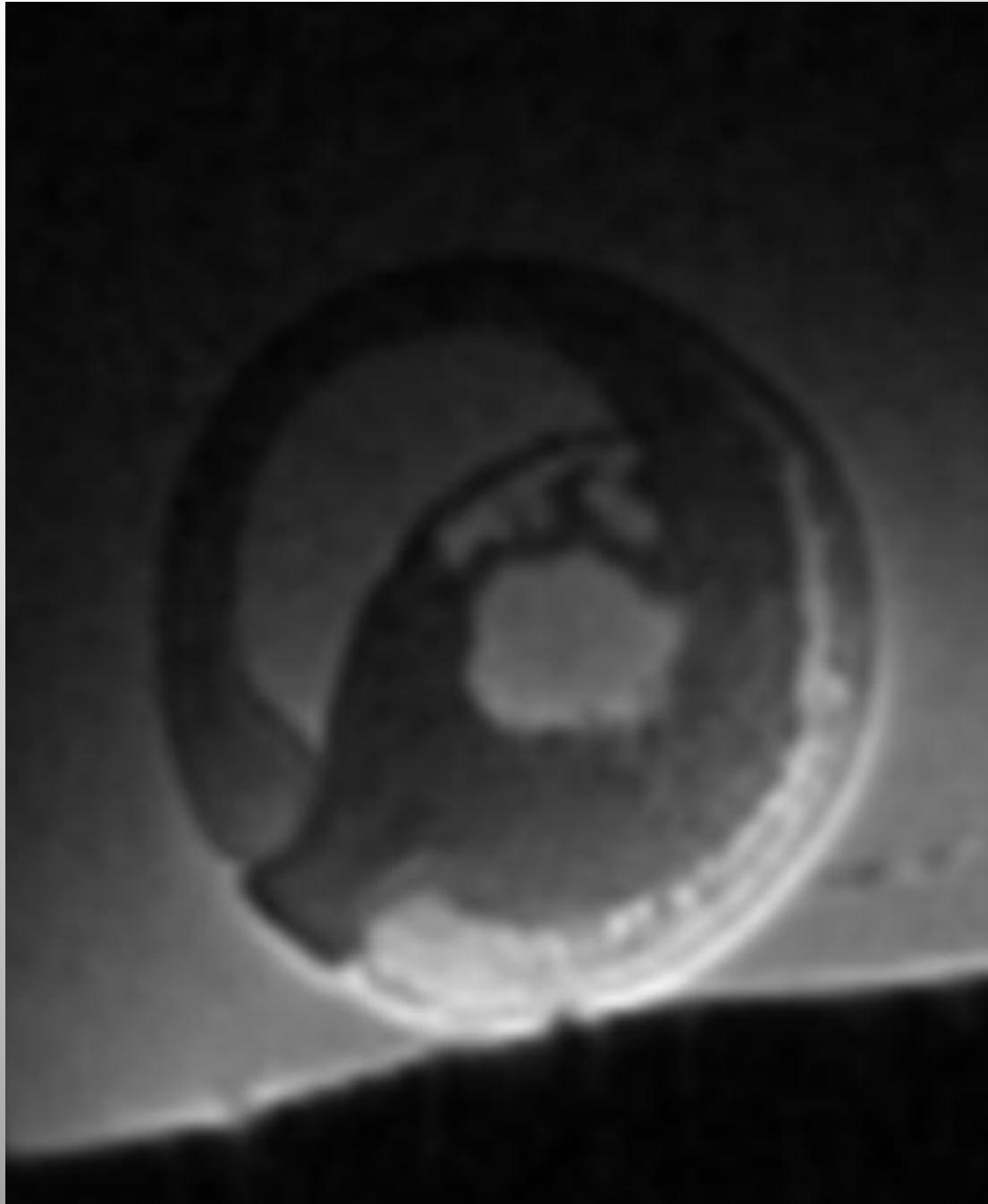


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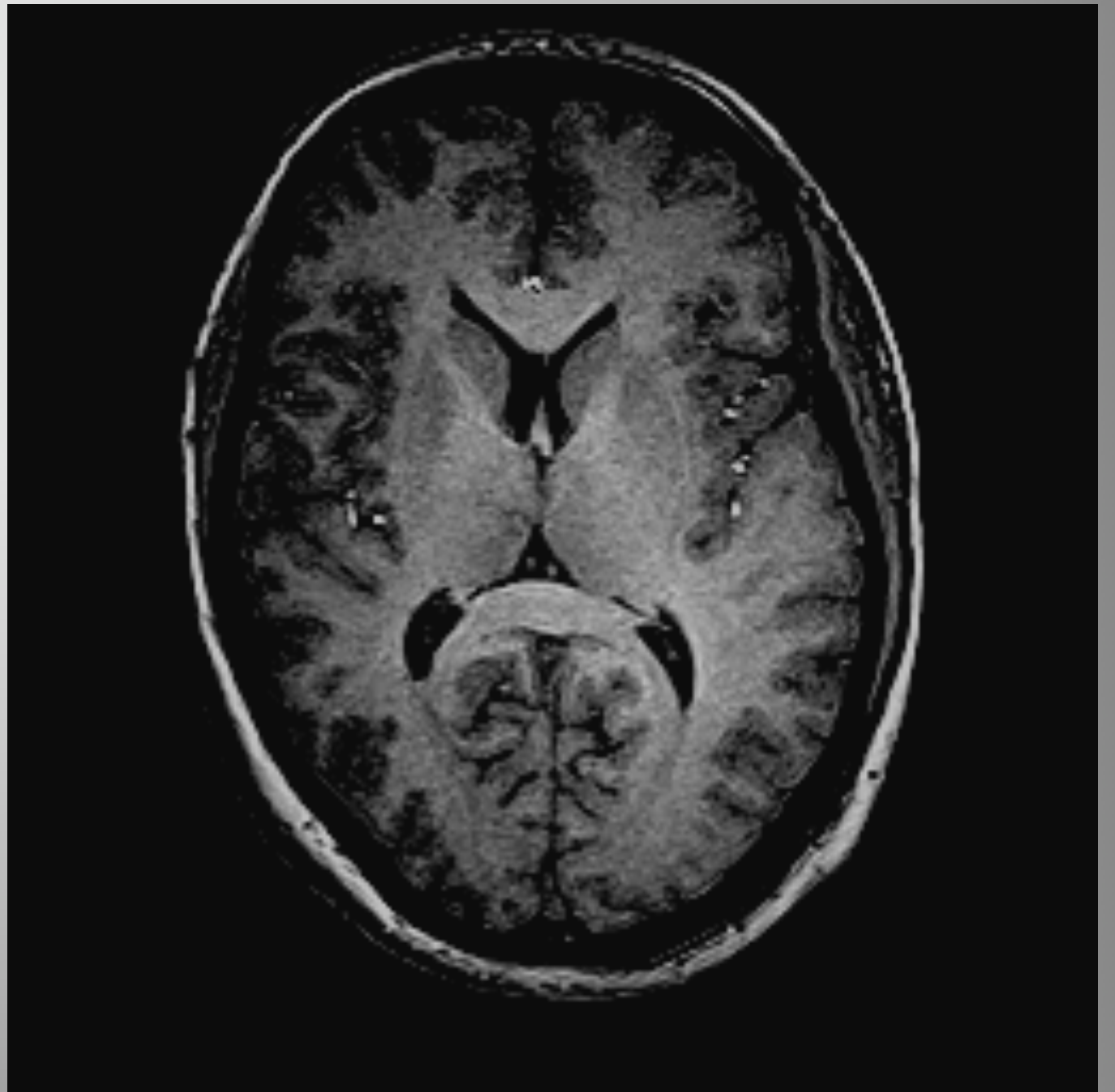
EPI Geometric Distortion



B_1 Inhomogeneity



12T 1mm Surface Coil



3T CP Head Coil

Motion Artifacts

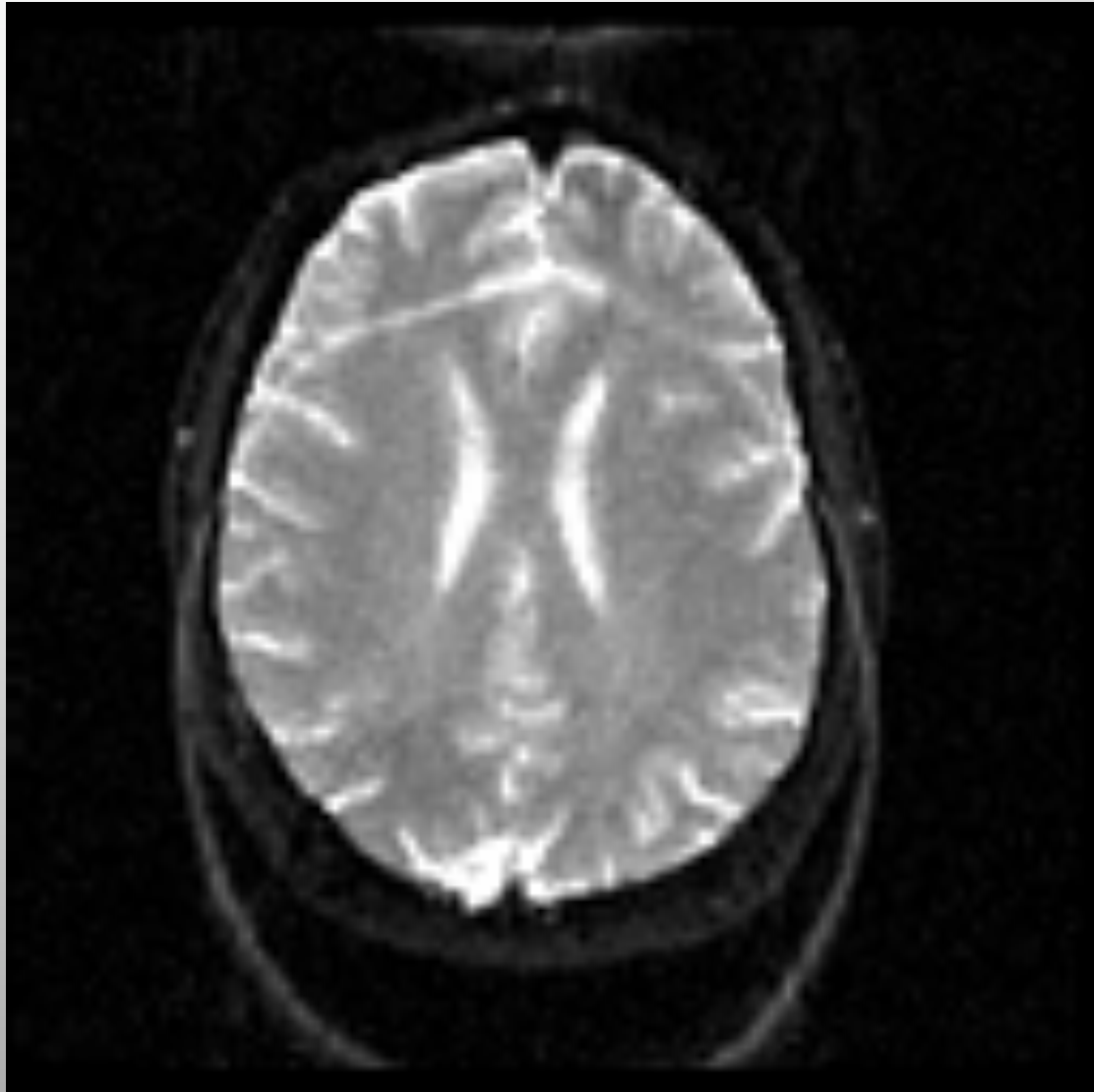


Which is the phase encoding direction?

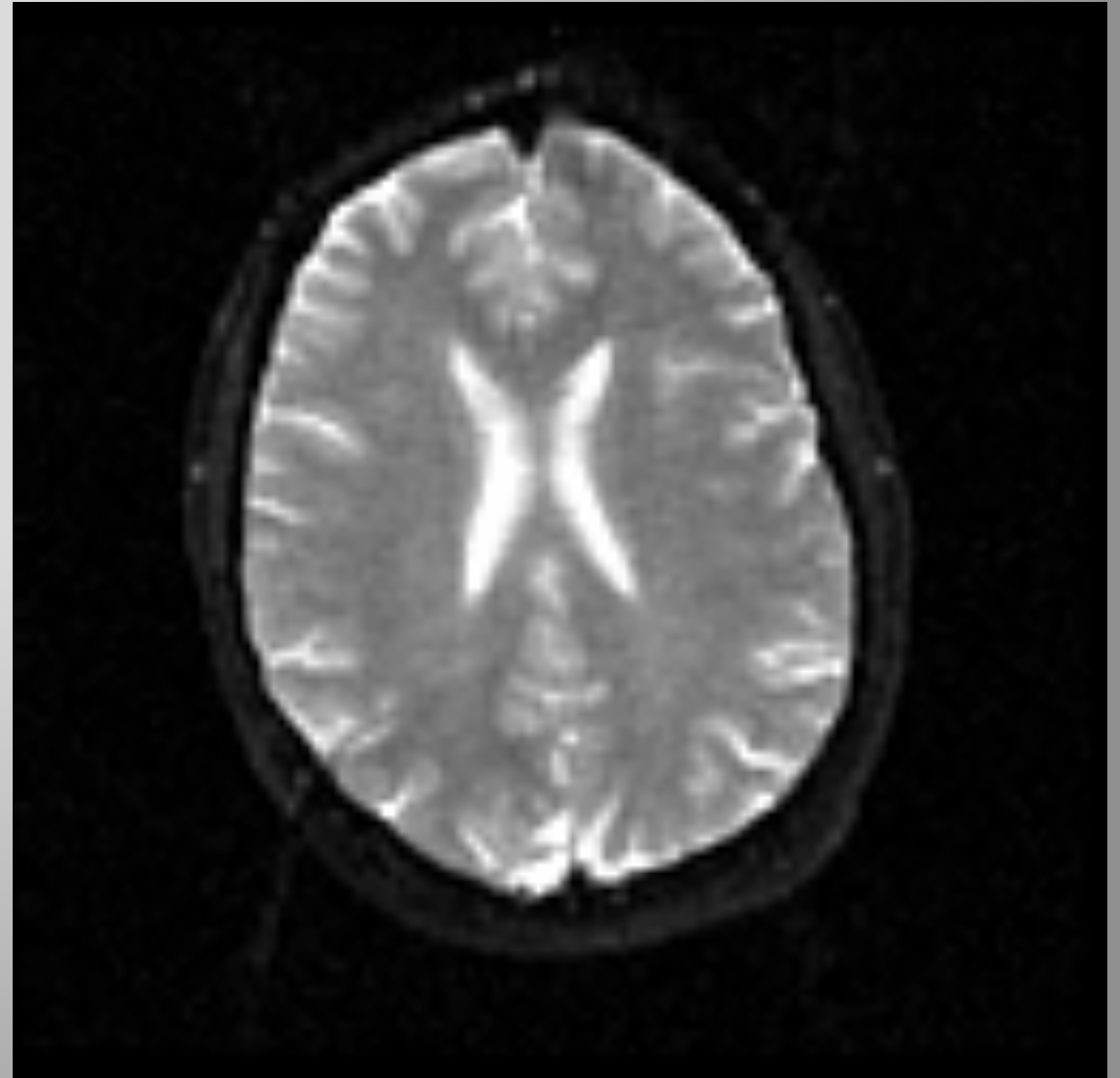
What is moving?

CSF pulsation artifact

Chemical Shift Artifact

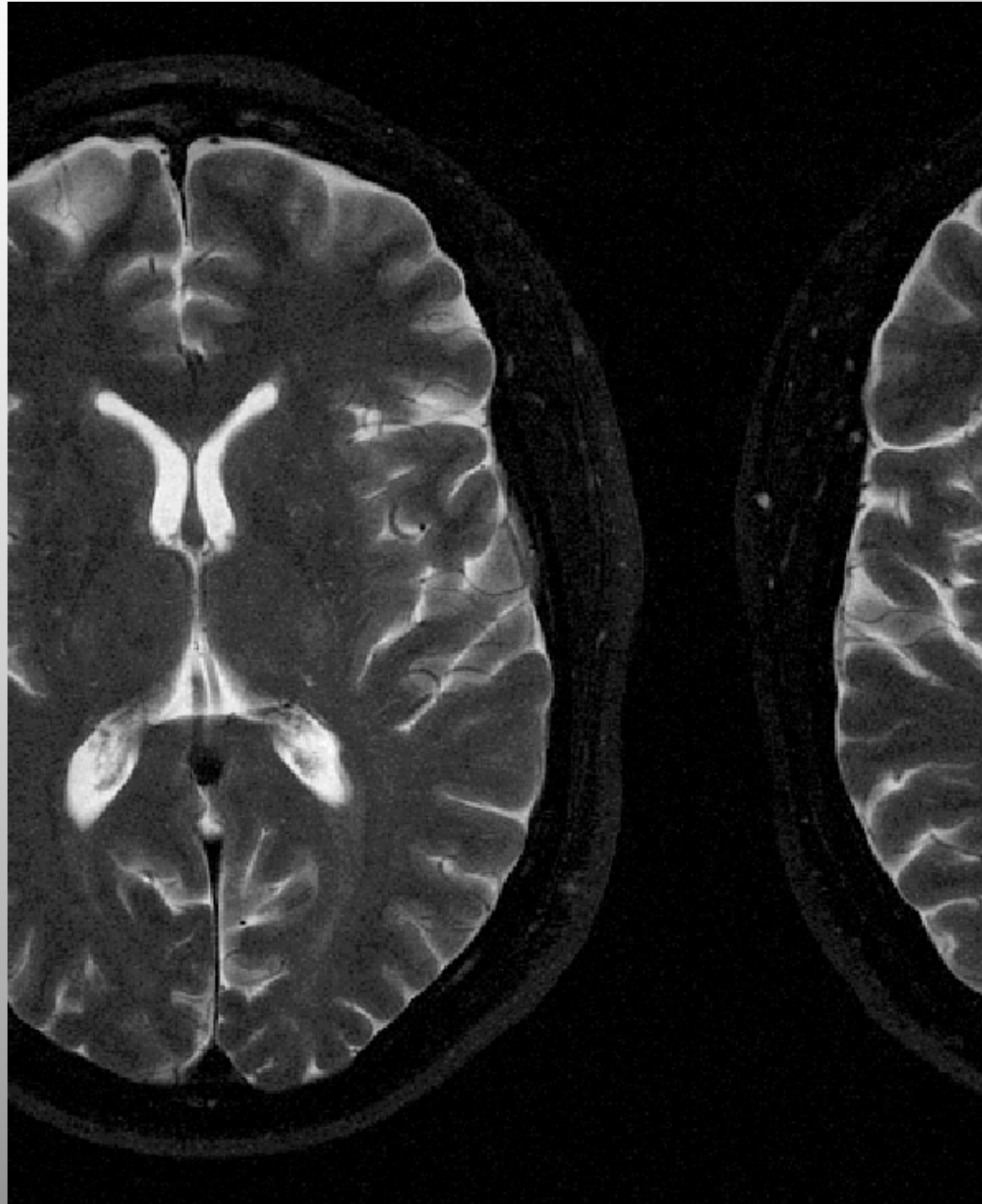


Without Lipid Suppression

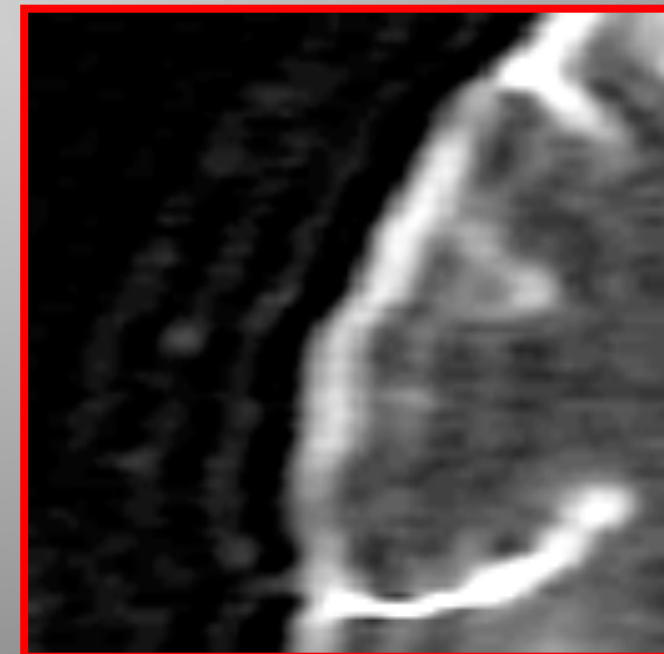
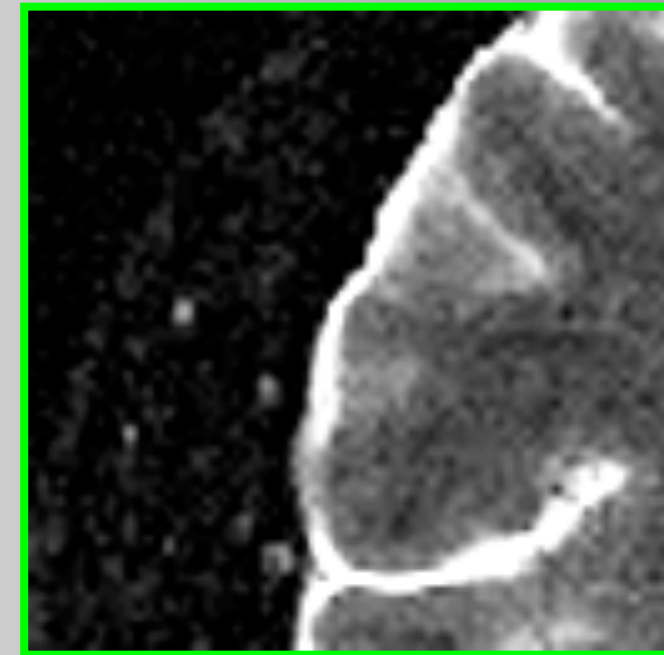
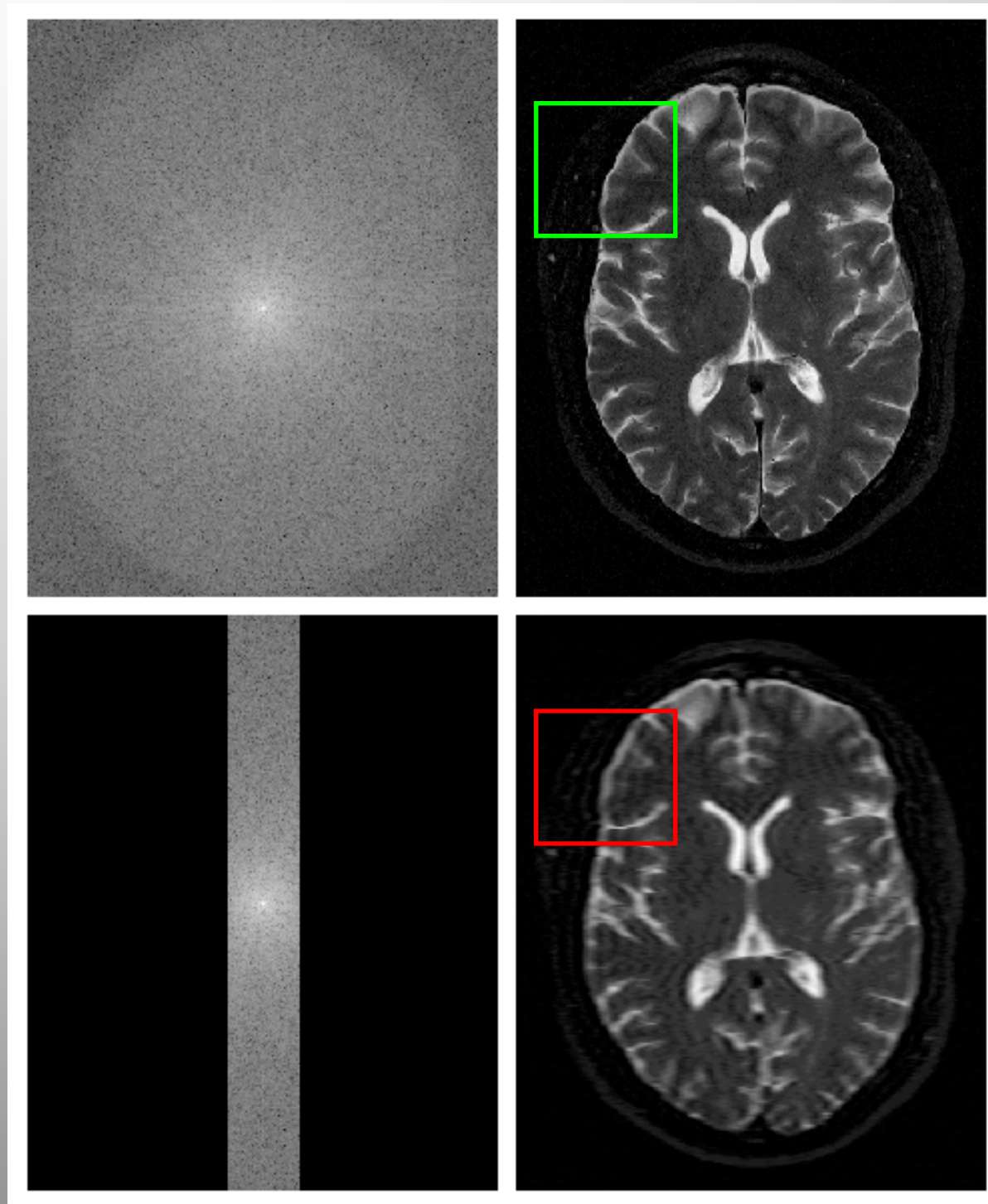


With Lipid Suppression

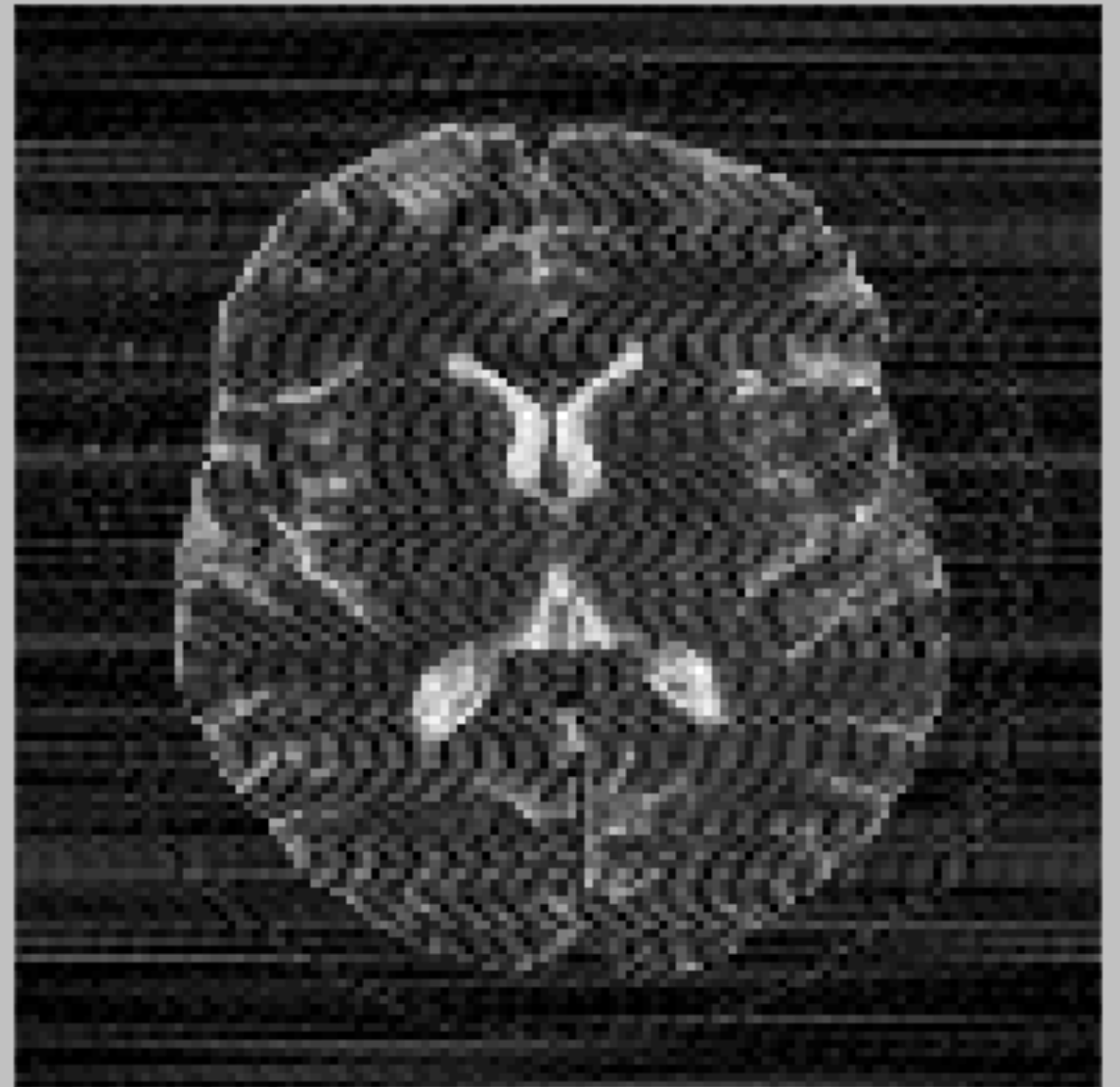
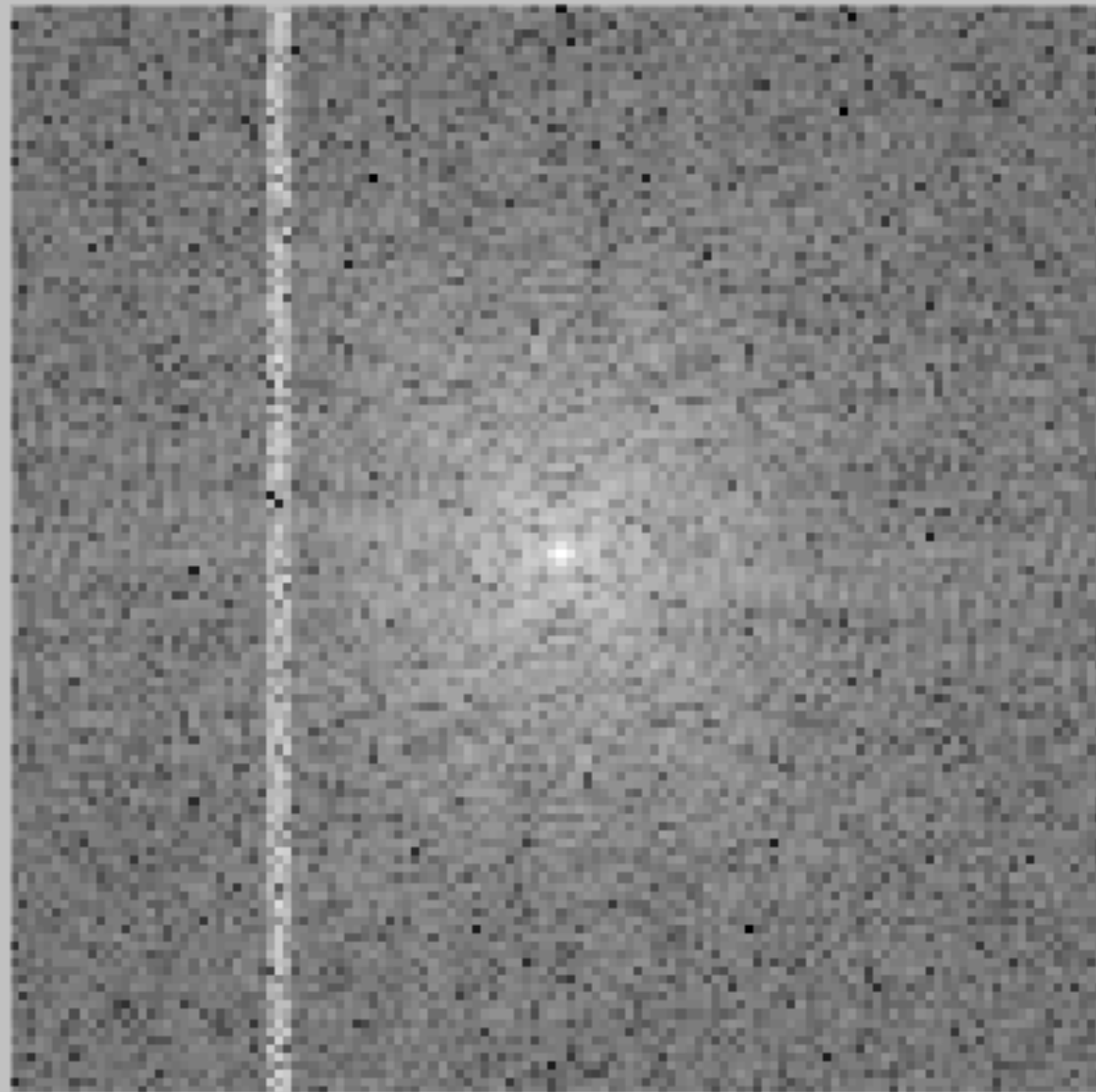
Phase Roll and Fold-over



Gibb's Ringing

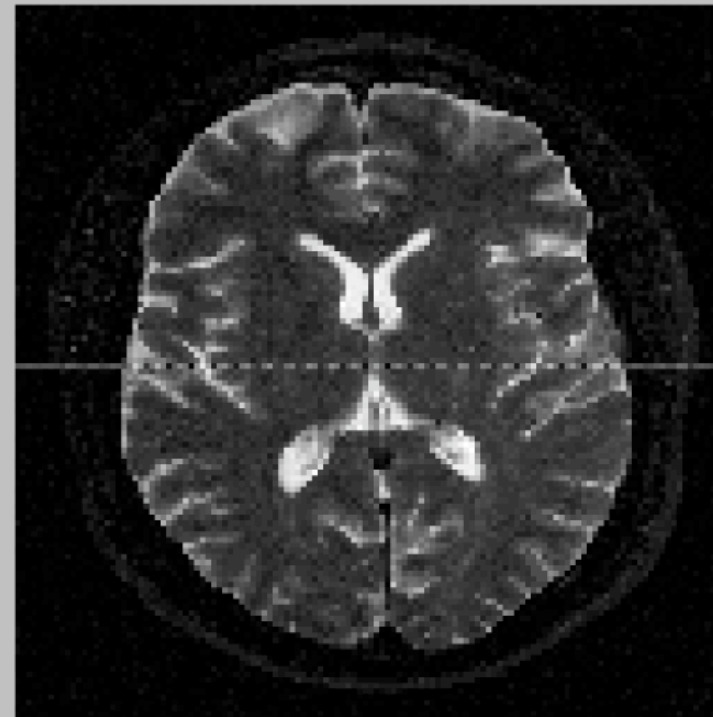
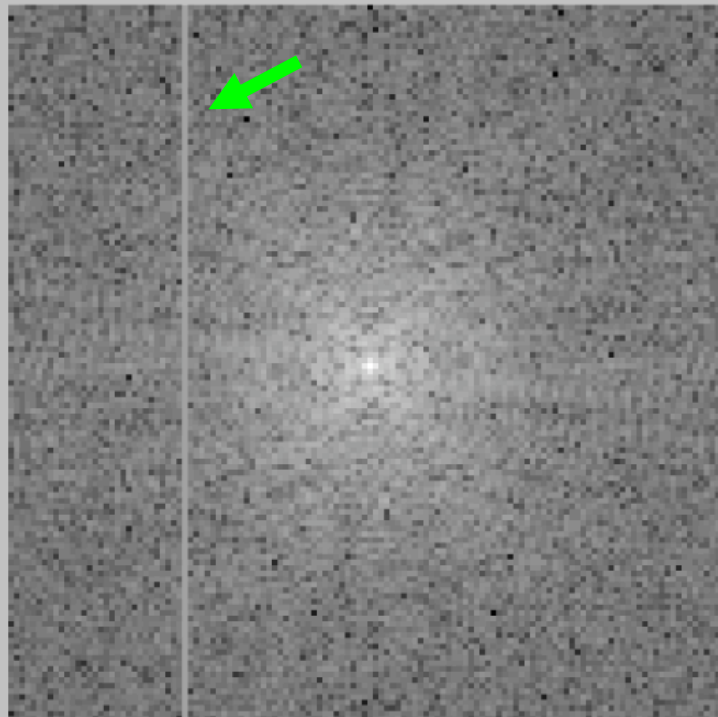
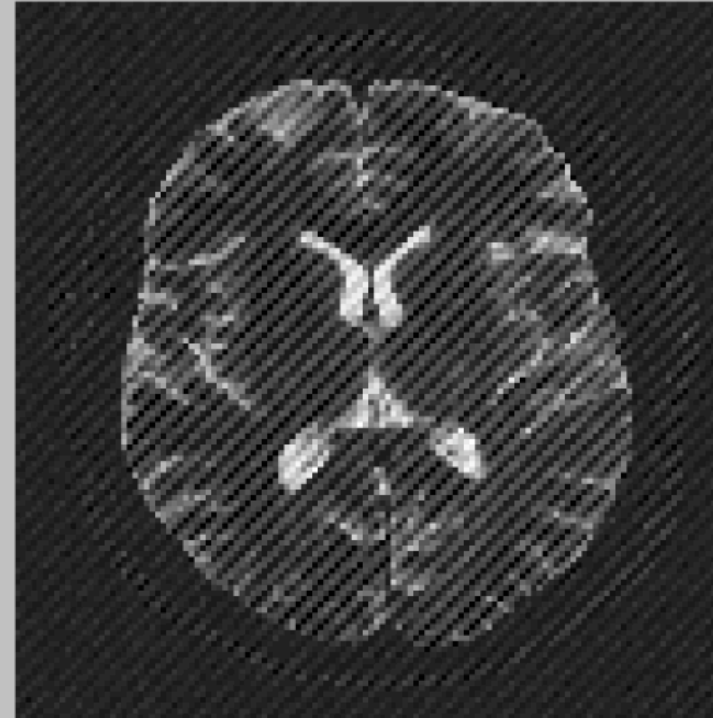
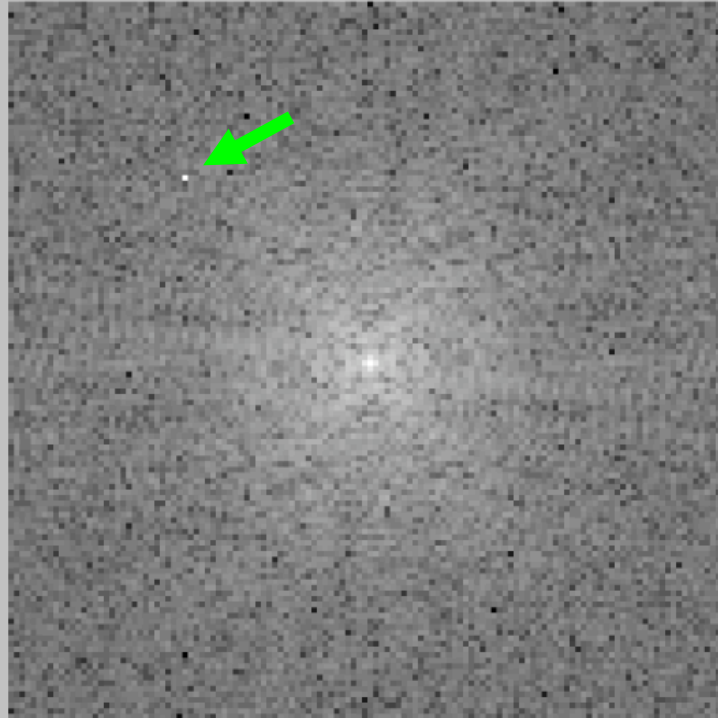


RF Interference

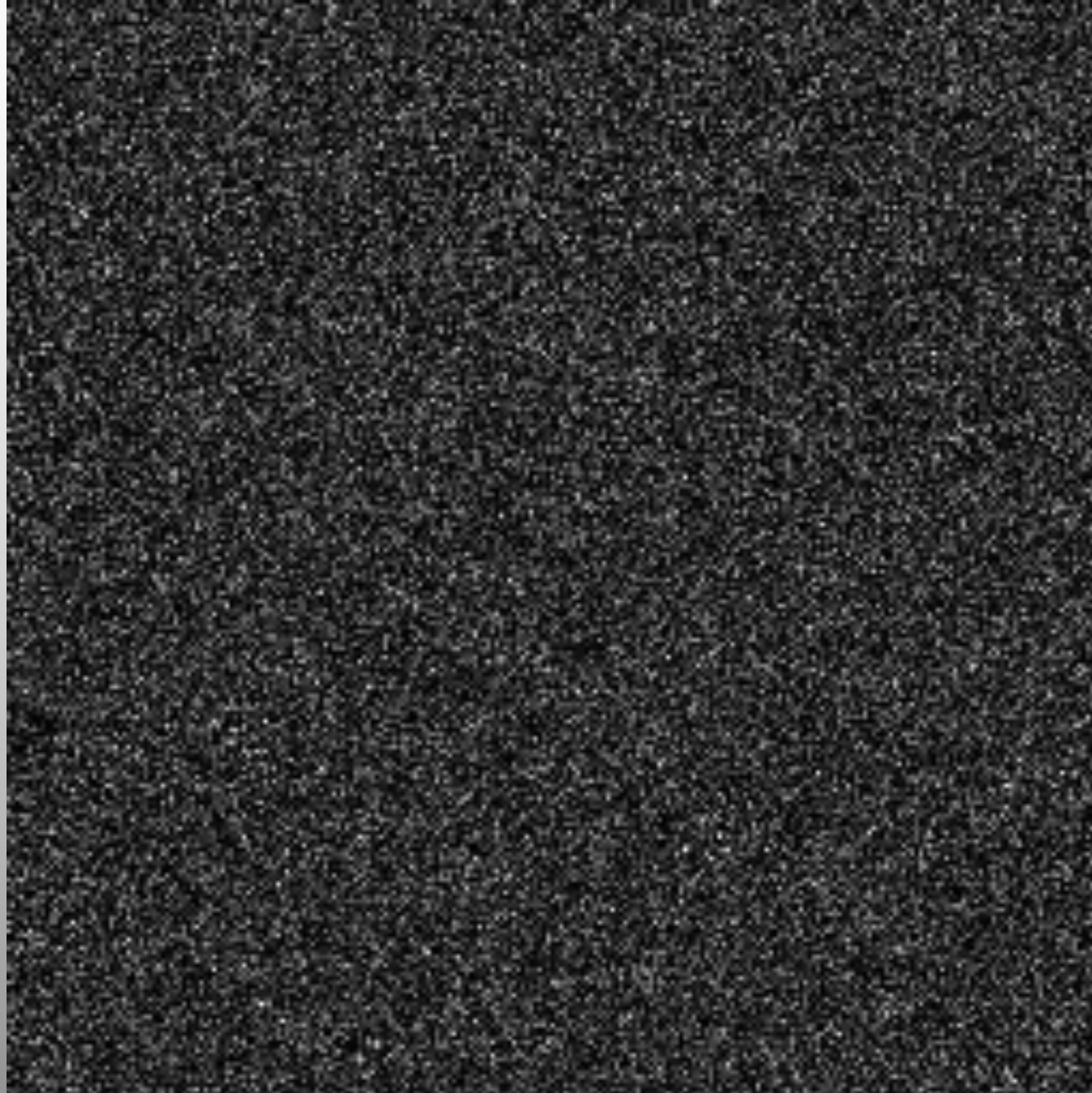


Frequency Encoding Direction

Digital Reconstruction Errors



RF Excitation Failure



Recommended Reading

- *Functional Magnetic Resonance Imaging: An Introduction to Methods*. Eds. Jezzard P and Smith S. Oxford University Press, UK.
- *Magnetic Resonance Imaging (3rd Edition)*. Stark DD and Bradley WG. Mosby, St Louis.
- *Magnetic Resonance Imaging: Theory and Practice (2nd Edition)*. Vlaardingerbroek MT and den Boer JA. Springer-Verlag, Berlin, 1999.
- *Magnetic Resonance Procedures: Health Effects and Safety*. Ed. Shellock FG. CRC Press, New York.

Advanced Course

- Echo Planar Imaging
- Turbo spin echo (RARE)
- Steady-state Imaging
- Magnetization Preparation (MP-RAGE)
- Introduction to fMRI
- MR Angiography
- Diffusion Tensor Imaging
- Chemical Shift Imaging
- Basic Image Processing for MRI
- Non-neuro MRI