Kspace facts

Resolution is determined by the largest spatial freq sampled.

FOV = matrix * resolution

If the object is real, half the information in kspace matrix is redundant. We only need to record half of it.

kspace

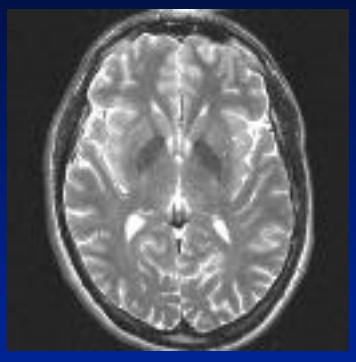
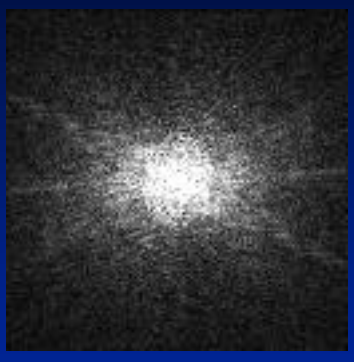
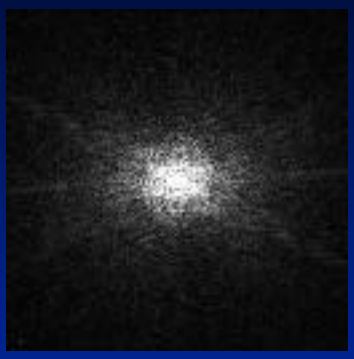


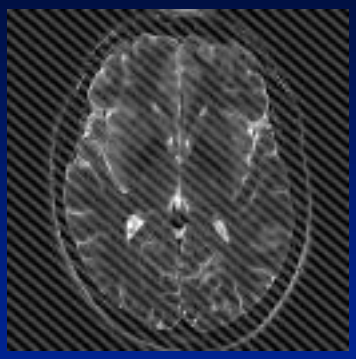
Image space (magnitude)



kspace (magnitude)

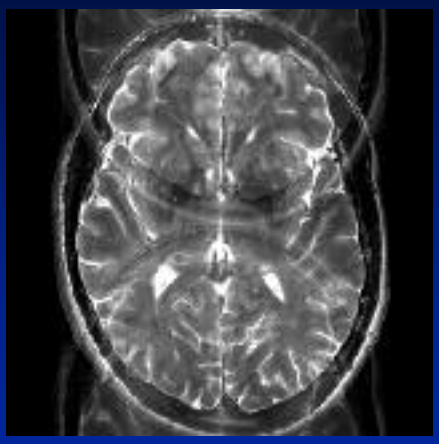
kspace artifacts: spike





One “white pixel” in kspace from a electric spark

Kspace artifacts: Symmetric N/2 ghost



Even numbered lines got $\exp(i\phi)$

Odd numbered lines got $\exp(-i\phi)$

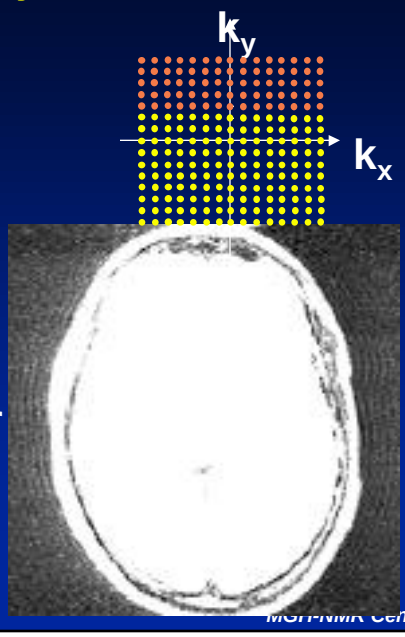
ϕ = 12 degrees

kspace artifacts: subject motion

Yellow = position1
Orange = moved 2 pixels

Movement in real space = linear phase shift across kspace.

=> Orange points have linear phase $\theta = a\, k_y$



Fast Imaging

"Dost thou love life?
Then do not squander time,
for that's the stuff
life is made of."

- Benjamin Franklin

Requirements for brain mapping

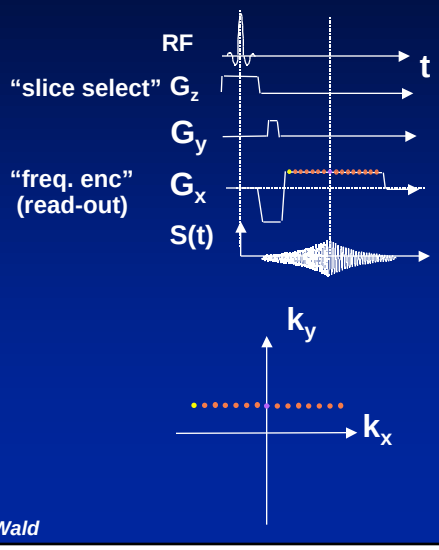
Considerations:

- Signal increase = 0 to 5% (small)
- Motion artifact on conventional image is 0.5% - 3%
- Need to see changes on timescale of hemodynamic changes (seconds)

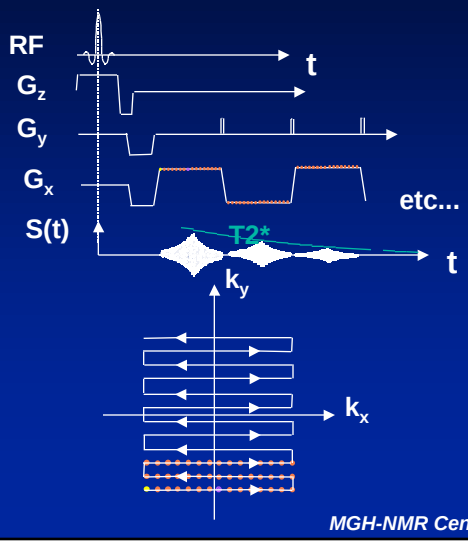
Requirement: Fast, "single shot" imaging, image in 80ms, set of slices every 1-3 seconds.

What's the difference?

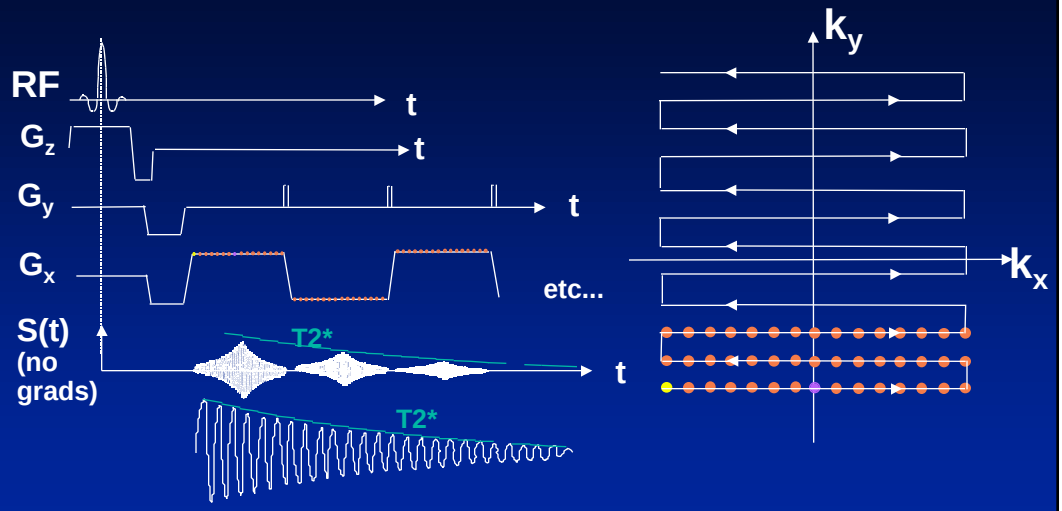
conventional MRI



echoplanar imaging



“Echo-planar” encoding

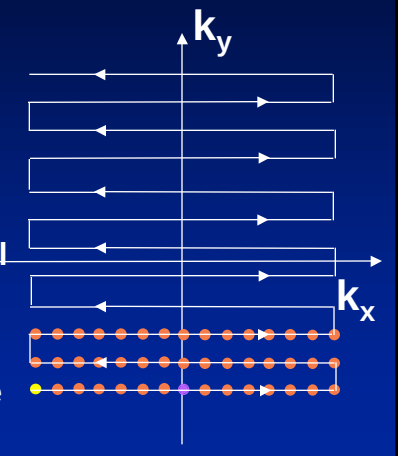


one excitation, many lines of kspace...

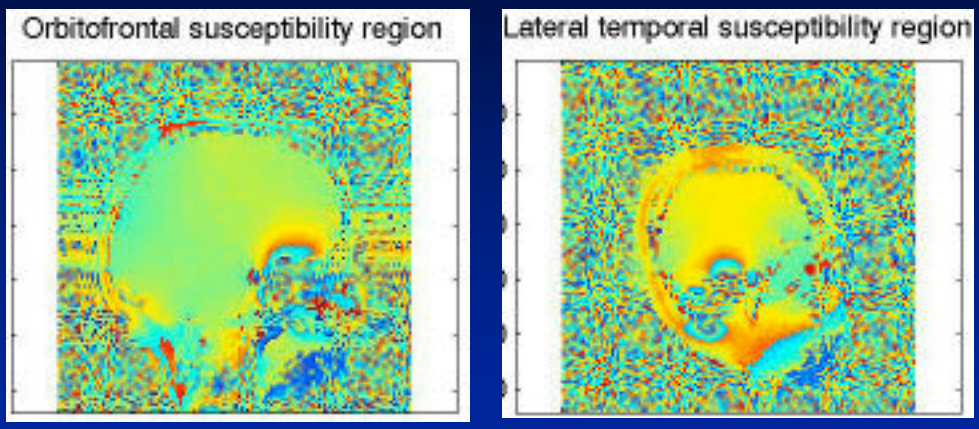
“Echo-planar” encoding

Observations:

- Adjacent points along k_x are taken with short Δt (= 5 us). (high bandwidth)
- Adjacent points along k_y are taken with long Δt (= 500us). (low bandwidth)
- A given line is read quickly, but the total encode time is longer than conventional Imaging.
- Adjacent lines are traversed in opposite directions.



Enemy #1 of EPI: local susceptibility gradients



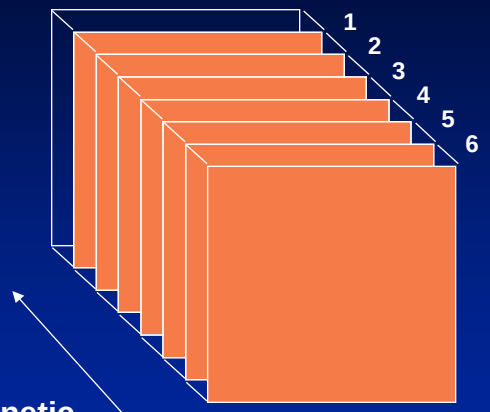
B_0 field maps in the head

EPI: Local susceptibility gradients

Local susceptibility gradients have 2 effects:

- **Local dephasing of the signal (signal loss) mainly from thru plane gradients**
- **Local geometric distortions, mainly from local in-plane gradients.**

Susceptibility: thru plane dephasing



Signal from whole slice comes from adding together the MR vectors. When in phase, add constructively, SNR increases like slice thickness.

Magnetic Field Uniform

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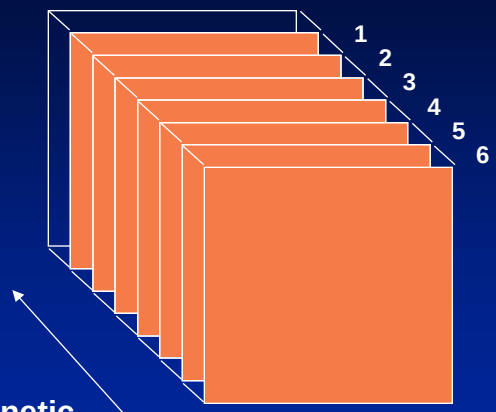
Susceptibility Artifact and Slice Thickness



Signal from whole slice comes from adding together the MR vectors, which get out of phase when the magnetic field is not uniform

Magnetic Field NONUniform

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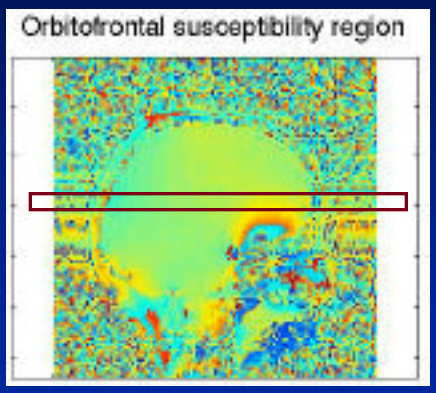
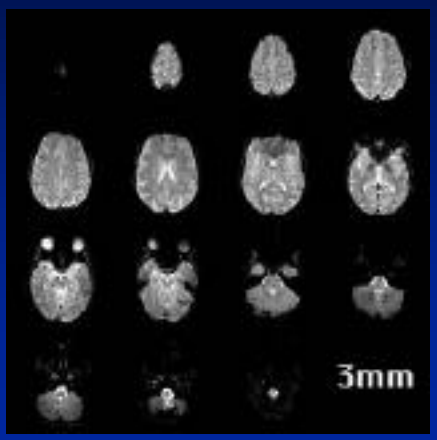
Local susceptibility gradients: thru-plane dephasing

Bad for thick slice above frontal sinus…





Local gradients: geometric distortion

Local gradient alters the helix of phase we have so carefully wound.

Phase error accumulates over entire kspace.
(conventional imaging phase is reset every line)

>> faster encoding is better.

Readout points are taken close together (~5us)

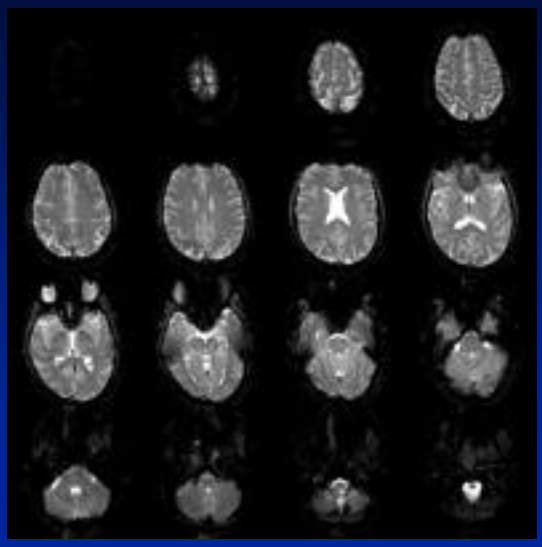
Phase encode points are taken farther apart (~500us)

>> distortion occurs in P.E. direction.

Local gradients: geometric distortion

Two sets of EPI:

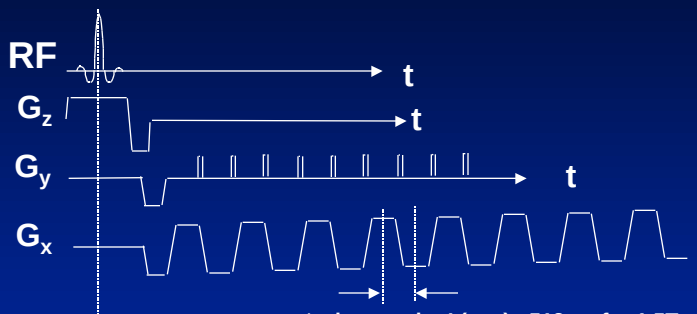
1) encode in 32ms
2) encode in 23ms



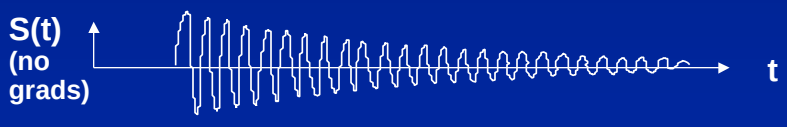
Characterization of grad. performance

- length of readout train for given resolution

(requires fast slew and high grad amplitude)



'echo spacing' (esp)= 512 us for 1.5T, readout length = 32 ms
= 366us for 3T, readout length = 23 ms

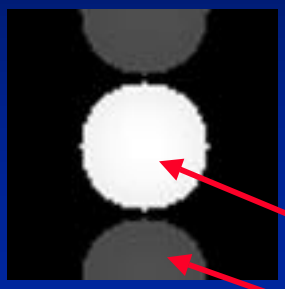


EPI problems: N/2 ghost

Asymmetry in alternate lines gives N/2 image ghost.

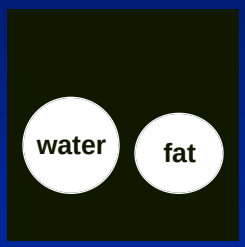
Asymmetry from:

Eddy currents
receiver filter
receiver timing
head coil tuning.

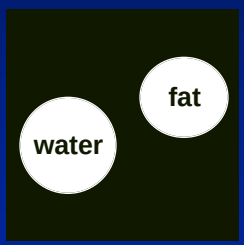


EPI problems: frequency offset

If one object has a different NMR frequency (e.g. fat and water) it gets shifted in PE direction. (why?)

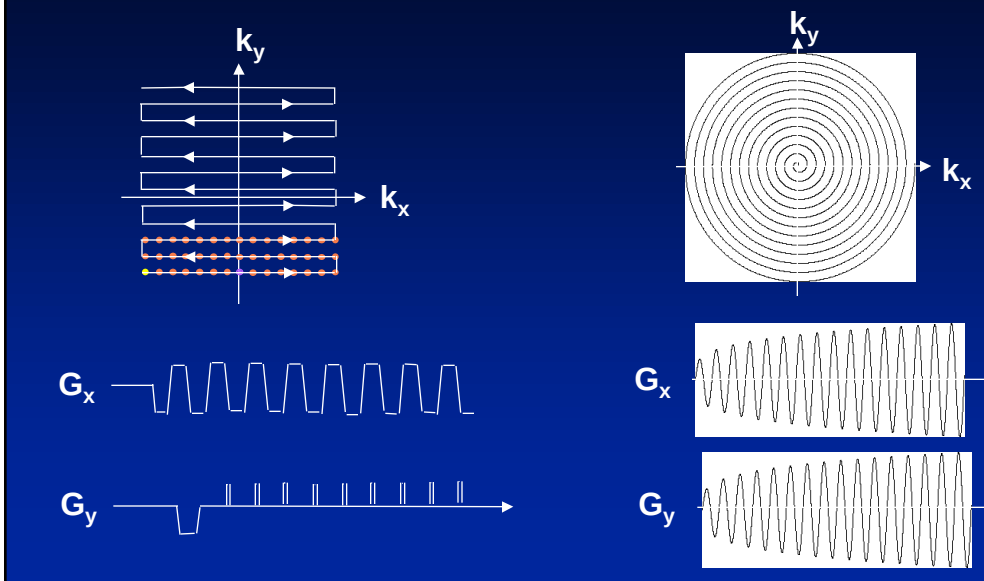


True location



Echoplanar image

EPI and Spirals



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	EPI	Spirals
Eddy currents:	ghosts	blurring
Susceptibility:	distortion, dephasing	blurring dephasing
k = 0 is sampled:	1/2 through	1st
Corners of kspace:	yes	no
Gradient demands:	very high	pretty high

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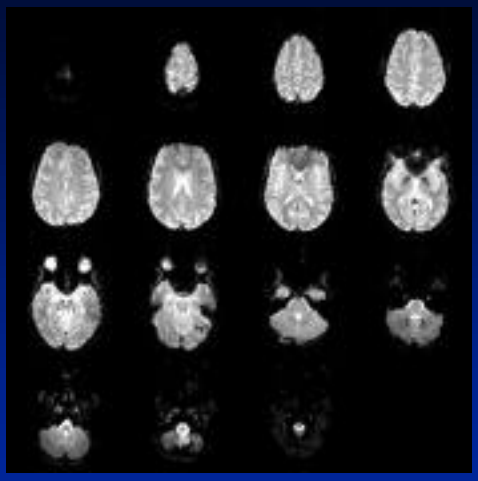
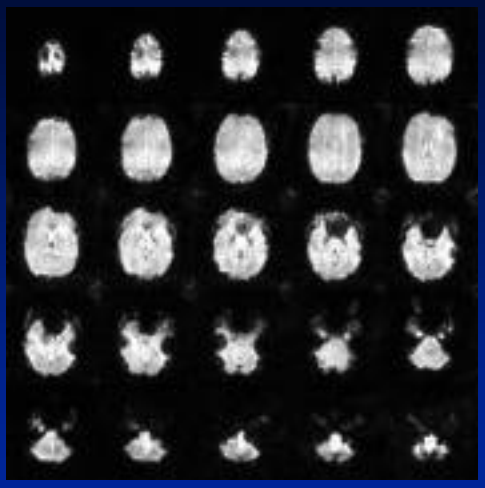
EPI and Spirals



EPI at 3T



Spirals at 3T
(from G. Glover)