**Kspace facts**

Resolution is determined by the largest spatial freq sampled.

\[ \text{FOV} = \text{matrix} \times \text{resolution} \]

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 $\exp(-i\phi)$

$\phi = 12$ degrees
kspace artifacts: subject motion

Yellow = position 1
Orange = moved 2 pixels

Movement in real space = linear phase shift across kspace.

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

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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
“slice select”
“freq. enc” (read-out)
RF
G_z
G_y
G_x
S(t)

T2*

etc...

ectoplanar imaging
RF
G_z
G_y
G_x
S(t)

Wald
MGH-NMR Center
“Echo-planar” encoding

Observations:

• Adjacent points along kx are taken with short $\Delta t$ (= 5 us). (high bandwidth)

• Adjacent points along ky are taken with long $\Delta t$ (= 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.

Wald  MGH-NMR Center
Enemy #1 of EPI: local susceptibility gradients

B₀ 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.

**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.
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?)
EPI and Spirals

Eddy currents: ghosts
Susceptibility: distortion, dephasing
k = 0 is sampled: 1/2 through
Corners of kspace: yes
Gradient demands: very high

Spirals
blurring
dehphasing
1st
no
pretty high
EPI and Spirals

EPI at 3T

Spirals at 3T
(from G. Glover)