Chapter 20
Magnetic Field Inhomogeneity Effects and $T2^*$ Dephasing

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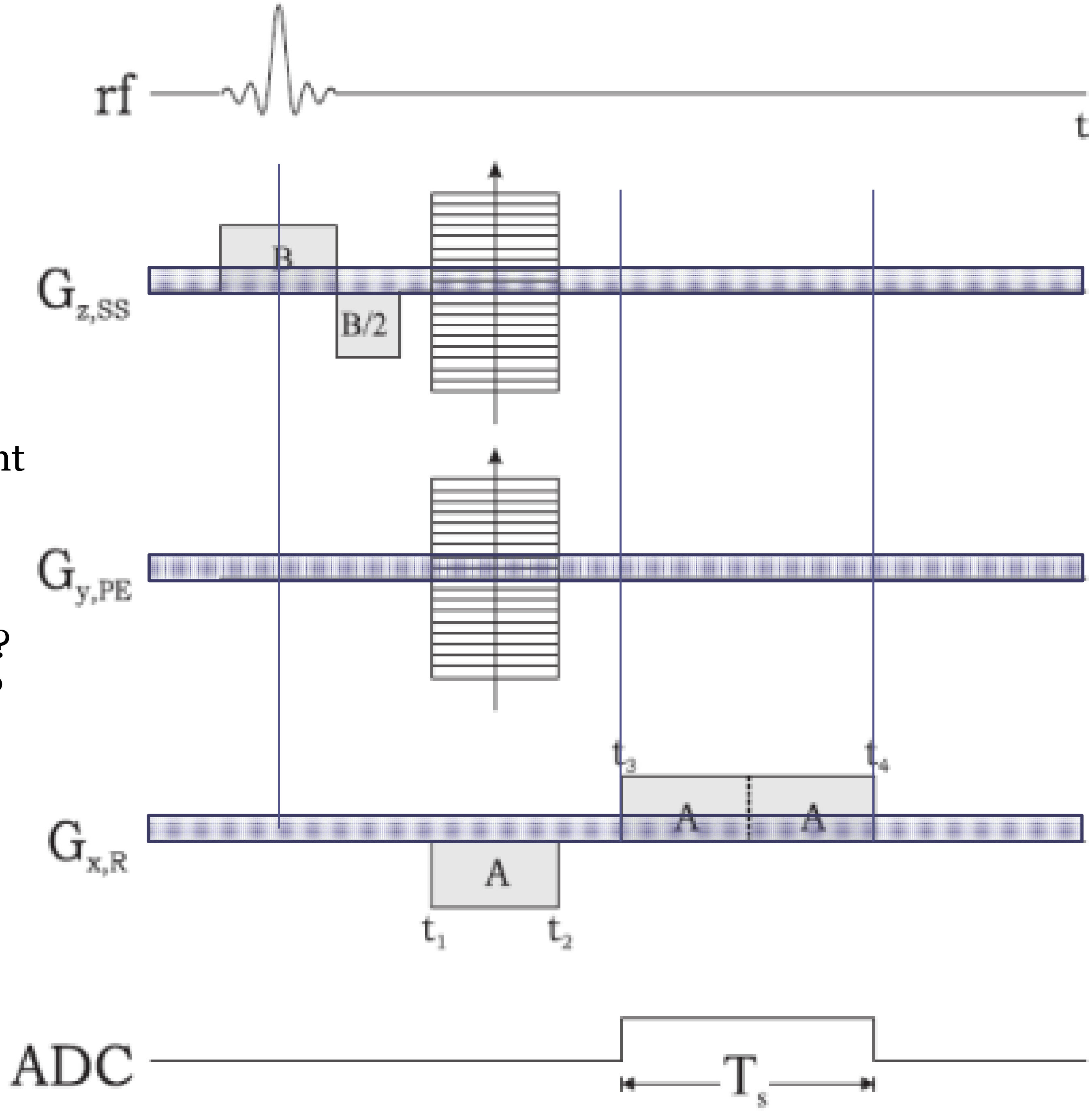
- **Previous classes:**
  - Frequency encoding, phase encoding, slice selection (Chap. 9, 10)
  - Concept of $T2^*$ and $T2'$(chap.4)
  - Fourier transform theorem (Chap. 11)
- **Today's content**
  - Global and local field inhomogeneity
  - Image distortion and echo shifting
  - Artifact correction/ reduction

BG gradients

- Location dependent
- Macroscopic
- Microscopic

- BG grad along RO?
- BG grad along PE?
- BG grad along SS?

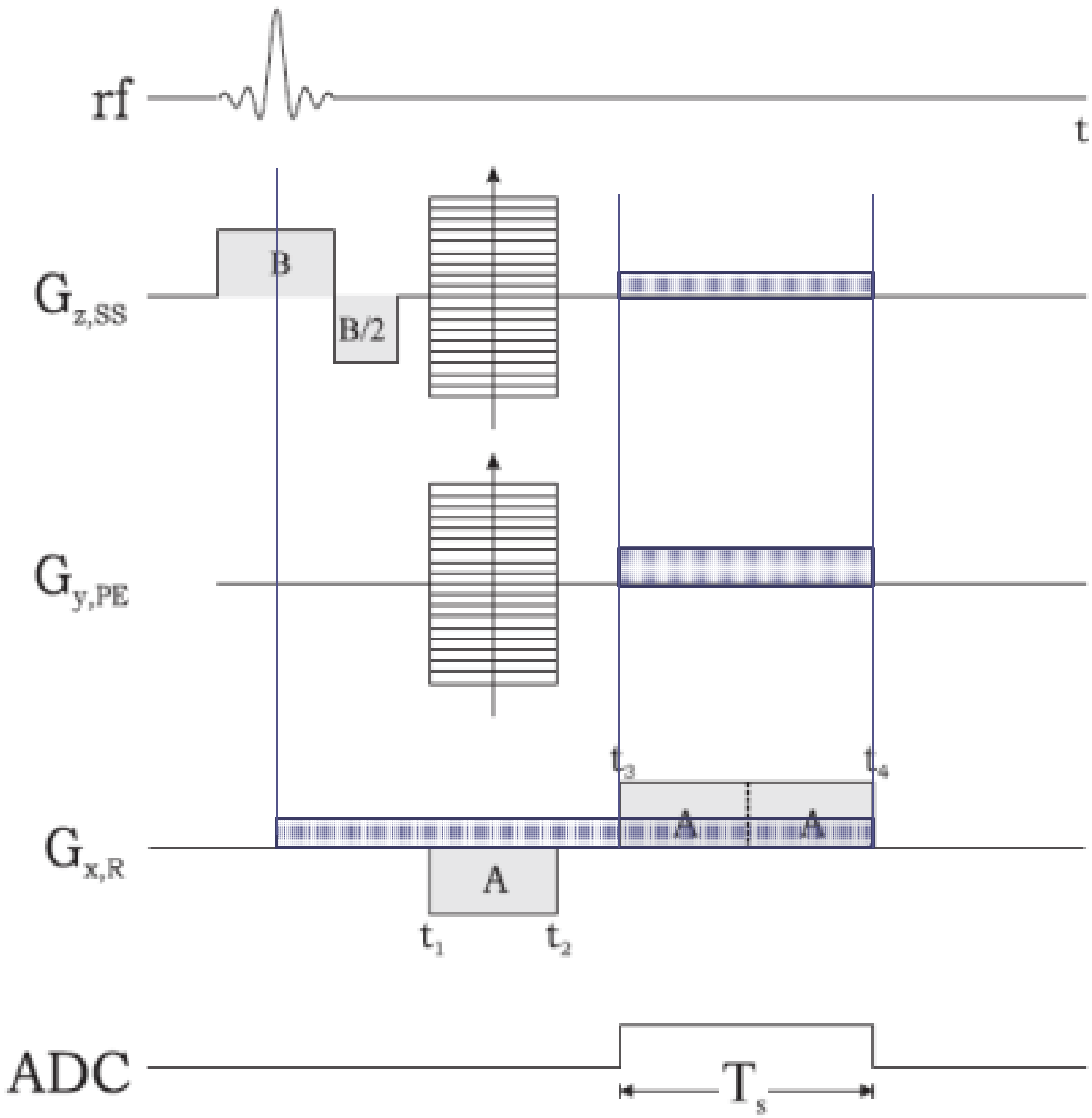


Dynamic BG gradients

- Global
  - Breathing
  - Eddy current

- Local
  - BOLD fMRI
  - Dynamic susceptibility contrast PWI (DSC-PWI)

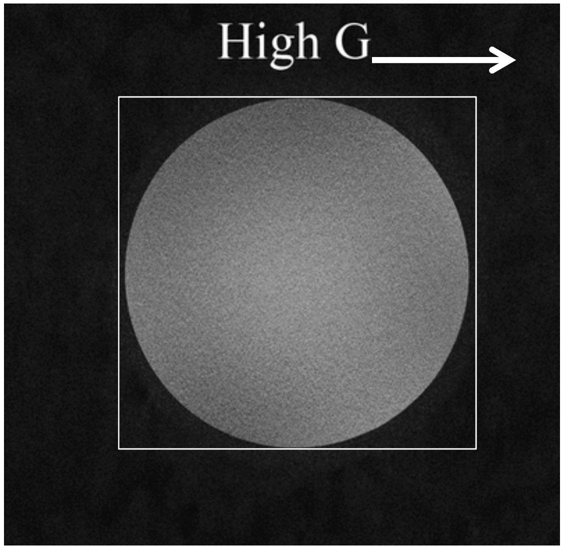
BG grad and Readout



Global distortion along RO

$$x' = x\left(1 + \frac{G_x'}{G_x}\right) = x/\lambda$$

- G_x' is BG gradient along RO during ADC readout
- Effect: scaling (elongate or compress)
  - 'The presence of the background gradient causes spins to be shifted parallel to the read direction'
- Solution
  - Use stronger Gx
  - Collect with Gx and -Gx
  - Improve field shimming



Local distortion along RO

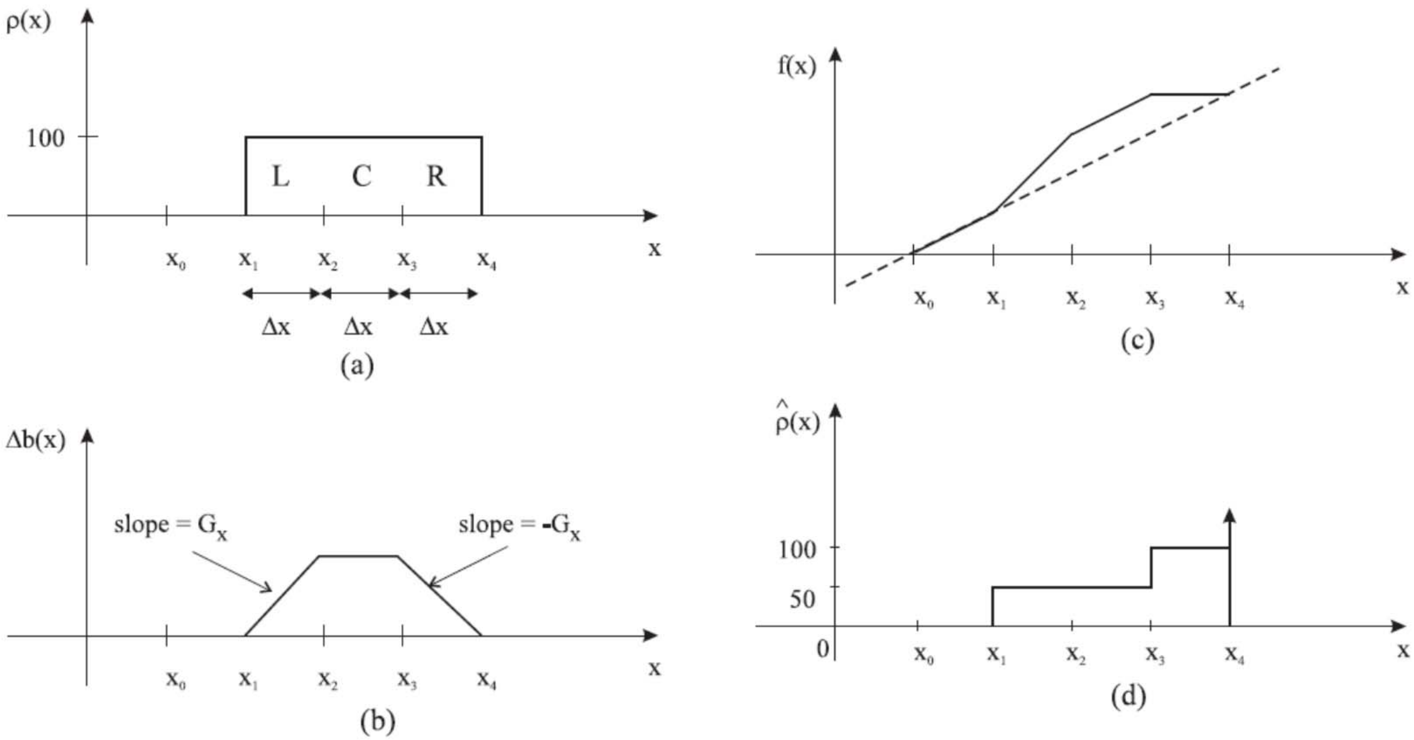
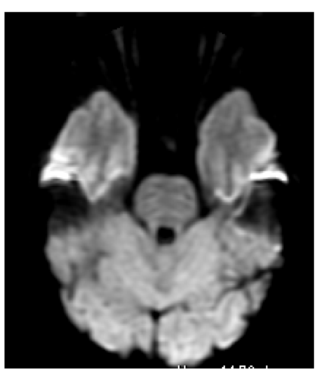
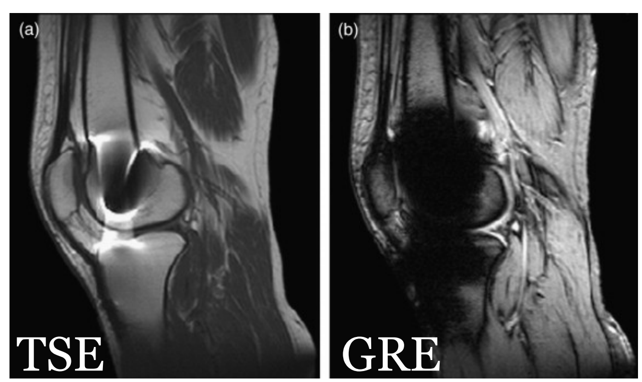


Fig 20.2

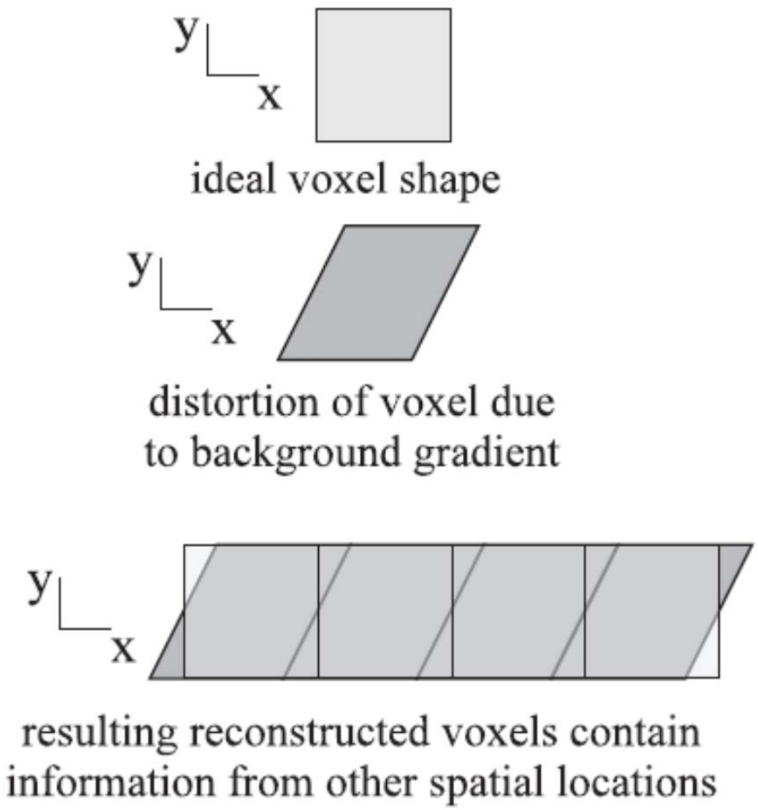


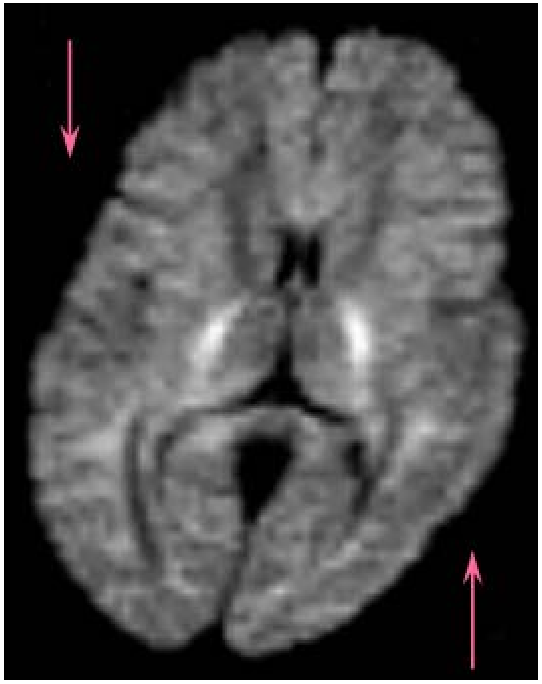


BG grad perpendicular to RO

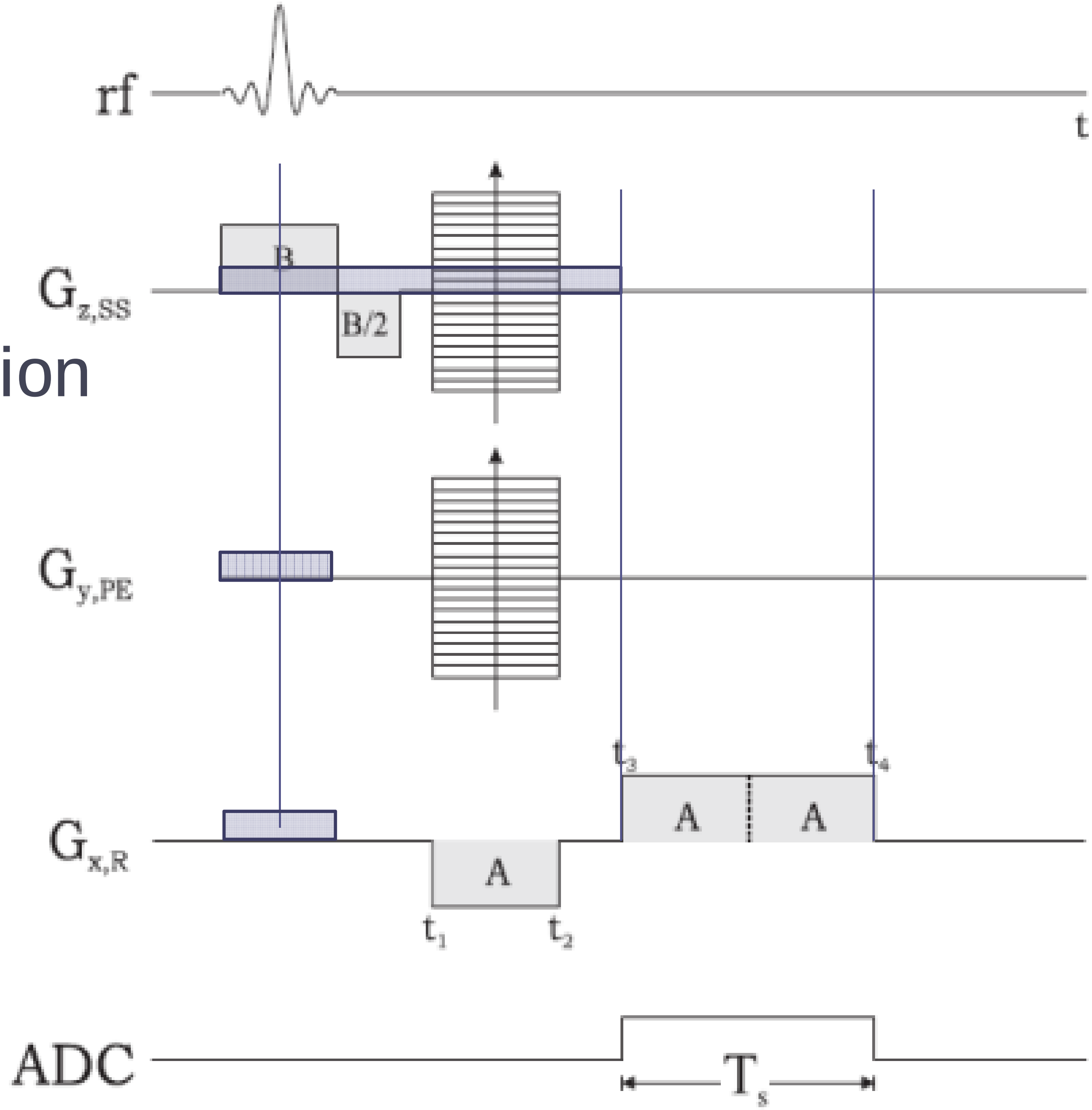
- BG gradient along PE during ADC readout

$$x' = x + \frac{G_y'}{G_x} y$$





BG grad and slice selection



Distortion perpendicular to RO

- BG gradient along SS (2D)
  - Slice distortion effect (shift, rotate, scale)

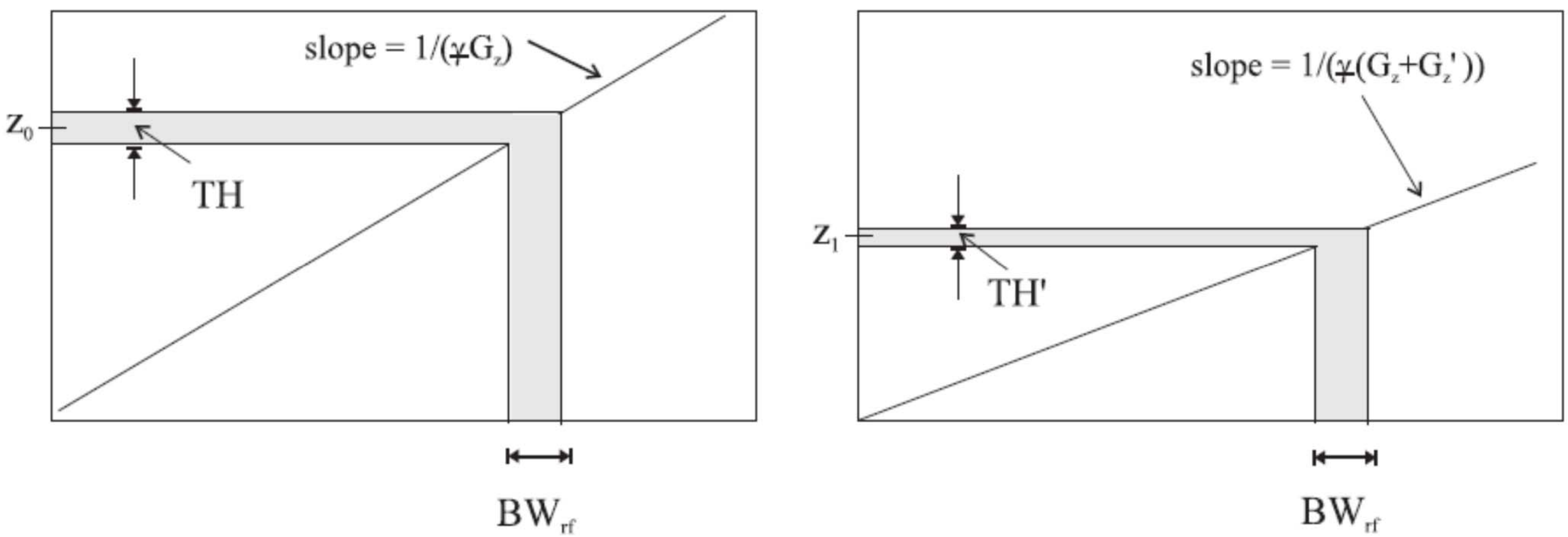


Fig 20.5

Spin Echo

Distortion:

$$k' = \left(1 + \frac{G_x'}{G_x}\right)k = \frac{k}{\lambda}$$

$$\rho'(x) = \lambda\rho(\lambda x)$$

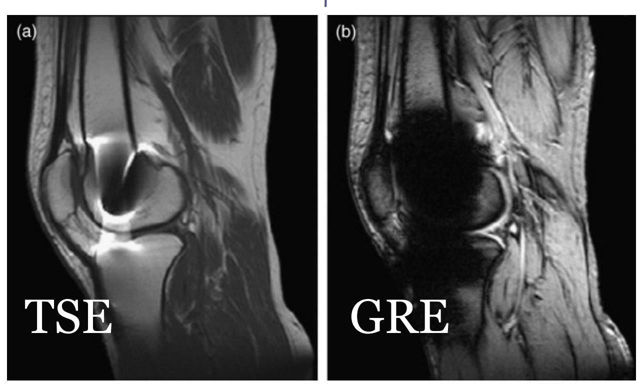
$$\int dx'\rho'(x') = \int dx\rho(x)$$

Gradient Echo

Signal dispersion:

$$\Delta\phi(\Delta x) = -\gamma G_x' \Delta x TE$$

$$\hat{\rho}(x) = \rho_0 sinc(\Delta\phi/2)$$

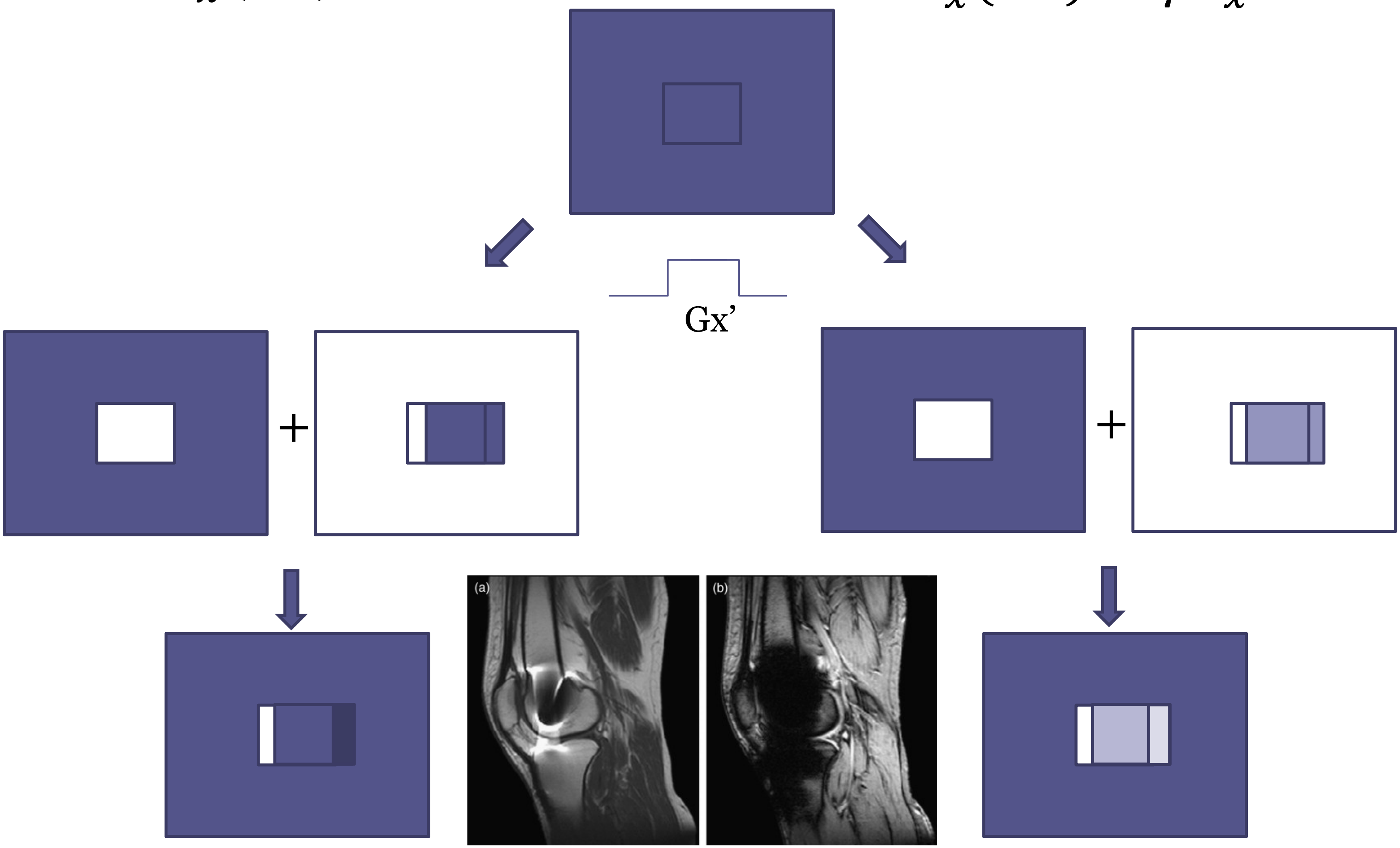


Spin Echo

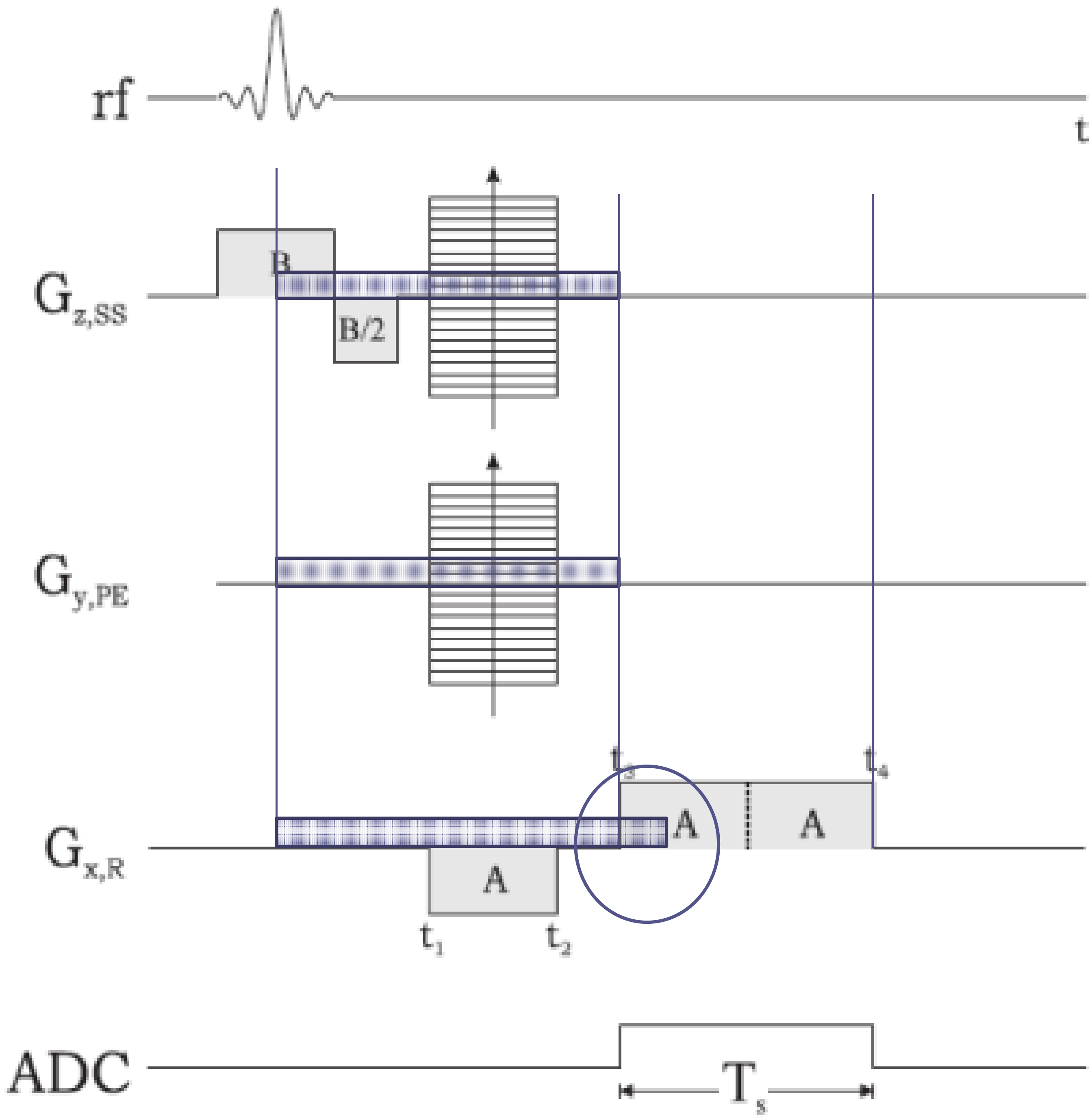
$$k_x(TE) = 0$$

Gradient Echo

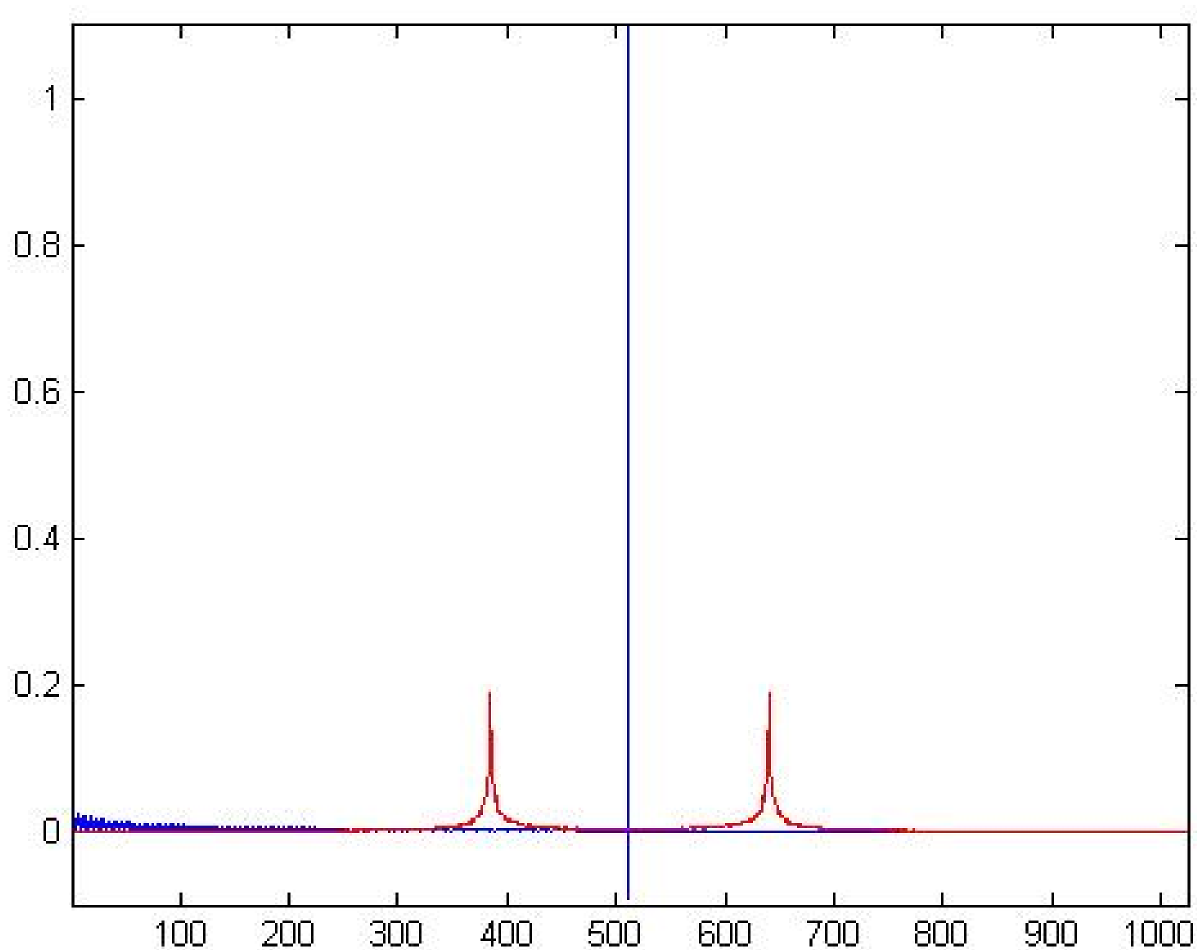
$$k_x(TE) = \gamma G_x' \mathrm{TE}$$



BG grad
and
Echo shift



Echo shift (RO or PE)



Nx=1024

N_{shift}=[illegible]

Echo shift due to BG gradient along PE

- A BG grad effectively adds a constant Ky or Kz to every line, shifting the whole k-space along PE direction

- Effective ky shift:

$$\Delta K_y' = -\gamma G_y' TE$$

equivalent to a shift of m lines:

$$m = \frac{\Delta K_y'}{\Delta K_y} = -\gamma G_y' TE \cdot L_y$$

Echo shift along SS direction (2D)

BG grad along SS

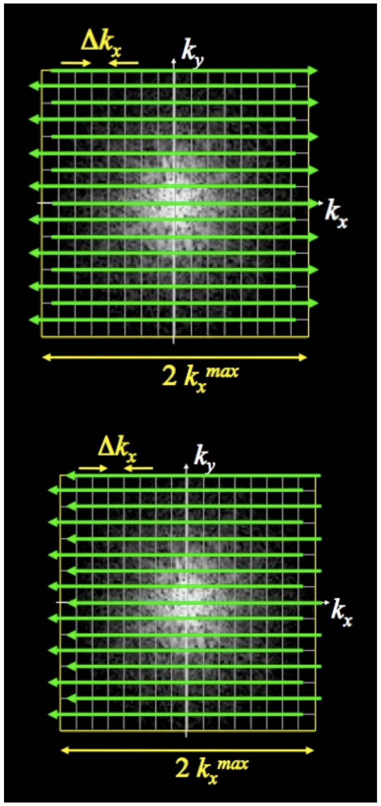
- From k-space point of view
  - Echo shift along Kz (and Nz=1)
- From gradient dephasing point of view
  - Extra dephasing gradient on SS before echo
- Result
  - Shifted slice position
  - Reduced signal in GRE (not SE)

BG grad perpendicular to SS

- Rotated (tilted) slice orientation
- Reduced signal in GRE (Not SE)

Echo shift along RO (e.g. ss-EPI)

Matrix size: 512x512
Odd lines: no shift
Even lines: 0-320 px shift

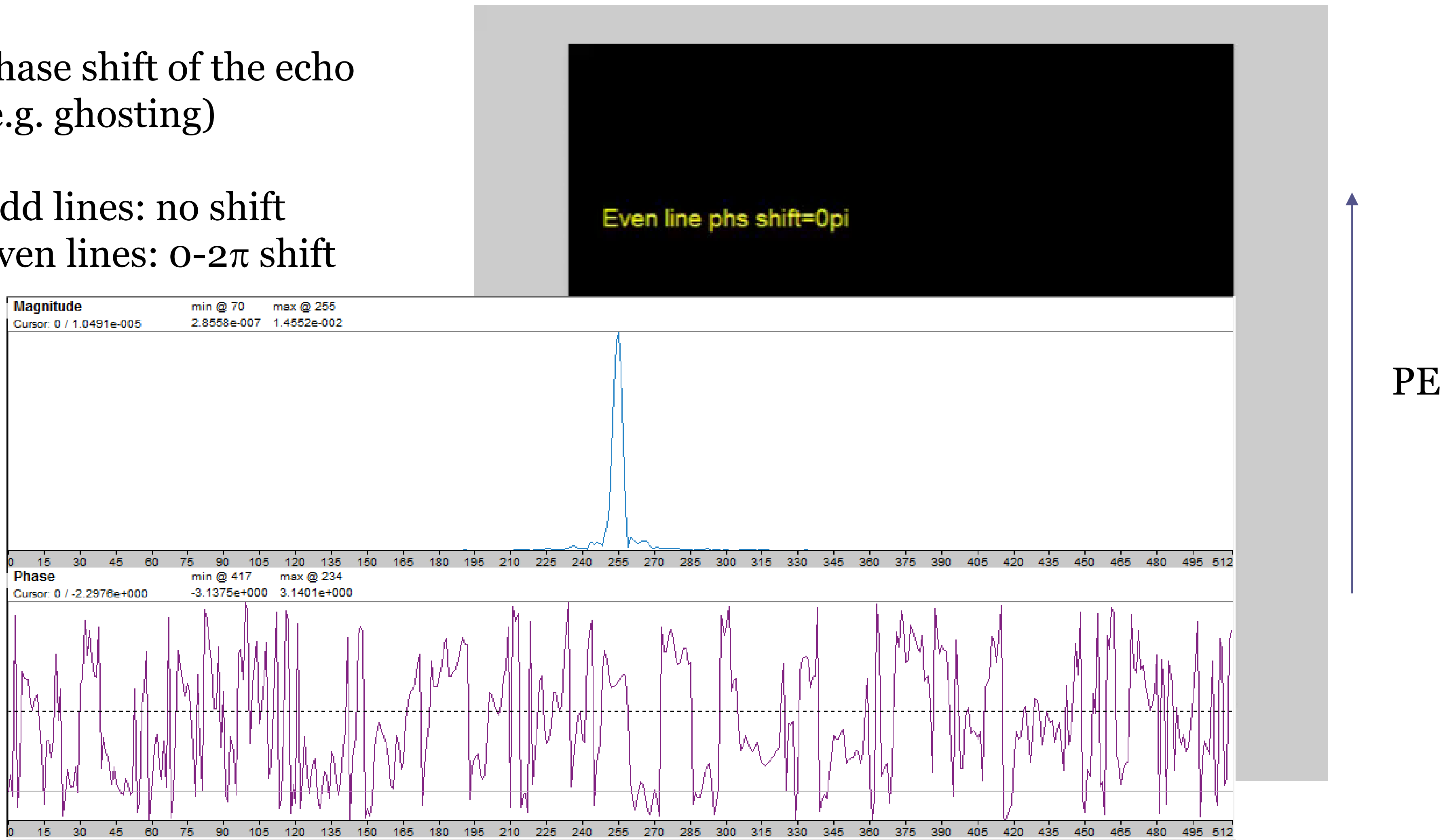


PE

Echo phase shift

Phase shift of the echo
(e.g. ghosting)

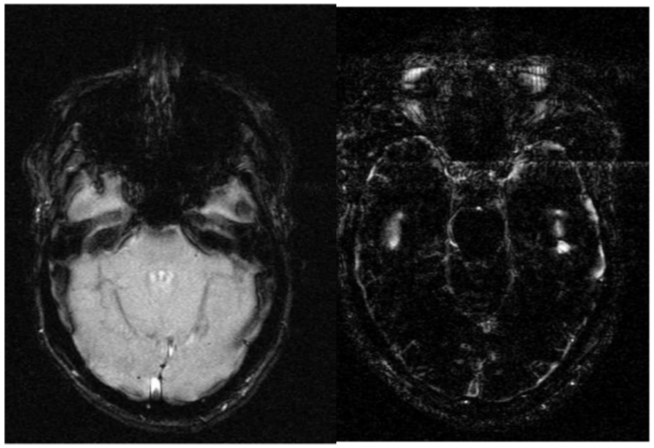
Odd lines: no shift
Even lines: 0-2π shift



Possible correction strategies

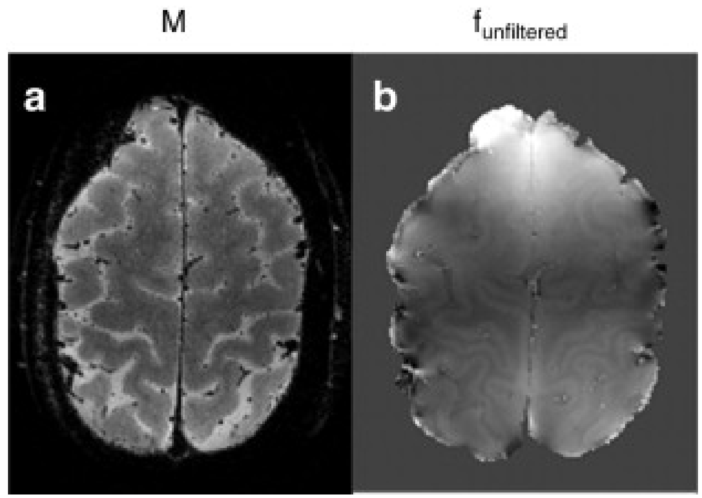
- Important: Cons must also be considered

- Strong RO gradient: reduce distortion (SNR)
- Short TE: reduce dephasing (T2*W)
- High resolution/thin slice: may reduce dephasing (SNR)
- Multi-echo + high BW vs. single eco + low BW (imaging contrast)
- SE vs. GRE (T2 vs. T2*)
- Variable SS rephase grad (z-shimming) (scan time)

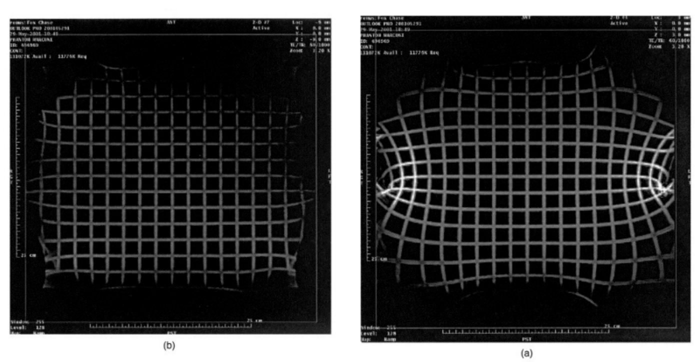


Possible correction strategies

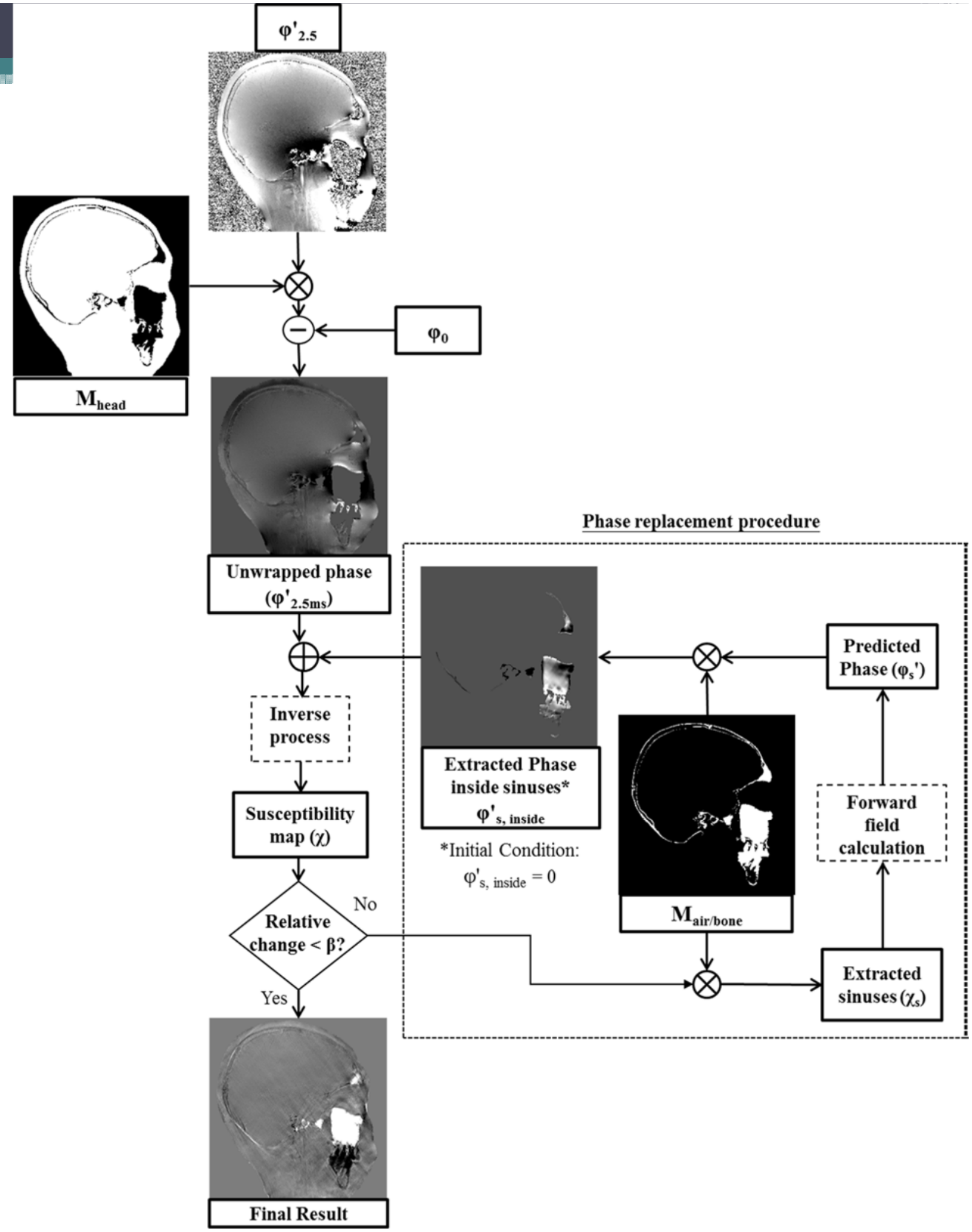
- Phase mapping



Schäfer, NI, 2009



Forward model prediction



Sagar et al. MRM, 2014

Homework

20.1, 20.2, 20.5, 20.6, 20.7, 20.9, 20.10

Next Session

Chapter 26