FYS-KJM 4740

**MR-teori og medisinsk diagnostikk**

# Kap 9
# Off-resonance effects

$$\mathbf{M}_z = \chi \mathbf{B_0} / \mu_0 = \chi \mathbf{H}_0$$

$B_0$= magnetic flux density (Tesla) = ‘field strength’
$H_0$=induced magnetic field (A/m)

‘Nuclear susceptibility’:

$$\chi = \frac{N_0 \gamma^2 \hbar^2 I(I+1)\mu_0}{3k_B T} = \frac{N_0 u_z^{\ 2} \mu_0}{3k_B T}$$

(positive and small due to small magnetic moment of nucleus)

‘Bulk suscptibility’: diamagnetic (<0) and much larger (absolute value) than nuclear susceptibility. Effective local field:

$$B_{eff} = (1+\chi)B_0$$

Diamagnetism (Lenz law):

$$\chi_d = -\frac{\mu_0 Z e^2 n \langle r^2 \rangle}{6m_e}$$

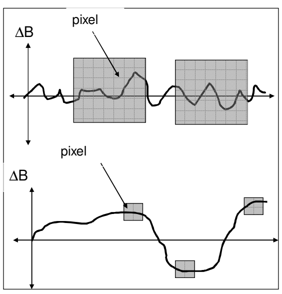
Paramagnetism:

$$\chi_p = \frac{N m^2 \mu_0}{3k_B T}$$

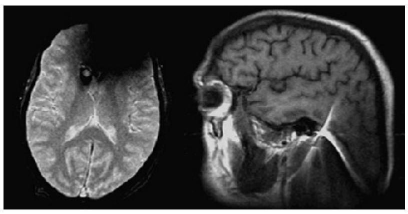
| **Material** | **Susceptibility (x $10^6$)** |
|---|---|
| Water | -9.63 |
| Human tissues | ≈ -11 to -7 |
| Whole blood (deoxygenated) | -7.9 |
| Whole blood (oxygenated) | -9.6 |
| Air | +0.36 |
| Ferritin | +520 |
| Liver with severe iron overload | ≈ 0 |
| Iron | +200 000 |
| Gadolinium | +0.32 |

Imaging effect of susceptibility changes depends on pixel bandwidth:

$$B_{eff} = (1+\chi)B_0$$



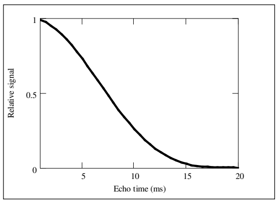

$$S = \int_{voxel} \rho(r) \cdot \exp(j\varphi(r))dr$$

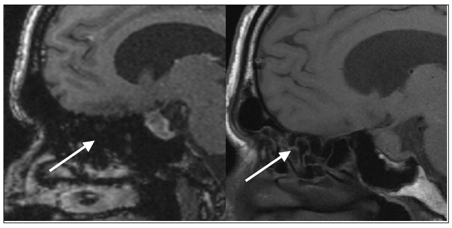


Signal loss: intravoxel dephasing

$$S = \int_{voxel} \rho(r) \cdot \exp(j\varphi(r))dr$$

$$S(TE) = \left[ \frac{1}{d} \int_{-d}^{d} \rho(r) \cdot \exp(j\Delta\omega r TE / d) dr \right]^3 = \left[ \frac{\sin(\Delta\omega TE)}{\Delta\omega TE} \right]^3$$



Geometric distortions

$$B_z = B_0 + G_x(t)x + G_y(t)y + \Delta B_z(x, y, z)$$

Spatial distortion due to $\Delta B_z$

$$\Delta x = \Delta\chi B_0 / G_x$$

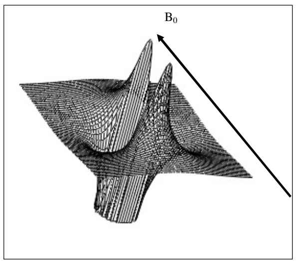
Pixel dimension:

$$\delta x = \frac{2\pi}{\gamma G_x N_x t_s}$$

To avoid spatial distortion we need $\Delta x << \delta x$:

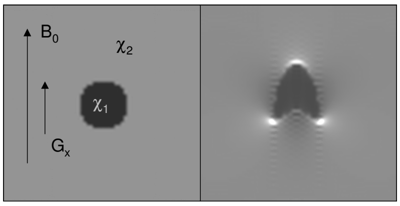
$$T_{read} << \frac{2\pi}{\gamma\Delta\chi B_0} \qquad T_{read} = N_x t_s$$

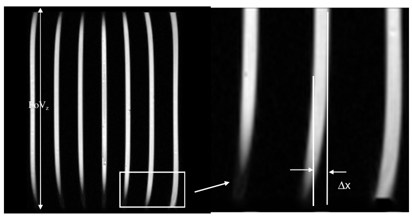
Geometric distortions




$$\Delta B_{z,o} = \Delta B_{z,i} R^2 \frac{(z^2 - x^2)}{(z^2 + x^2)^2}$$

Geometric distortions



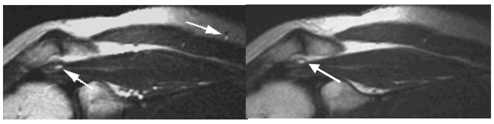




$$\delta B_0 = \Delta x G_x$$

Water-fat shift

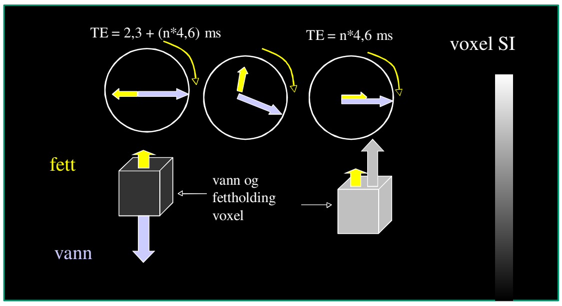
$BW = \frac{2\pi}{T_{read}} \geq \Delta\omega$ Δω (water-fat)=220 Hz @ 1.5 T

$\delta x = 3.5 \cdot 10^{-6} \cdot B_0 / G_x$

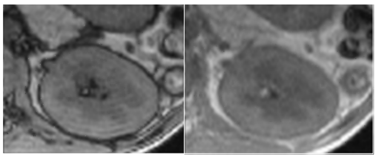


## 'in-phase / out-of-phase' effekter i GRE sekvenser

ved 1.5 T:




Water-fat shift (in/out of phase effects)



TE= 2.3 ms TE= 4.6 ms