FYS-KJM 4740

MR-teori og medisinsk diagnostikk

Kap. 10
Spinn i bevegelse

Beskrive bulk flow som en serie-ekspasjon:

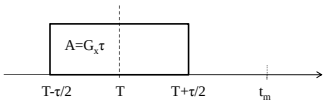
$$\mathbf{r}(t) = \mathbf{r} + \mathbf{v}t + \frac{1}{2}\mathbf{a}t^2$$

v=hastighet; a=akselerasjon

Ved konstant flow (a=0) in en gradient G(t) får vi i en fase-effekt lik:

$$\phi(t) = \gamma\int_0^t (\mathbf{r} + \mathbf{v}\tau)\mathbf{G}(\tau)d\tau = \mathbf{r}\gamma\int_0^t \mathbf{G}(\tau)d\tau + \mathbf{v}\gamma\int_0^t \mathbf{G}(\tau)\tau d\tau$$

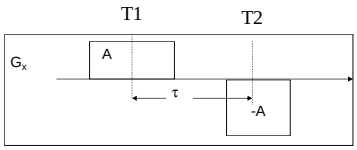
Effekt av konstant gradient i utlesnings(x) -retningen



$$\varphi(t_m) = \gamma\int_{T-\tau/2}^{T+\tau/2} x(t)G_x dt = \gamma\int_{T-\tau/2-t_m}^{T+\tau/2-t_m} (x_m + vt')G_x dt' = \gamma x_m A + \gamma vA(T - t_m)$$

Fase-effekt er proposjonal med flow-hastighet.
Proposjonalitetskonstant = første-momentet av arealet under Gradient x tids-kurven

Effekt av bipolare gradienter

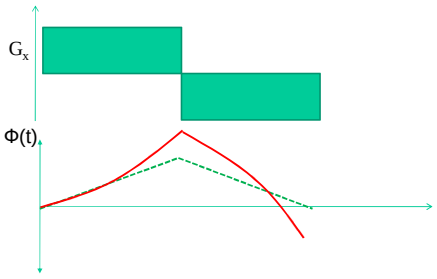


$$\varphi(\tau) = v\gamma AT_1 - v\gamma AT_2 = -\gamma Av(T2 - T1) = -\gamma Av\tau$$

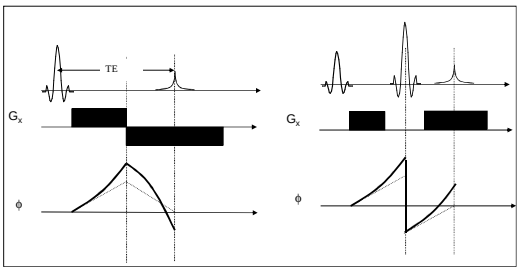
0. ordens moment: $\int G(t)dt$

1. ordens moment: $\int G(t)tdt$

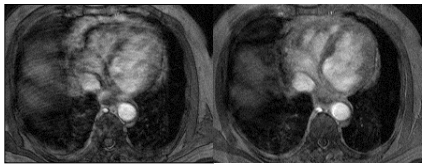
Effekt av bipolare gradienter



Fase-effekt i GRE og SE



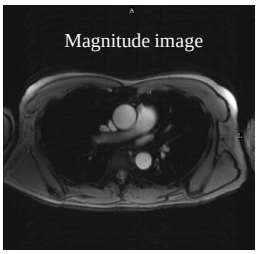
For å unngå fase-effekter for stasjonære spinn:
0.ordens gradientmomenet = 0 ved ekkosenter

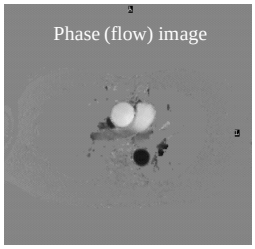


Flow void (intravoxel dephasing)

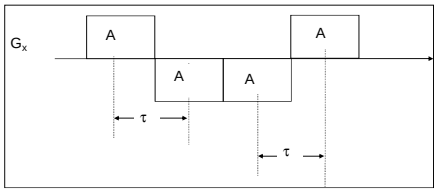
Siden fase-effekt er proposjonal med flow-hatighet kan vi kvantifisere flow dersom vi kan måle fasen nøyaktig. Detter krever imidlertid at Φ <=π slik at:

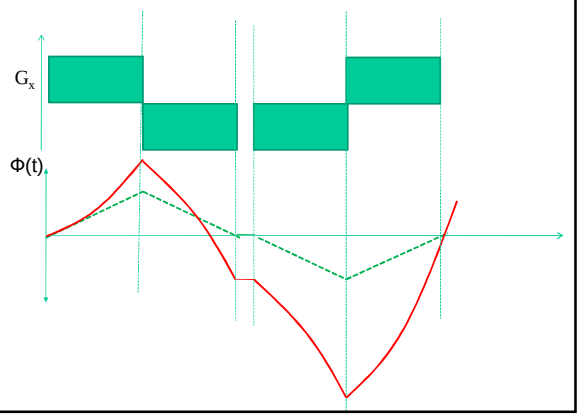
$$|v_{max}| = \pm\pi / \gamma A \tau$$

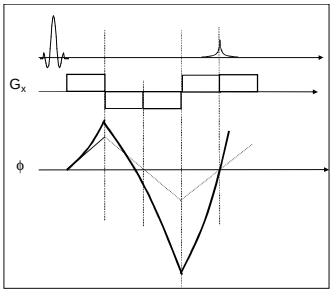




Flow-kompenasajon ved bruk av to bipolare gradienter





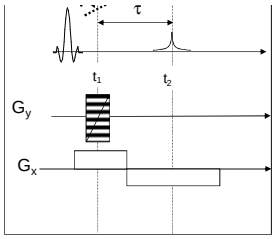


Feilregistrering grunnet flow

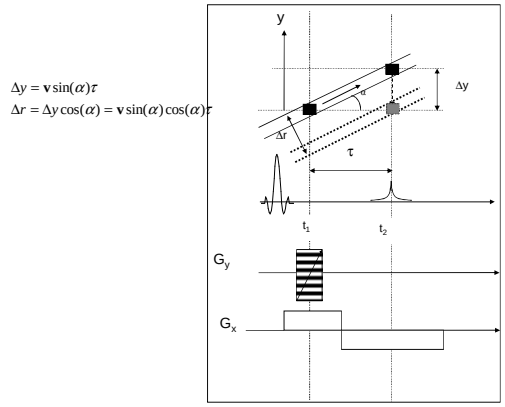
Spinn v. posisjon *y* ved tid t_1

$$\varphi = \gamma n \Delta A y(t_1)$$

ΔA = endring i grad. areale mellom sussesive fasesteps



Hvor er samme spinn ved ekko-avlelsning (t_2)?



Feilregistrering grunnet flow

Inntreffer kun i faseretningen
Bare for kar med vinkel !=0º i forhold til både fase og frekvensretning

Effekt av pulsatil flow

Ved periodisk varasjon i fase-effekt i blod blir MR-signalet modulert av en fasekomponent:

$$S(y) = \int_{k_y} M \cdot \exp(jyk_r)\exp(j\theta(k_y))dk_y$$

Hvor θ(k) kan uttrykkes som en Fourier serie (siden periodisk):

$$\theta(k_y) = \exp\left[jA\sum_n c_n \exp(jn\omega_c k_y) \right]$$

A= maks amplitude og c_n er konstanter

Pulstatil flow gir *ghosting* i faseretningen!

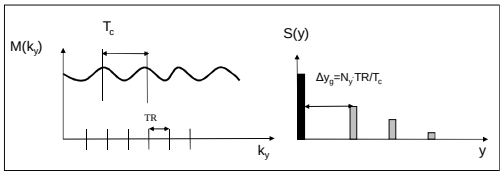
Avstand mellom hvert *ghost* objekt er gitt ved:

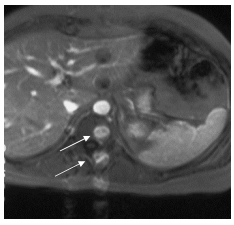
$$\Delta y_g = N_y TR / T_c$$

T_c = periode på pulsatilitet

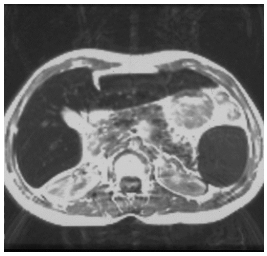
TR = repetition time (steady state sekvenser) eller ekko spacing (FSE, EPI)

N_y = antall fasekodinger





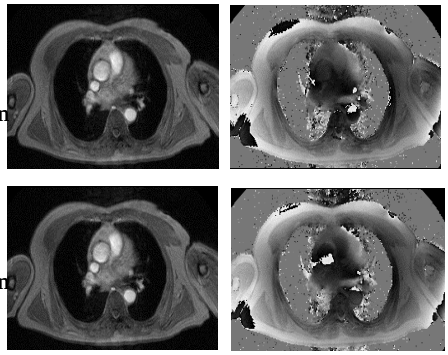
Pulsasjons-artefakter (i faseretning) forårsakes også av respirasjon



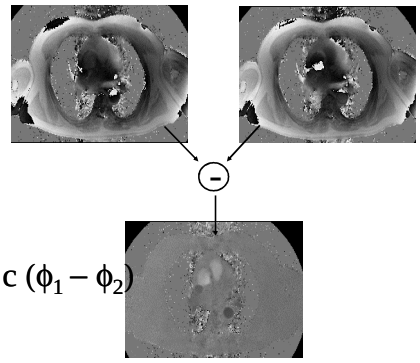
Kvantifisering av flow

Uten flow Compensation

Med flow Compensation



Flow kvantifisering ved subtraksjon

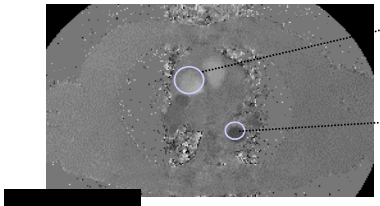


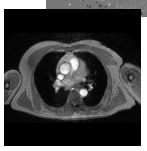
$$v = c\,(\phi_1 - \phi_2)$$

Phase Contrast Flow Quantification

Vmean 46 cm/s
Vmax 103 cm/s

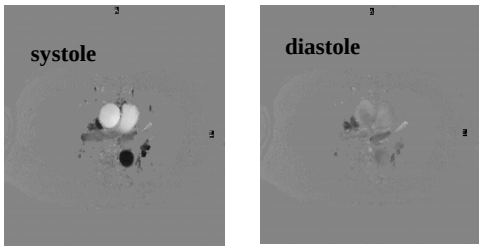
Vmean -54 cm/s
Vmax -70 cm/s





TD 154 ms

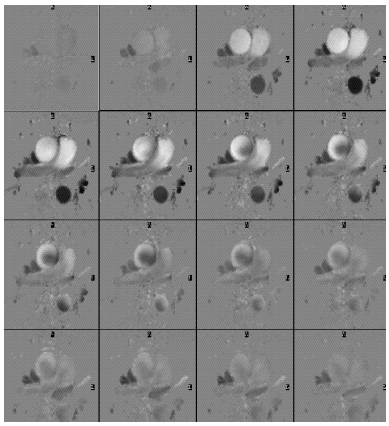
MR Velocity Maps

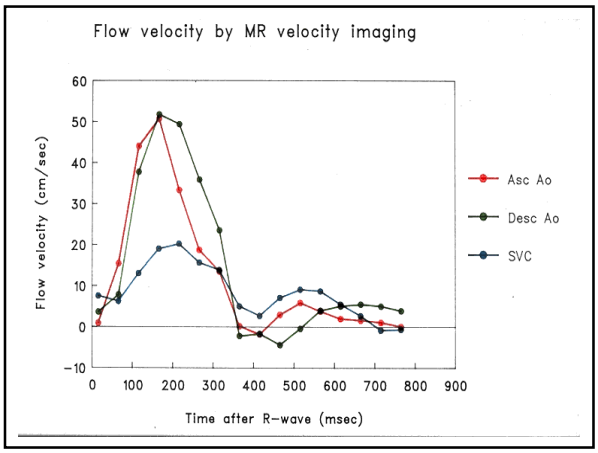


Velocity map

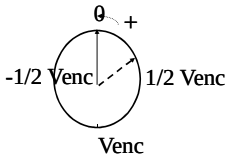
temporal resolution 40 ms

16 phases of 22

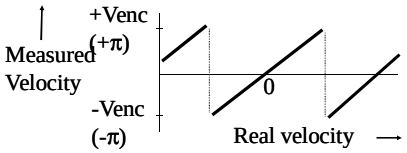




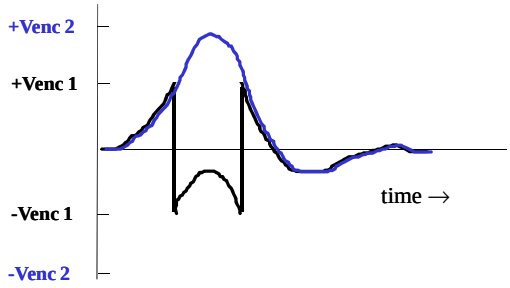
Velocity Aliasing



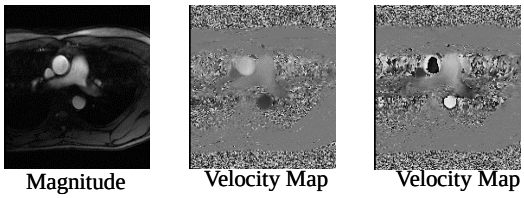
- Phase limited to:
- [-π ,+ π]



Velocity Aliasing



Velocity Aliasing

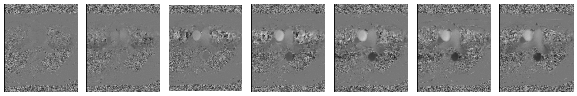


Magnitude Image | Velocity Map Venc 150 cm/s | Velocity Map Venc 70 cm/s

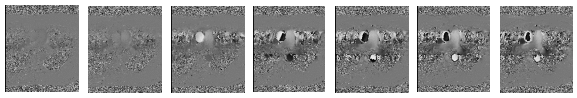
100 ms after R tag

Velocity Aliasing

Venc 150 cm/s



Venc 70 cm/s



TD 0 *25* *50* *75* *100* *125*

150 ms

Limitations with MR flow measurements

- Complex flow-> flow void *(use short TE)*
- aliasing (use correct *Venc)*
- Angulation *(correct positioning)*
- Flow missregistration *(use short TE)*