# Imaging Gradients

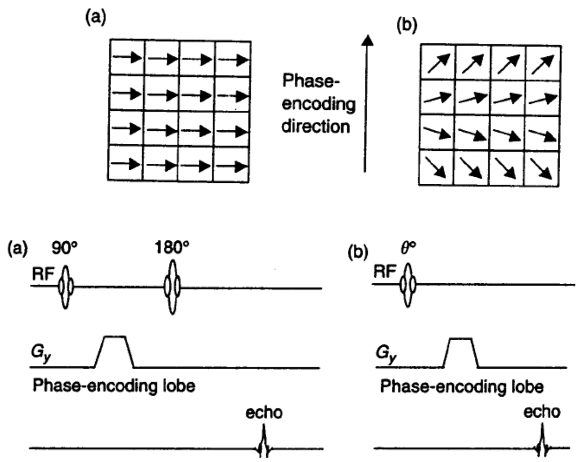
Nov2, 2005

Reference: Handbook of pulse sequences

# Phase-Encoding Gradients

- Spatial Localization in MRI employs both phase and frequency encoding.
- Phase encoding creates a linear spatial variation of the phase of the magnetization.
- Phase : angle made by the transverse magnetization vector with respect to some fixed axis in the transverse plane

# Phase Encoding




# Phase-Encoding

- Phase encoding must be applied before readout gradient
- Different phase variation is introduced by changing the area under the phase encoding gradient
- Phase encoding is used to spatially encode information orthogonal to the frequency-encoded direction

## Mathematical description

- For a y –phase encoding gradients $G_y$

$$\omega = \gamma G_y y$$

$$\phi = \gamma y \int_0^T G_y(\tau) d\tau = 2\pi k_y y \qquad (1)$$

- The effective magnetization $M_p = M_x + iM_y$

$$S(k_y) = \int M_p(y) e^{-i\phi(y)} dy \qquad (2)$$

## Phase-Encoding (cont'd)

- Transforming (2) to a discrete eq. using (1)

$$S(k_y) = \sum_{n=0}^{N-1} M_p(n\Delta y) e^{-2\pi i (n\Delta y) k_y} \qquad (3)$$

- Repeat the phase encoding steps for N times
- For N phase encoding lines, the area covered in k-space is $(N-1)\Delta k_y$

# Phase-Encoding (cont'd)

- For N phase-encoding step acquired sequentially starting at the top edge of k-space

$$k_y(m) = k_{y,\max} - m\Delta ky \qquad m = 0,1,\ldots, N-1$$

$$k_{y,\max} = \frac{1}{2}(N-1)\Delta ky$$

$$\Rightarrow k_y(m) = (\frac{N-1}{2} - m)\Delta ky \qquad (4)$$

The signal:

$$S(m) = \sum_{n=0}^{N-1} M_p(n\Delta y)e^{-2\pi i(n\Delta y)(\frac{N-1}{2}-m)\Delta ky} \qquad m = 0,\ldots, N-1 \qquad (5)$$

# Phase-Encoding (cont'd)

$\Delta ky$ chosed based on the Nyquist criteerion

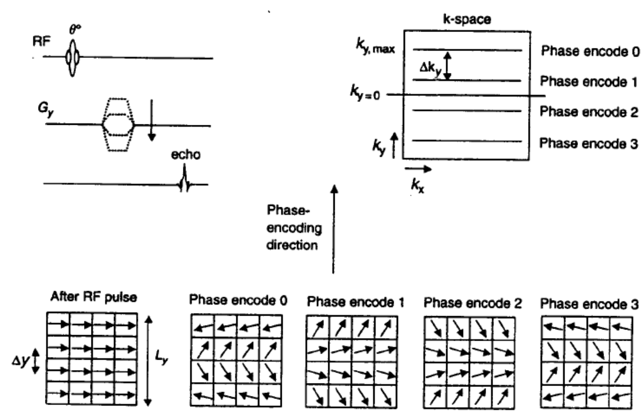
$$\Delta ky = \frac{1}{FOV_y} = \frac{1}{N\Delta y}$$

$$N\Delta k_y = \frac{1}{\Delta y}$$

equation 5 becomes

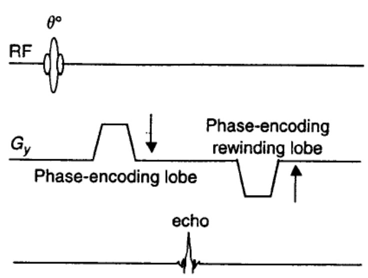
$$S(m) = \sum_{n=0}^{N-1} M_p(n\Delta y)e^{-\pi in(N-1)/N}e^{-2\pi imn/N} \qquad (6)$$

## Gradient echo with four phase encoding steps



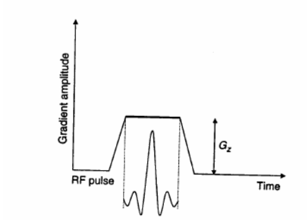

## Rephasing Lobe

- For each phase encoding step a rephaser with a negative area is applied



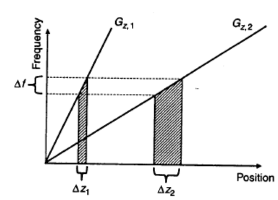
## Slice Selection Gradients

- Spatially selective RF pulses require a slice-selection gradient.
- The slice selection gradient is a constant gradient that is played concurrently with the selective RF pulse.




## Slice Selection Gradients

- A slice rephasing lobe generally follows the slice-selection gradient.
- The slice selection gradient translates the band of frequencies into the desired band of locations.
- Increasing the amplitude of the slice selection gradient decreases the thickness of the slice for a fixed RF bandwidth



# Mathematical description

$f = \frac{\gamma}{2\pi} B$ applying the slice selection gradient $\vec{G}_z$

$f = \frac{\gamma}{2\pi}(B_0 + G_z \Delta z)$

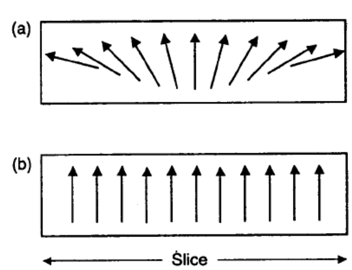
$f_{rot} = \frac{\gamma}{2\pi} G_z \Delta z$

$\Delta z = \frac{2\pi \Delta f}{\gamma \vec{G}_z}$

How can we obtain thinner slices??

# Slice Rephasing

- Rephasing lobe restores the signal



# Examples