Correction Gradients

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Reference: Handbook of pulse sequence

Correction Gradients

1. Concomitant-Field Correction Gradients
2. Crusher Gradients
3. Eddy-Current Compensation
4. Spoiler Gradients
5. Twister Gradients

Concomitant-Field

- Gradients generated concurrently with the applied gradient produce magnetic field components perpendicular to B_z resulting in:
  - Deviating the net magnetic field vector from B_0
  - Causing the magnetic field to exhibit higher order spatial dependence know as Concomitant field
- The length of the Concomitant field is proportional to G^2/B_0
- Concomitant field occurs when a gradient is active and disappears when it is turned off

Concomitant-Field Phase

- Due to the Concomitant-Field the spins in the transverse plane accumulates phase that is spatially and temporally dependent
- Artifacts produced by the concomitant-field phase:
  - Geometric distortion, Image shift, ghosting, intensity loss, blurring, and shading

Concomitant-Field Phase Correction

- Concomitant-Field Phase correction during image reconstruction
- Hardware compensation
- **Alteration of the gradients waveforms in the pulse sequence**

Resulting Net Magnetic Field due to the Concomitant-Field

- Assuming cylindrical gradient coils:

$$B = B_0 + \vec{G}.\vec{r} + B_c$$
$$= B_0 + G_x x + G_y y + G_z z$$
$$+ \frac{1}{2B_0}\left[\frac{{G_z}^2}{4}(x^2 + y^2) + ({G_x}^2 + {G_y}^2)z^2 - G_x G_z xz - G_y G_z yz\right]$$

- x, y, z is the physical coordinate for the magnet, i.e. the magnet geometry play a role
- Squared term: self squared terms
- Hyperbolic terms: cross terms

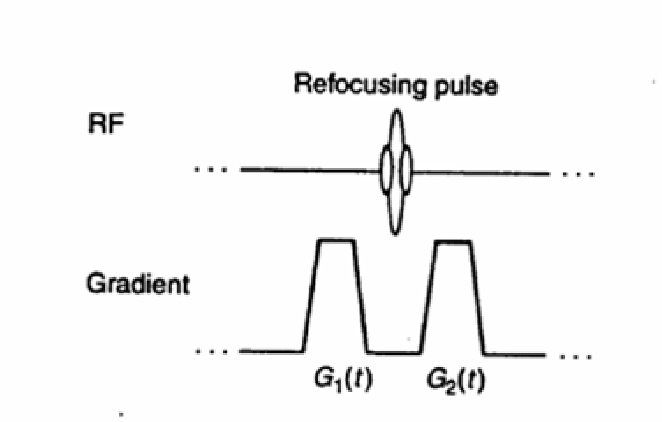
Example

Concomitant-Field Correction Gradient

- Achieved either by altering existing gradient lobes or by the addition of new gradient lobes.
- Several techniques are used:
  - **Waveform symmetrization**
  - Phase subtraction
  - **Waveform reshaping**
  - Quadratic nulling
  - Others

Waveform Symmetrization

- Negating the phase of a gradient lobe by adding an identical opposite lobe
- Examples: diffusion-weighting gradients

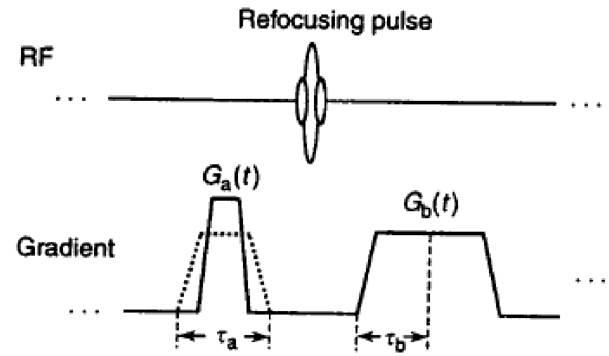


Waveform Reshaping

- The following two conditions must be satisfied:

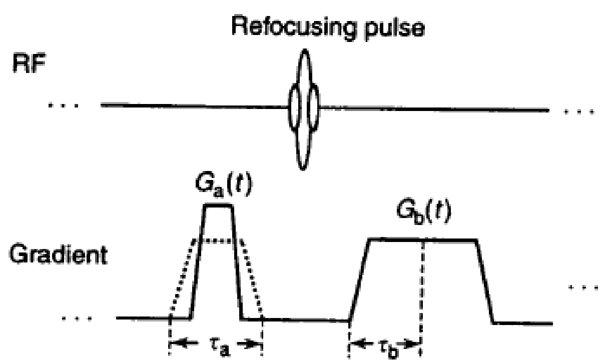
$$\int_0^{\tau_a} G_a(t)\,dt = \int_0^{\tau_b} G_b(t')\,dt'$$

$$\int_0^{\tau_a} G_a^2(t)\,dt = \int_0^{\tau_b} G_b^2(t')\,dt'$$



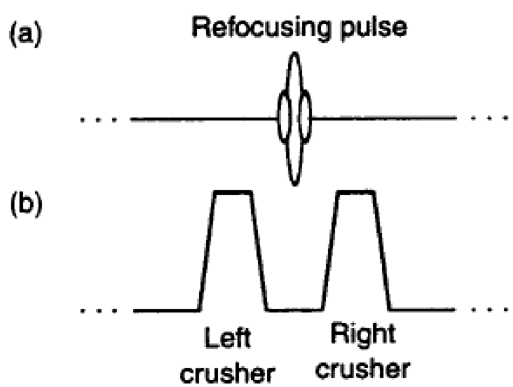
HW P2

- Assume all the gradient lobes below have the same ramp time δ. if the amplitude of G_b is fixed at G_0 and half of the duration of the gradient of the plateau is Δ, calculate the amplitude and duration of lobe G_a based on the equations of wave reshaping

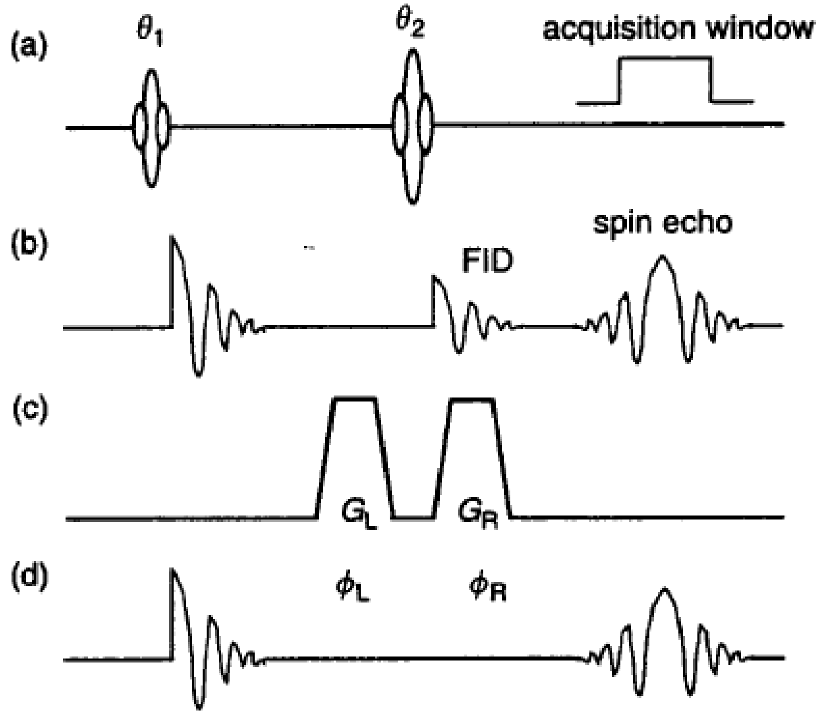


Crusher Gradients

- Crusher Gradients: is a correction gradient that preserves the desired signal pathways while eliminating unwanted ones by manipulating the phase of the signals.
- Consists of two lobes with the same polarity immediately before and after the refocusing RF pulse with the same or different areas.
- The crusher gradients are used to manipulate the phase coherence of the transverse magnetization.
- It can dephase or rephase the signal
- They are used with pulse sequences with at least one refocusing RF pulse



Qualitative Description



Quantitative Description

$$\phi_L(r) = \gamma A_L r$$

$$\phi_R(r) = \gamma A_R r$$

- For a spin-echo signal, the magnetization is in the transverse plane before and after the refocusing pulse. The net phase is zero if both areas are equal
- For the FID signal produced by by the nonideal refocusing pulse, only $\phi_R(r)$ applies
- If $\phi_R(r)$ is sufficiently large, the phase dispersion can completely destroys the signal coherence removing the FID from the data acquisition window.

HW P3

- A patient is imaged with h = 22 mT/m and S_R = 120 mT/m/ms. FOV = 24 cm, with a matrix dimension of 256^2 , slice thickness = 5 mm. If a spin echo pulse sequence is used, design a crusher to eliminate the FID signal arising from a non-ideal refocusing pulse.

Spoiler Gradients

- A spoiler gradient spoils unwanted signal that would otherwise produce artifact in the image.
- They are typically applied at the end of a pulse sequence.
- The longitudinal magnetization is preserved and experience no effect
- The area of the spoiler is large so it can adequately dephase the residual magnetization

Question

- What is the difference between crusher gradients and spoiler gradients

HW P4

- In plane resolution = 0.5 mm x 0.5 mm, slice thickness = 2 mm. If a phase dispersion of 4π across the voxel is required to eliminate the residual transverse magnetization, calculate the area of the spoiler gradient when it is applied along
  - The phase encoding direction
  - The slice selection
  - The longest diagonal direction of the voxel