Centre for the Clinical Application of Particles

January 3, 2021

Magnetic Resonance Imaging

Week 5; Lecture 10; Section 3: Encoding spatial information: 2

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Section 3

Encoding spatial information into net magnetisation

Spatial encoding and field gradients

Gradient pulse causes Larmor frequency to become a function of position

So, the phase of the nuclear precession will become a function of position over the period of a gradient pulse

Exploit these features to:

- Encode x position into k_x via "frequency encoding"
- Encode y position into k_y via "phase encoding"

Remember, gradient pulses G_i are such that:

$$B_z(x, y, z, t) = B_0 + xG_x(t) + yG_y(t) + zG_z(t)$$

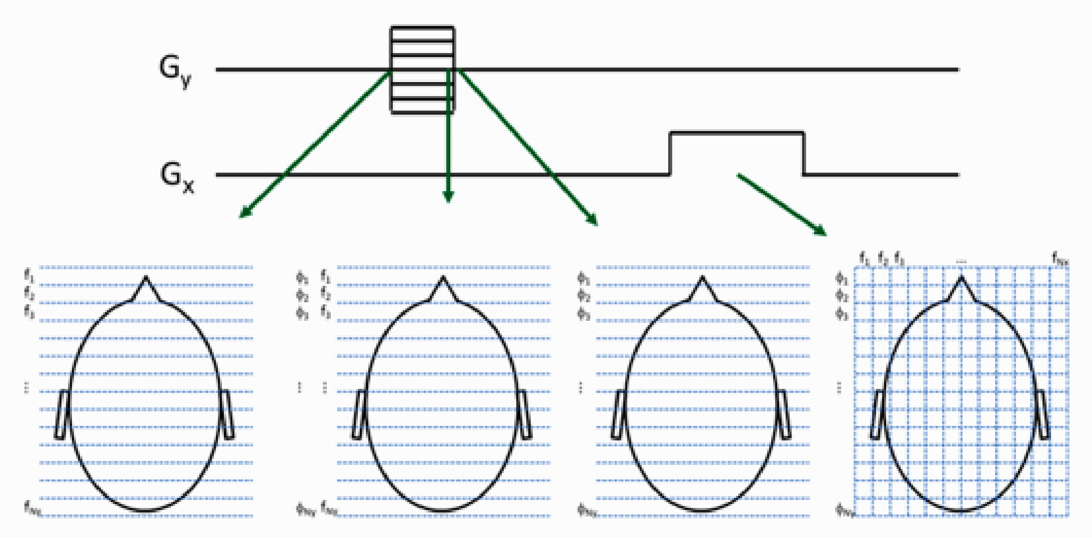
$G_x = \frac{\partial B_z}{\partial x}$; i.e. a magnetic-field gradient in x direction

magnetic field xG_x is in the $\hat{\mathbf{k}}$ direction

$G_y = \frac{\partial B_z}{\partial y}$; i.e. a magnetic-field gradient in y direction

magnetic field yG_y is in the $\hat{\mathbf{k}}$ direction

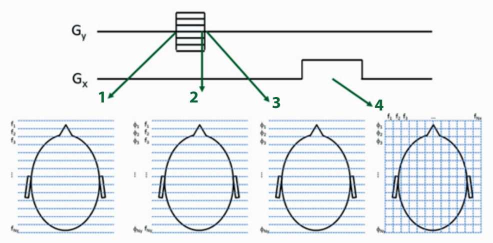
Conversion of field gradient into *k* space



Conversion of field gradient into k space

Example:

phase encode y,
frequency encode x



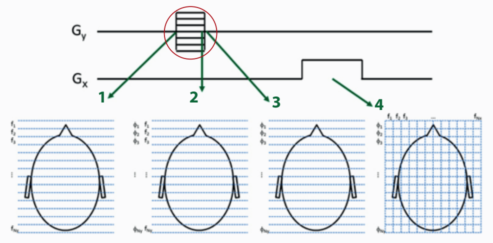
1. At start of phase encoding-pulse, spins are in phase. G_y causes Larmor frequency to be function of y: $\nu = f(y)$
2. At end of phase encoding pulse, phase of precession, ϕ, has become a function of y, i.e. $\phi \to \phi(y)$
3. As time passes, phase dependence on y is preserved, i.e. $\phi = \phi(y)$
4. Gradient pulse G_x causes Larmor frequency to become a function of x. Result is that y-position information is encoded in $\phi = \phi(y)$ and x-position information is encoded in $\nu = f(x)$

Spatial encoding gradient pulses part of pulse sequence

Example:

phase encode y,

frequency encode x



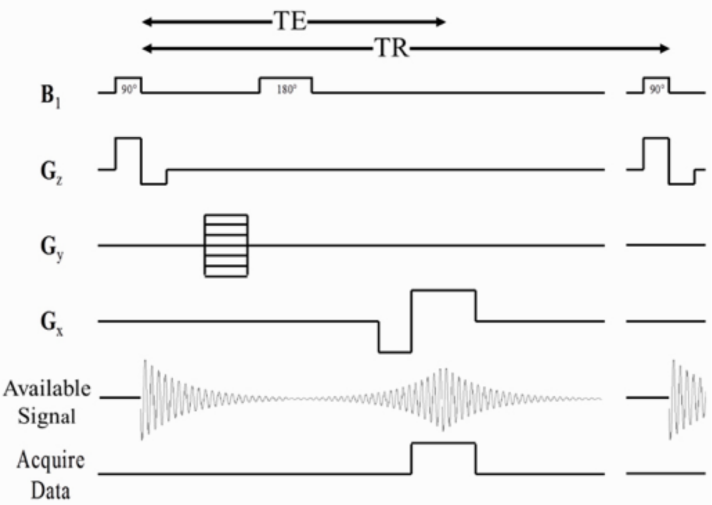
Phase- and frequency-encoding pulses part of a longer pulse sequence that repeats with period TR

At each repeat the amplitude of G_y, the phase-encoding pulse, has a different amplitude (as indicated on the figure)

For example:

- 1^{st} iteration of sequence: $G_y = 0$;
- 2^{nd} iteration of sequence: $G_y = +\eta$;
- 3^{rd} iteration of sequence: $G_y = -\eta$;
- ...

Example pulse sequence



Example of spin-echo pulse sequence

Data is acquired at spin-echo time as shown

Combination of phase and frequency encoding pulses and repetition to obtain N_y data points completes ones transverse slice

Summary of section 3

Field gradient makes Larmor *frequency* a function of position;

Phase difference as a function of position develops during application of gradient pulse

Exploit the position dependence of frequency and phase to encode image in k-space

Pulse sequences designed to optimise contrast within slice for various tissues and types of investigation