Medical Image Processing for Diagnostic Applications

Modalities – Magnetic Resonance Imaging - Part 2

Online Course – Unit 54

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Pattern Recognition Lab (CS 5)

Topics

Magnetic Resonance Imaging

Summary

- Take Home Messages
- Further Readings

Magnetic Resonance Imaging: Gradient Coils

With the theory of the last unit, we can only measure a combined signal of the complete object.

$\rightarrow$ A method is required to encode different locations differently.
$\rightarrow$ This is achieved by so-called **gradient coils**.

Magnetic Resonance Imaging: Gradient Coils

- In *z*-direction two coils are used with currents running in opposite direction.
- This creates a gradient within the magnetic field.

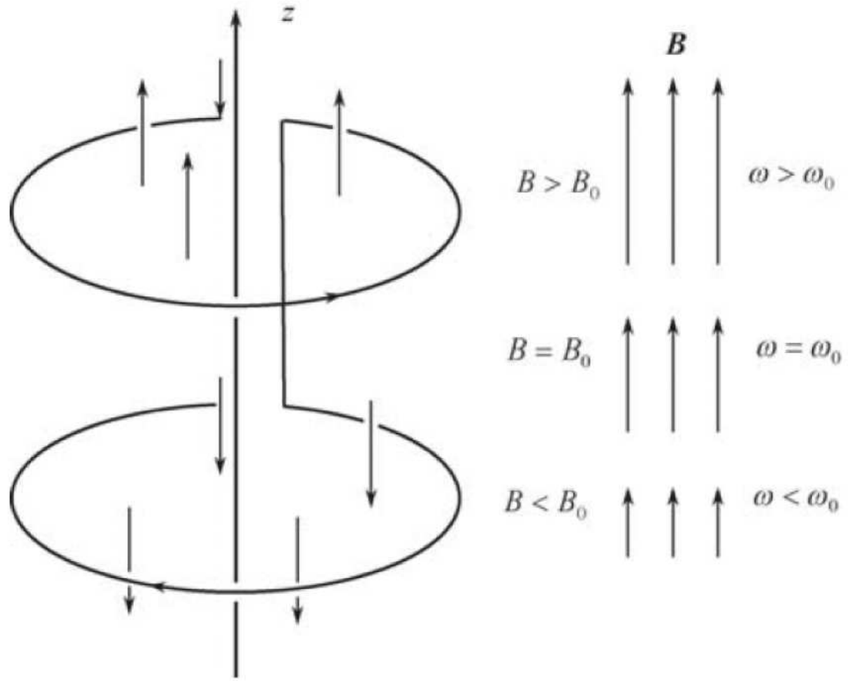

Figure 1: Scheme of two coils in *z*-direction (Zeng, 2009)

Magnetic Resonance Imaging: RF Pulse

If we use an RF pulse at only one frequency, we can excite only one layer of the object:

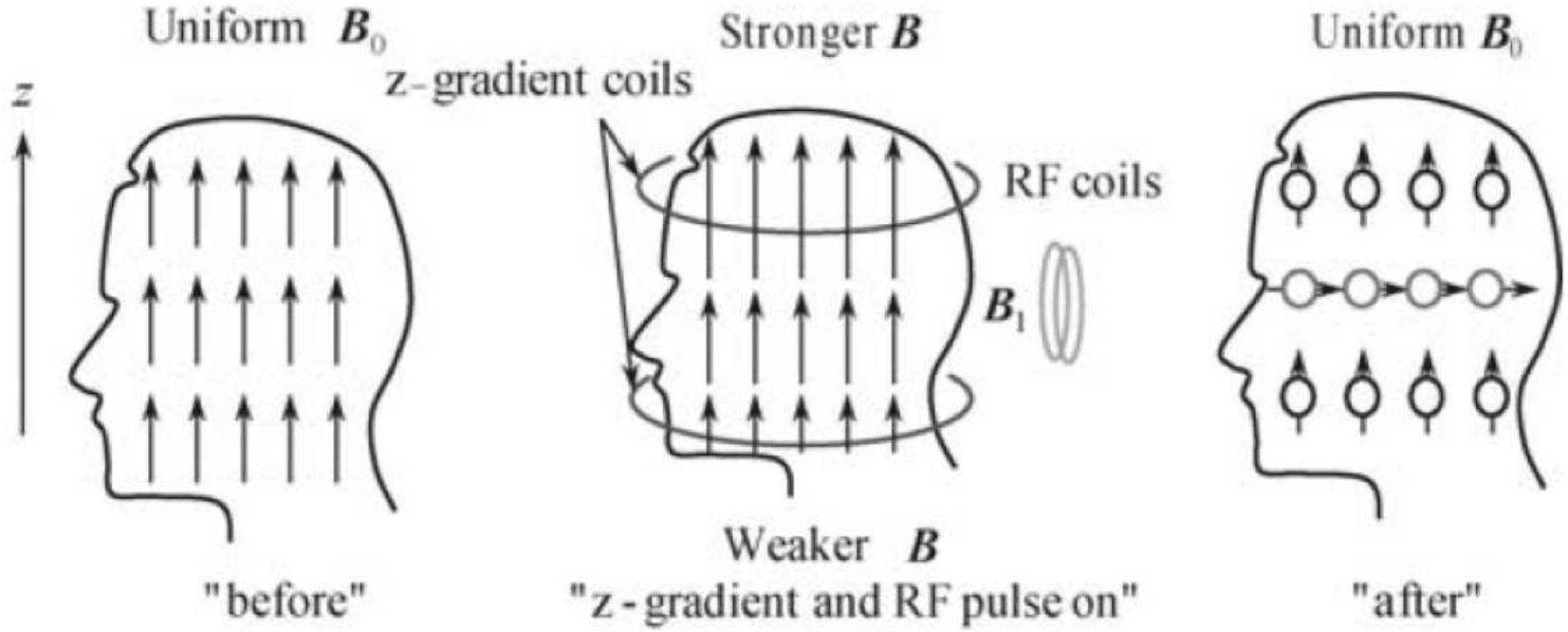

Figure 2: Illustration of single layer excitation (Zeng, 2009)

Magnetic Resonance Imaging: Encoding in y-Direction

- Encoding in *y*-direction is performed by varying the phase of the spins.
- This is achieved by turning on a gradient in *y*-direction for a short time.

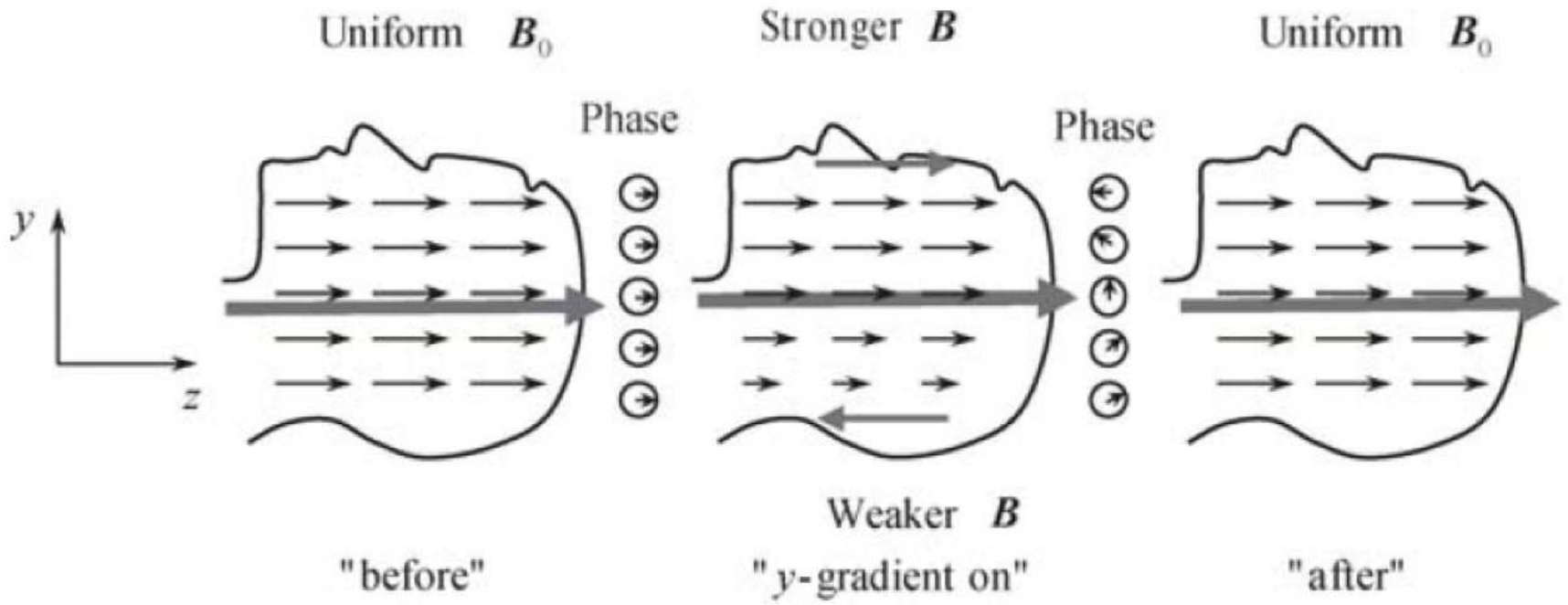

Figure 3: Modulating the spin phase (Zeng, 2009)

Magnetic Resonance Imaging: Encoding in x-Direction

Encoding in *x*-direction is performed by varying the magnetic field during the read-out of the RF pulse:

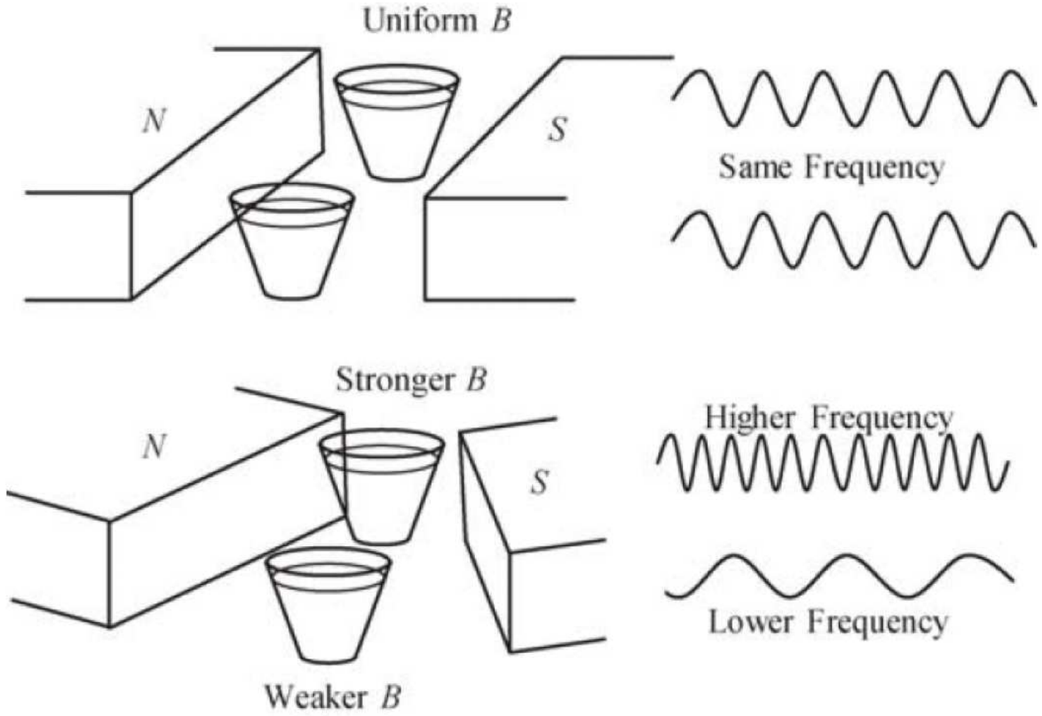

Figure 4: Scheme of magnetic field variation (Zeng, 2009)

Magnetic Resonance Imaging: Encoding in x-Direction

Encoding in *x*-direction is performed by varying the magnetic field during the read-out of the RF pulse:

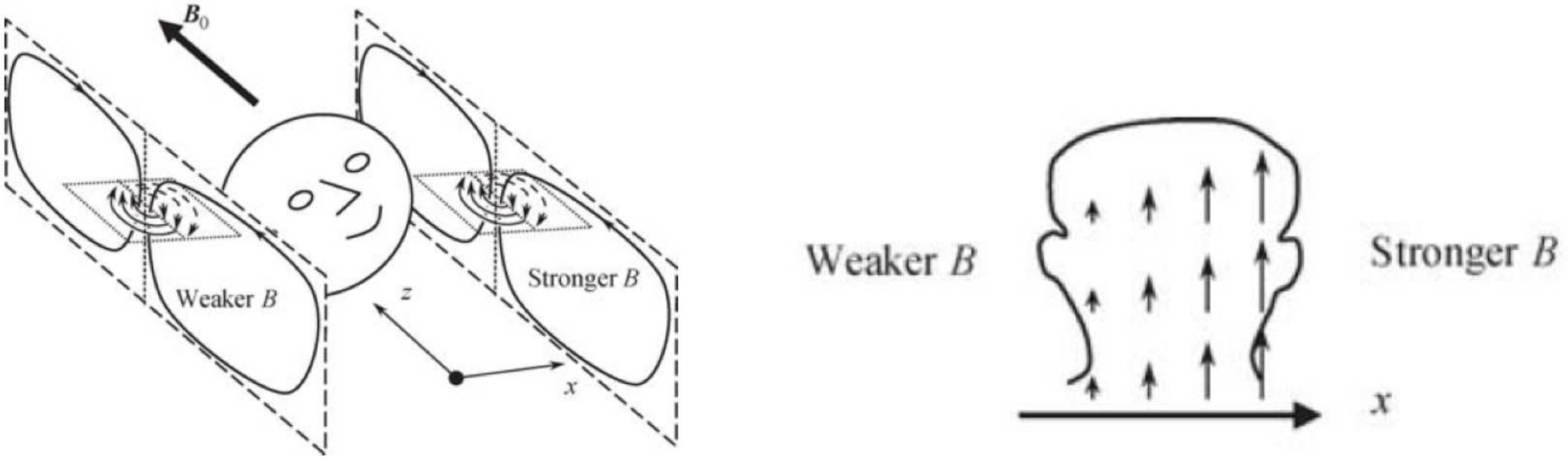

Figure 5: Illustration of the field variation during read-out (Zeng, 2009)

Magnetic Resonance Imaging: Sequence

Each step has to be performed in the right sequence:

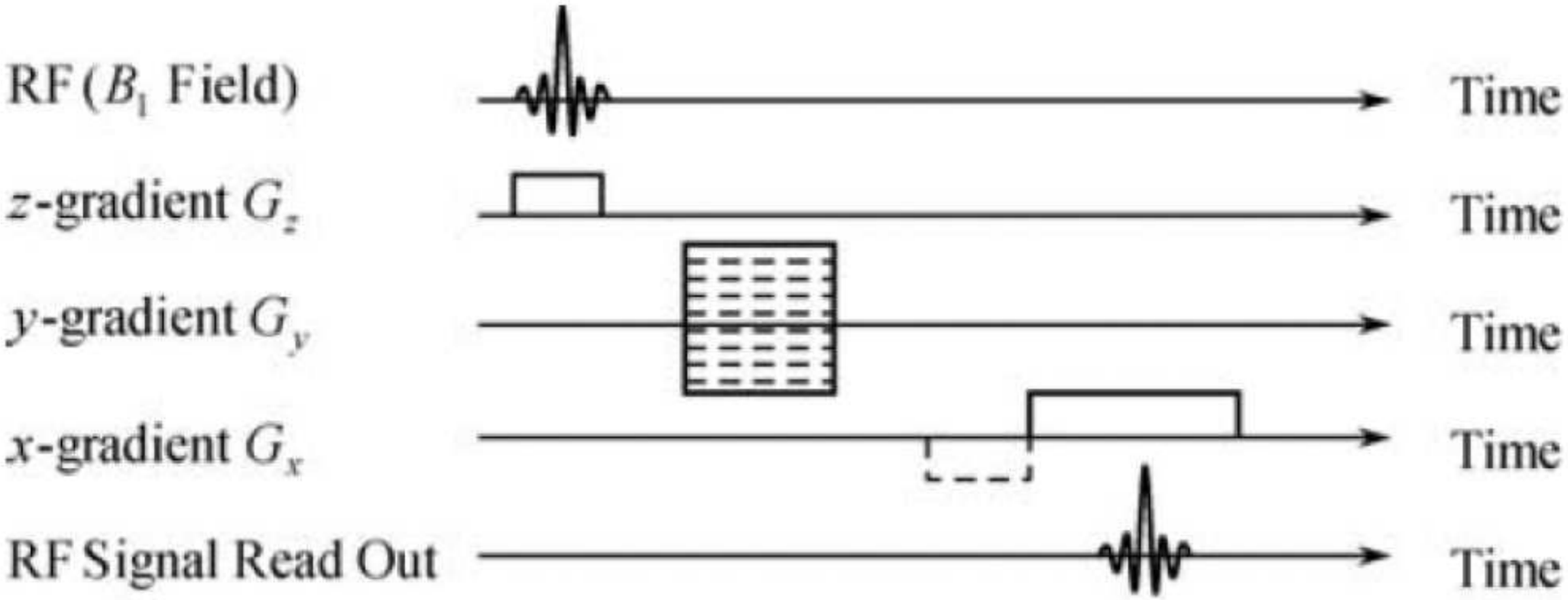

Figure 6: Timing diagram (Zeng, 2009)

Magnetic Resonance Imaging: Read-out

- Read-out data contains the sum over all locations for each frequency.
- Reconstruction is performed by an inverse Fourier transform.
- The read-out space is referred to as **k-*space***.
- *k*-space can be read out arbitrarily with different timing of pulses and gradients.

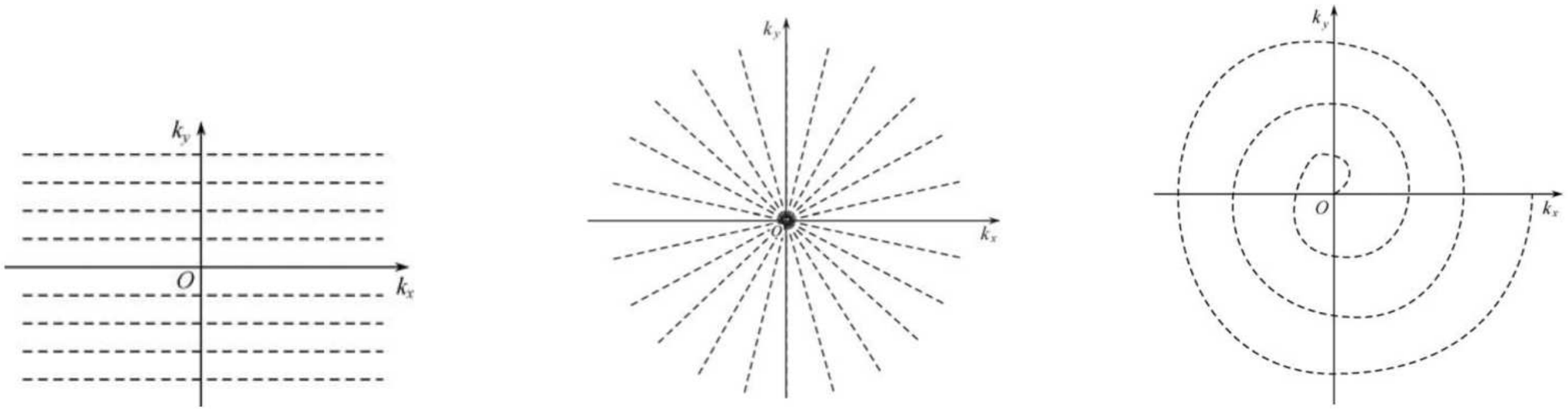

Figure 7: Examples for *k*-space sampling (Zeng, 2009)

Magnetic Resonance Imaging

- MRI enables high contrast imaging of soft tissue $\rightarrow$ excellent for diagnostic purposes.
- Magnetic labeling enables the marking of certain protons $\rightarrow$ blood flow can be visualized.
- Magnetic resonance is dependent on the amount of oxygen in the blood $\rightarrow$ oxygen consumption can be visualized.
- Many more possibilities ...

Topics

Magnetic Resonance Imaging

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Take Home Messages

- Tissue localization is enabled by using gradient coils and a specific read-out sequence.
- The read-out space for MRI is called *k*-space, and reconstruction is done from Fourier space (in contrast to CT where we start in the spatial domain).
- Every modality has its strengths and its weaknesses $\rightarrow$ MRI supports many acquisition modes.
- Combination of modalities helps to alleviate particular problems $\rightarrow$ hybrid systems, e. g., SPECT/CT and PET/MR, are emerging technologies.

Further Readings

Two reads for more insight into modalities:

Avinash C. Kak and Malcolm Slaney. *Principles of Computerized Tomographic Imaging*. Classics in Applied Mathematics. Accessed: 21. November 2016. Society of Industrial and Applied Mathematics, 2001. DOI: 10.1137/1.9780898719277. URL: http://www.slaney.org/pct/

Gengsheng Lawrence Zeng. *Medical Image Reconstruction – A Conceptual Tutorial*. Springer-Verlag Berlin Heidelberg, 2010. DOI: 10.1007/978-3-642-05368-9