Aalto University
School of Electrical
Engineering

Basics of MRI

ELEC- E8736

MATLAB exercise

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Background

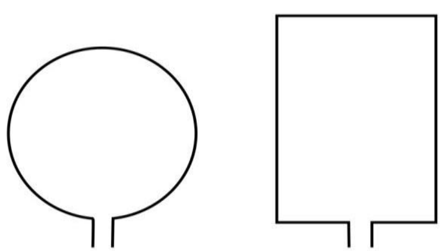
- An object was imaged with a 3 T MRI scanner at Aalto Advanced Magnetic Imaging Center.
- A set of receive coils were used for signal detection.
- The arrangement of the receive coils is explained in the next two slides.

Signal detection with coils

Surface coil

- A surface coil is essentially a loop of conducting material. This type of receiver coil is placed directly on or over the region of interest for increased magnetic sensitivity.
- MR imaging is increasingly performed using arrays of small surface coils placed near or on the body, often in conjunction with parallel imaging.

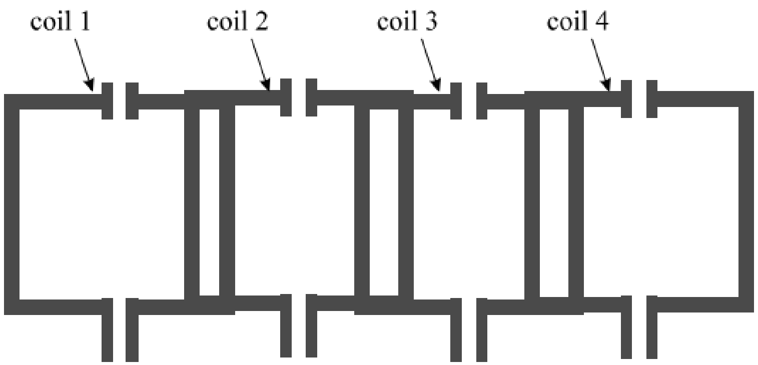
Surface coils



Signal detection with coils

Phased array coils

- In MRI, a phased array coil generally refers to a set of receive coils whose signals are combined to obtain a uniform image over a region larger than any individual coil could cover while taking advantage of the high SNR available from the smaller individual coils.
- The signals obtained from the individual coils are combined to give a single image. See Chapter 27.4 in Brown et al. (2014).



Brown et al. (2014)

Imaging parameters

Properties

Prio Recon	Off
Load to viewer	On
Inline movie	Off
Auto store images	On
Load to stamp segments	Off
Load images to graphic segments	Off
Auto open inline display	Off
Wait for user to start	Off
Start measurements	single

Routine

Nr. of slice groups	1
Slices	35
Dist. factor	25 %
Position	L1.2 P15.7 H3.0 mm
Orientation	Coronal
Phase enc. dir.	R >> L
AutoAlign	---
Phase oversampling	0 %
FoV read	200 mm
FoV phase	100.0 %
Slice thickness	1.5 mm
TR	4500.0 ms
TE	108.0 ms
Averages	1
Concatenations	2
Filter	Prescan Normalize, Elliptical filter
Coil elements	HEA;HEP

Imaging parameters

Resolution

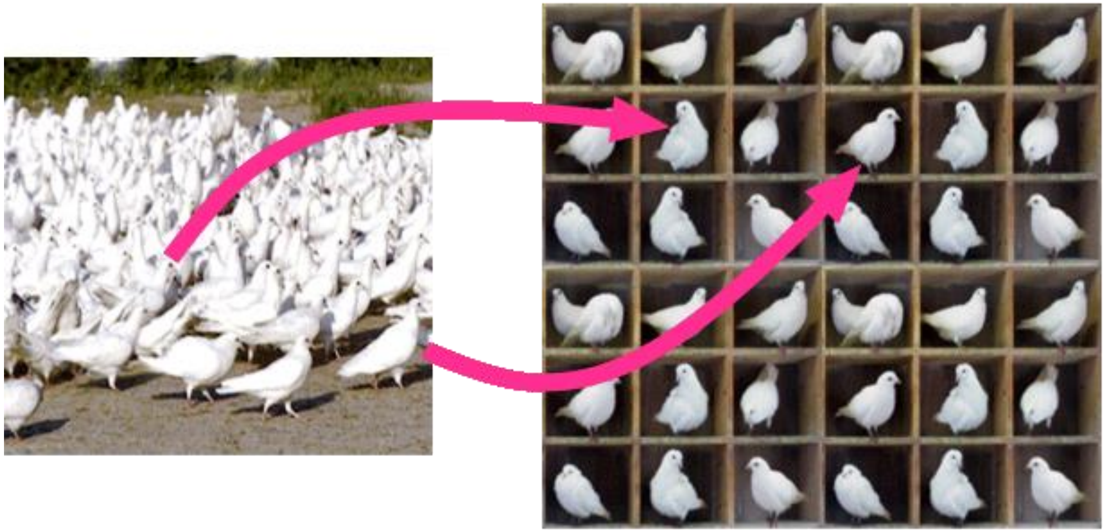
Base resolution	512
Phase resolution	100 %
Phase partial Fourier	Off
Trajectory	Cartesian
Interpolation	Off
PAT mode	GRAPPA
Accel. factor PE	2
Ref. lines PE	27
Reference scan mode	Integrated
Image Filter	Off
Distortion Corr.	Off
TD	0.0 ms
Unfiltered images	Off
Prescan Normalize	On
Normalize	Off
B1 filter	Off
Raw filter	Off
Elliptical filter	On
Mode	Inplane

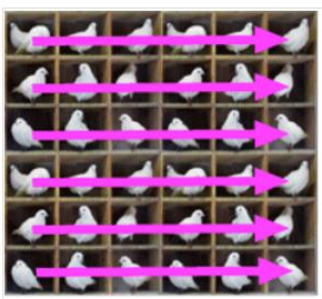
Geometry

Nr. of slice groups	1
Slices	35
Dist. factor	25 %
Position	L1.2 P15.7 H3.0 mm
Phase enc. dir.	R >> L
Phase oversampling	0 %
Multi-slice mode	Interleaved
Series	Interleaved
Nr. of sat. regions	0
Position mode	L-P-H
Fat suppr.	None
Water suppr.	None
Special sat.	None
Special sat.	None
Table position	P
Restore magn.	Off

Filling of *k*-space

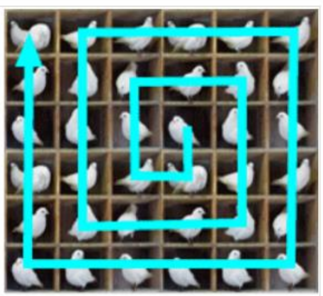
Data is acquired in the spatial frequency domain (*k*-space).



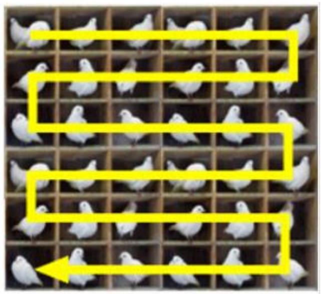


Cartesian

Radial



Spiral



Zig-Zag

http://mriquestions.com/k-space-trajectories.html

Inverse Fourier transformation

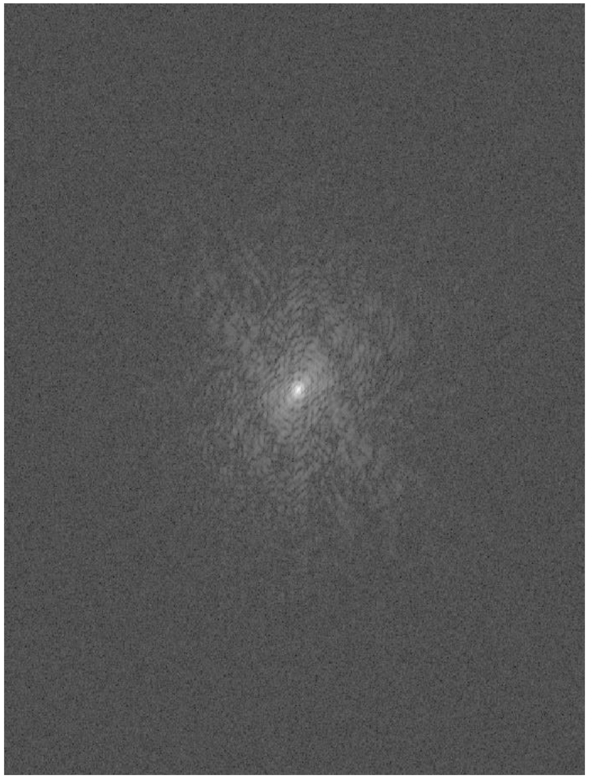
- The *k*-space is filled with data directly from MR signal.
- Image is recovered from *k*-space data using inverse Fourier transform

$$s(k_x, k_y) \;=\; \int\int\int dx\, dy\, dz\, \rho(x,y,z) e^{-i2\pi(k_x x + k_y y)}$$

Fourier transformation

$$\hat{\rho}(x,y) = \int dk_x s(k_x, k_y) e^{i2\pi(k_x x + k_y y)} = \int dz\, \rho(x,y,z)$$

Inverse Fourier transformation



Data in *k*-space

Data

The data are contained in the files **slice6_116.mat** and **slice6_1732.mat**. The data files contain 32 (16 per data file) individual 1024 $\times$ 522 *k*-space data matrices, each obtained from a different receiver coil. Each of these *k*-space data matrices can be used to reconstruct an imperfect and partial MRI image.

- Number of slices 1
- Slice thickness: 1.5 mm
- Slice number: 6 / 35
- Resolution: 1024 x 522
- Number of coils: 32

Task 1

As described in Chapters 9, 10 and 11, **reconstruct** the 32 images corresponding to each receiver coil via discrete two-dimensional Fourier transform.

Hint: Recall the MATLAB functions *fftshift* and *ifftshift* to position the image correctly.

Task 2

You should now have 32 reconstructed partial images of the object. To produce the final complete image, try combining the coil images by

- averaging
- the sum of squares (SoS) reconstruction

$$Z_{x,y}^{\mathrm{SoS}} = \sqrt{\sum_{i=1}^{32} \left(Z_{x,y}^{\mathrm{coil}(i)}\right)^2}$$

where $Z_{x,y}^{\mathrm{coil}(i)}$ stands for the pixel value at (x; y) of the i:th coil image.

Task 3

Compute the **signal-to-noise ratio** in the final SoS-reconstructed image.

Write a **short report** where you explain how image reconstruction is done and describe your signal-to-noise ratio calculations. Include some of the reconstructed 32 partial coil images as well as the final images obtained by averaging and the SoS. Also include separate MATLAB file(s).

The report is to be returned by **April 14** on MyCourses (Exercises section).