

Magnetic Resonance Imaging

Week 6; Lecture 13; Section 2: MRI artefacts: chemical shift

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Section 2

MRI artefacts: chemical shift

Origin of the chemical shift artefact

The chemical shift artefact occurs when the chemical environment causes the precessional frequency for ^1H nuclei in different molecules to differ

The artefact can arise at tissue boundaries or can be due to a particular tissue being composed of a variety of molecules each of which contribute significantly to the signal

Consider for example, the precessional rates of ^1H in water and in fat in a magnetic field of 1.5 T:

- The gyromagnetic ratio for ^1H in water differs from that in fat by 3.5 ppm
- For water, at 1.5 T, the Larmor frequency is given by $\nu_w = \gamma B_0 = 42.6 \times 1.5 = 64 \text{ MHz}$
- 3.5 ppm of ν implies a “chemical shift” in the Larmor frequency of fat of $3.5 \times 10^{-6} \times 64 \times 10^6 = 220 \text{ Hz}$
- ν_{fat} is larger than ν_w by 220 Hz at 1.5 T

Magnitude of the chemical-shift artefact

Consider an image that has $N_x = 256$ pixels in the x direction and for which the sampling time over which the frequency-encoding pulse G_x is on is 8 ms

Under these conditions, the bandwidth, BW, corresponding to the full x -coordinate range is:

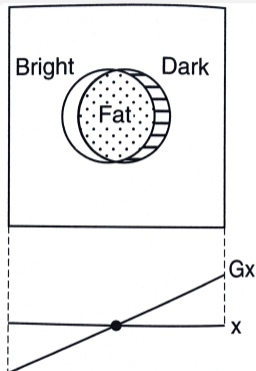
$$BW = \frac{N_x}{T_S} = \frac{256}{8 \times 10^{-3}} = 32 \text{ kHz}$$

This means that the frequency step per pixel, Δf is given by:

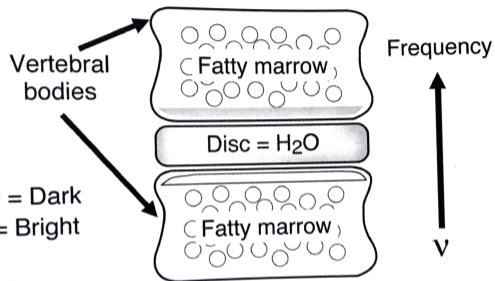
$$\Delta f = \frac{BW}{N_x} = \frac{32 \times 10^3}{256} = 125 \text{ Hz}$$

We see that Δf is smaller than the chemical shift between the Larmor frequency for fat and water at 1.5 T

Chemical shift example 1: vertebrae



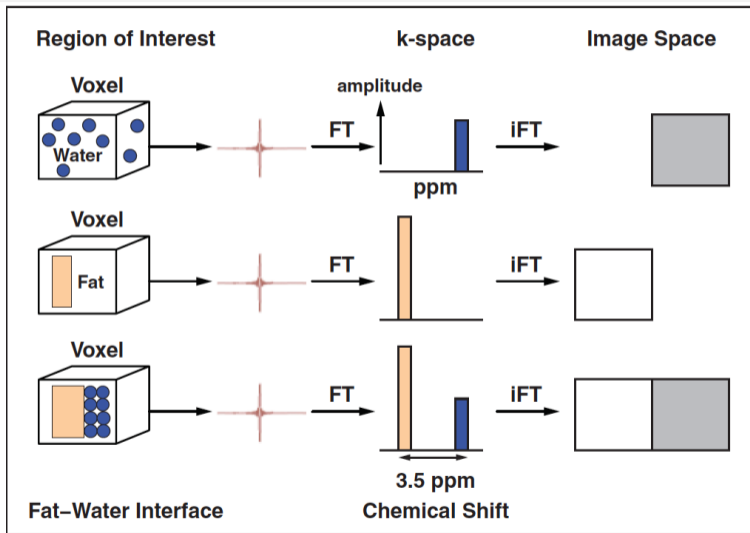
Circle of fat in water volume. Chemical shift causes fat contribution to be displaced towards lower x . Result: a bright band on one side of the fat body (signals from the water and fat overlap), dark band on the other side



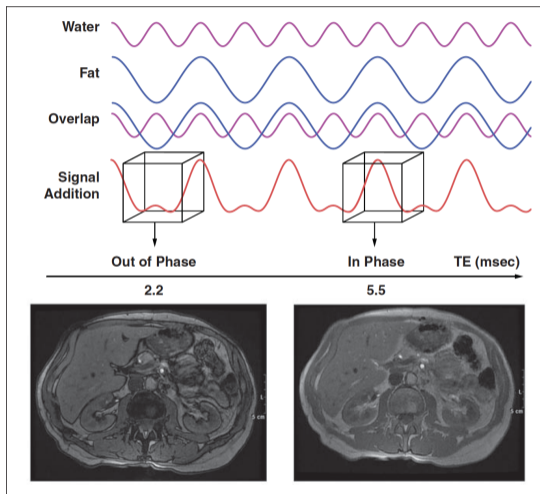
Dark band observed at bottom of “upper” fatty marrow

Bright band observed at top of “bottom” fatty marrow

Chemical shift example 2: voxel sharing water and fat



Chemical shift example 2: voxel sharing water and fat



Signal from fat and water is out of phase when $TE = 2.236$ ms. Signals from fat and water in single voxel therefore interfere destructively. Result is a dark band surrounding fat-water interfaces

At $TE = 5.516$ ms, signals are back in phase and constructive interference occurs restoring normal contrast

Summary of section 2

Chemical shift artefact occurs when chemical environment causes Larmor frequency to differ

Impact is on voxels that share the two different types of tissue. Addition of signals from different tissue types within voxel can modulate signal strength