Medical Imaging
Magnetic Resonance Imaging, an Overview
(Outline of Lecture 1)

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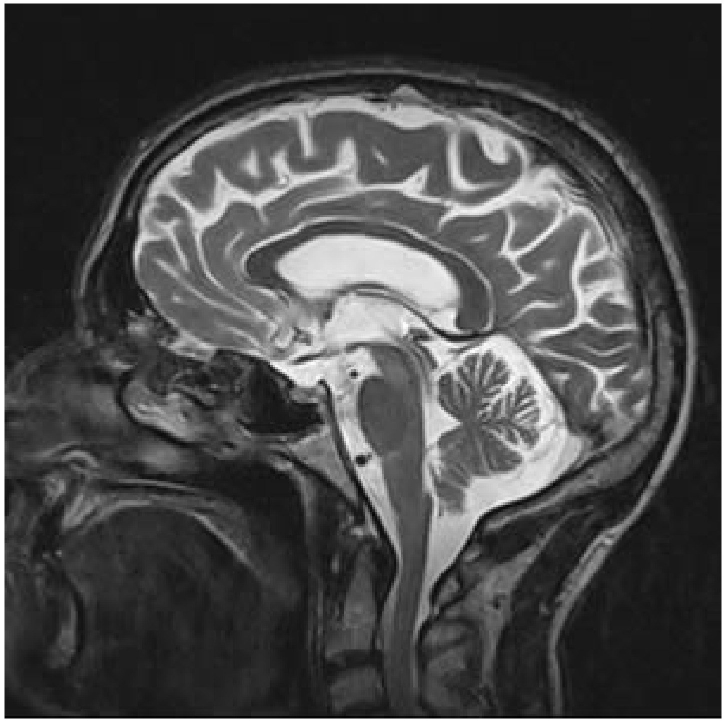
1. Overview



- What do we see in the image? What is measured?
- What physical effects are used? Which fields of physics are needed?
- What hardware components are needed? How should they interplay?

1. Overview

- **Living tissue:** 60-80% water + macro-molecules
  - both contain hydrogen ^{1}H, its nucleus $\rightarrow$ proton
  - proton has spin 1/2 $\rightarrow$ magnetic dipole
  - the water is either free or bounded to the surface of macro-molecules

- **Magnetic dipole:** localised stationary distribution of currents
  - magnetic dipole moment $\vec{m}_{\text{mg}}$
  - magnetic field $\vec{B}_{\text{dipole}}$ of a magnetic dipole
  - homogeneous external field $\vec{B}_0$ exerts a torque $\vec{\tau}$ on a magnetic dipole

- **Larmor precession** of a dipole in an external magnetic field
  - Larmor precession $\vec{\omega}_0 = \gamma \vec{B}_0$, gyromagnetic ratio
  - decay, macroscopic effect in a system of interacting dipoles in a heat bath, magnetisation $\vec{M} \sim \vec{B}_0$.

1. Overview

- **Resonant excitation** by Radio Frequency pulses
  - circularly rotating magnetic field $\vec{B}_1(t) \perp \vec{B}_0$ (Larmor frequency)
  - appropriate pulse length $\rightarrow$ spins precess coherently in the plane $\perp \vec{B}_0$
  - decay of the macroscopic magnetisation $\vec{M}_\perp$, $\vec{M}$ approaches $\vec{M}_0$.
  - decay times T_1 and T_2.
  - decaying coherent precession induces a current in a receiver coil
- **Spatial localisation** needed for imaging
  - add a small, linear, position dependent magnetic field
  - by using pulses - choose a slice and vary frequency and phase of the precession spatially

1. Overview

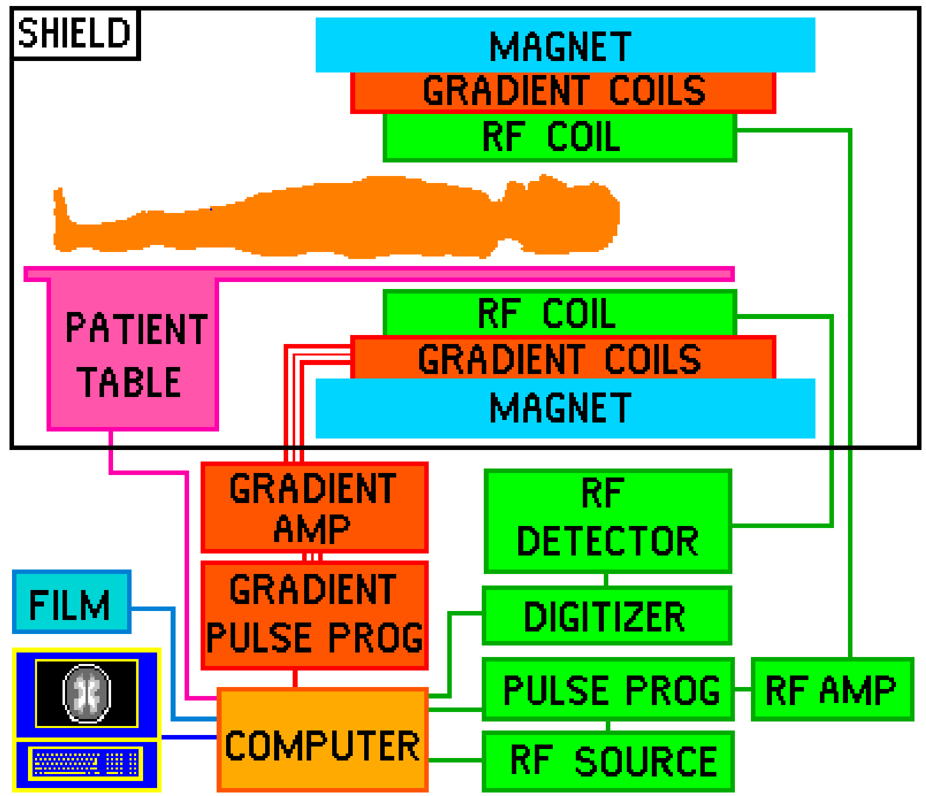
- **Measurement:** the measured signal $s(\vec{r})$ is

$$s(\vec{r}) = \rho(\vec{r})\left[1 - \exp^{-T_R/T_1(\vec{r})}\right]\exp^{-T_E/T_2(\vec{r})}$$

  - $\rho(\vec{r})$ – density of protons (water) at $\vec{r}$
  - $T_1(\vec{r})$ – T_1 decay at $\vec{r}$
  - $T_2(\vec{r})$ – T_2 decay at $\vec{r}$
  - T_E, T_R – process parameters

1. Overview

- System Architecture



- **Hardware components**
  - Electromagnet for $\vec{B}_0$, where $B_0 > 1$ Tesla, homogeneity
  - Gradient field coils with small rise time
  - RF transmitter/receiver