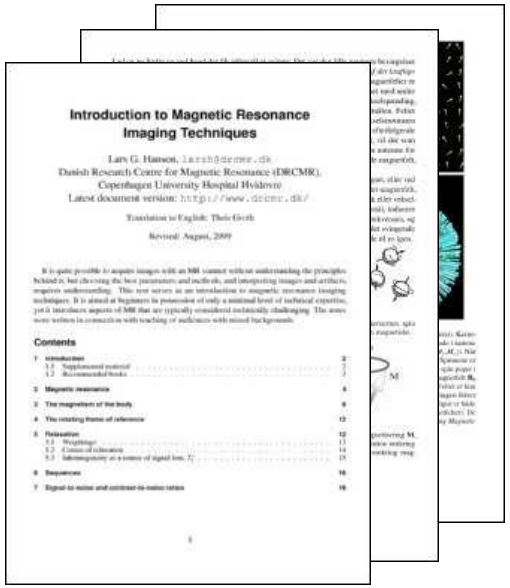
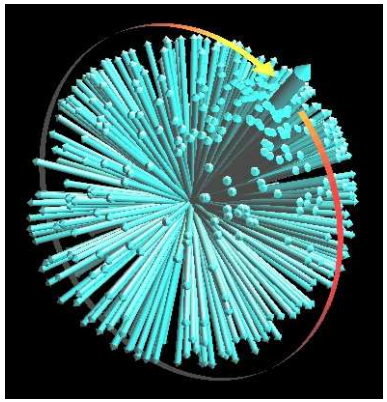
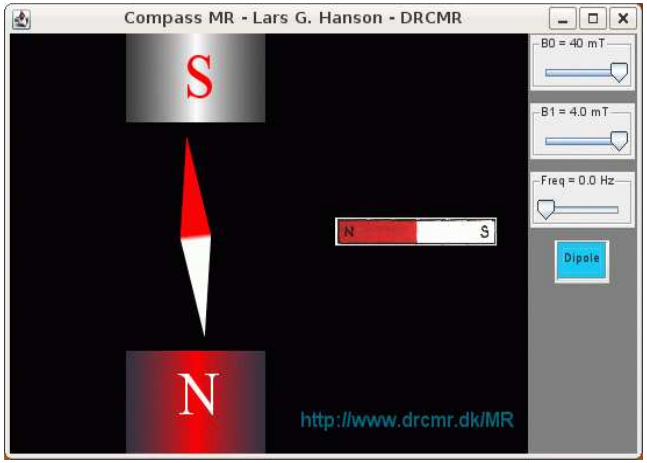
Other free educational resources available at
http://www.drcmr.dk/MR



Course notes explaining basic MRI concepts and techniques. Written in English for a broad audience but with technical rigor. 48 pages. May be freely distributed.



Scene from animation supplementing the article *"Is Quantum Mechanics needed for explaining Magnetic Resonance?"* in Concepts of Magnetic Resonance, 2008.

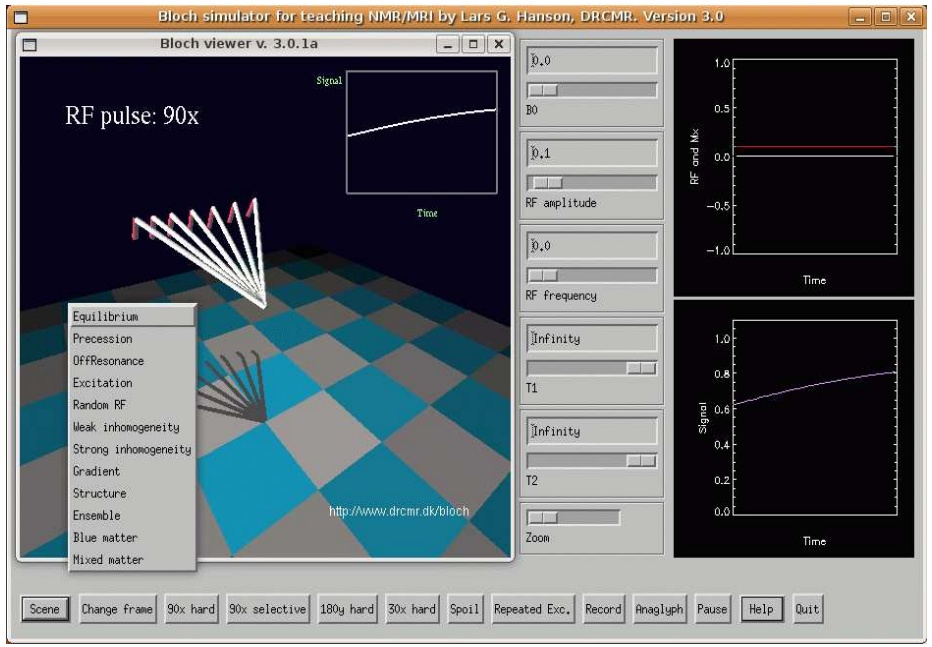


Java Applet demonstrating basic magnetic resonance. The similarities and differences to nuclear magnetic resonance are described in accompanying notes. The applet runs directly in a web browser if a free Java-plugin from Sun Microsystems is installed (already done at many PCs — open *http://www.drcmr.dk/MR* to run or install Java).

Hvidovre Hospital

The Bloch Simulator and Viewer

Free, interactive MRI visualisation



Overview

The Bloch Simulator is 3D graphical software for visualising spin physics and MRI techniques [1]. It provides demonstrations and exploration of otherwise abstract concepts involved in MRI. It is useful for students and teachers alike and is available online at no cost.

Phenomena such as precession, resonance, excitation, inhomogeneity and relaxation can be demonstrated. Likewise, rotating frames, weightings, spoilers, spin-echoes, simulated echoes and more can be explored. Finally, MR imaging concepts can be demonstrated, e.g., how the similarity between induced phase roll patterns and the structures of the imaged object is reflected in the MR signal.

Usage

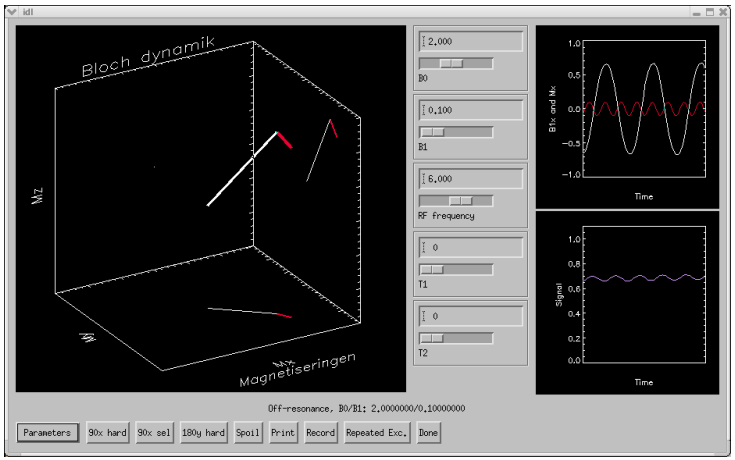
The figure above illustrates the basic usage of the software. The snapshot is taken half way during excitation of a group of spins in presence of B_0-inhomogeneity. Spin evolution and field influences (torque) are illustrated as moving bars (white and red, respectively). Initial sample and field conditions such as "Equilibrium", "Gradient" or "Structured object" are chosen via a pull down menu. Afterwards the spin isochromats are manipulated interactively using sliders that change field and sample properties or via buttons generating sequence events (e.g. RF pulses or spoiling). Downloads, demonstrations and explanations are on the web page, http://www.drcmr.dk/bloch

Implementation

The software is offered in two parts: The core is an all-in-one simulator developed in the programming language IDL for an "IDL virtual machine" (IDL can execute compiled programs free of charge [2]). This part offers vector graphics based 3D visualisation of Bloch dynamics. An optional open-source 3D Bloch Viewer written in freely available Perl improves the graphics considerably by taking advantage of the capabilities of modern graphics cards. Transversal magnetization components are illustrated via "floor shadows" and signal curves. Dynamics in the rotating frame are illustrated by spinning the entire scene, including the floor.

Requirements

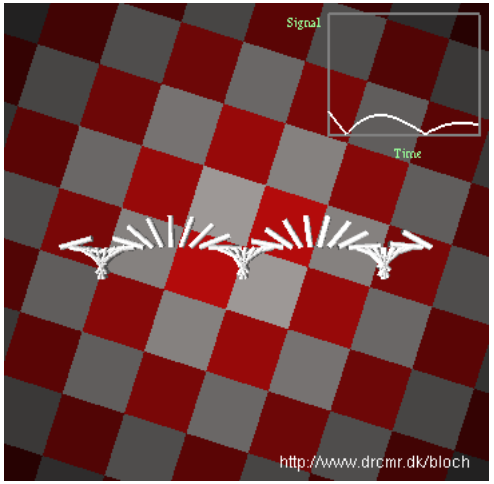
The software runs on practically all computers and platforms, (Windows, Mac, Linux and more). A modern graphics card with OpenGL support is required, however, for the optional Viewer to run well. If that is not available, vector graphics will be used, and dynamics in the rotating frame of reference will be less clear. IDL and the Bloch Simulator are easy to install - Perl and the Bloch Viewer slightly less so.



The simulator uses vector graphics that are improved considerably by the Bloch Viewer.

Physics and project background

MRI involve spin systems in varying magnetic fields. Their dynamics are described by the Bloch equations which are equally precise from classical and quantum perspectives [3,4]. Literally, teaching of these issues typically involves considerable hand-waving. Computers offer attractive alternatives for demonstrating spin dynamics. The purpose is to offer free, platform-independent, inspiring, flexible and easy-to-use software for educational purposes. Excercises are described in the online help.



Even complex concepts can be visualised using the simulator. The graphs show two stages of a stimulated echo sequence. Above: A phase roll is generated using a gradient. Right: Situation after spoiling in the TM-period. The phase roll capability is particularly useful for explaining k-space imaging.

The software is provided by
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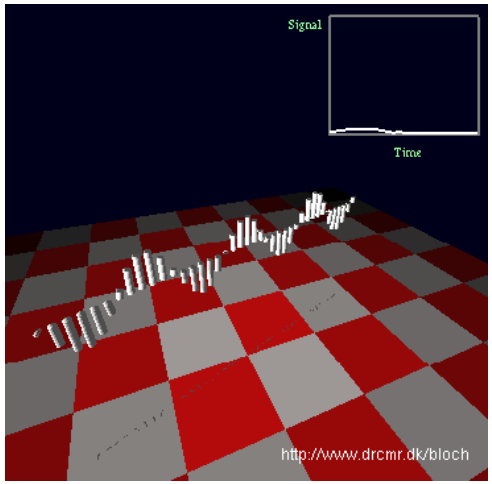
The Danish Research Centre for Magnetic Resonance (DRCMR),
Copenhagen University Hospital,
Hvidovre, Denmark



Licensing

References

[1] Hanson, LG. A graphical simulator for teaching basic and advanced MRI techniques. RadioGraphics 2007, 10.1148/radiol.e27
[2] ITT Visual Information Solutions, *http://www.ittvis.com/idl/*
[3] Bloch F, Nuclear induction, Phys Rev 70:460-73, 1946.
[4] Hanson LG. Is quantum mechanics necessary for understanding magnetic resonance? Concepts in Magnetic Resonance Part A 2008, 32A(5), 329-340.