WHAT IS MAGNETIC RESONANCE?

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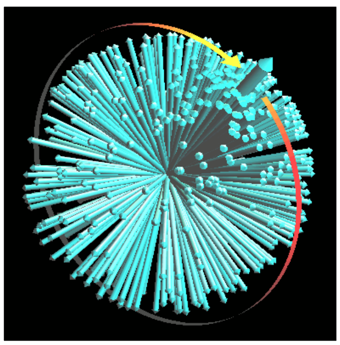
The presentation is aimed at those who wish a simple, intuitive and correct understanding of the basic magnetic resonance (MR) phenomenon, or have a need to convey that to others. Such people would typically include radiologists, radiographers, chemists and physicists. In particular, the presentation is aimed at people that may have felt confused or dissatisfied by typical introductions to MR presented in most textbooks on the subject. Such explanations are typically relying on elements of quantum mechanics (QM) not accessible to all. Furthermore the QM elements are often misinterpreted by students, authors and lecturers [1]. Fortunately, quantum mechanics plays no role in the basic understanding of magnetic resonance, which is a classical phenomenon [2] (in contrast to the spin or J-coupling phenomena, for example, that are not explicable by classical mechanics alone, but which both can enter in a classical description of magnetic resonance).



This presentation uses graphical software and simple concepts to explain the MR phenomenon. Initially magnetic resonance involving a compass needle in a static and a varying magnetic field is introduced. Using simple Java®-based software [3] running in any browser, students can experiment and "discover" compass MR. The phenomenon of nuclear MR differs from compass needle MR, however, since nuclei are not only magnetic, but also rotate (have spin, possess angular momentum). Consequently nuclei precess around north rather than vibrating in a plane through north. Adding to the experience with compass MR, the presentation describes these differences and their consequences using animations (see figure and [3]) derived from the freely available Bloch Simulator [4]. Hence a complete picture of NMR that is equally valid quantum mechanically and classically is provided [2]. The slight differences in interpretation are covered for those who are technically oriented.

Shortcomings of the typical explanation
The explanation of MR appearing in most textbooks is based on the claim that nuclear spins align parallel or anti-parallel to an applied magnetic field. This non-intuitive notion is inspired, but not supported by quantum mechanics [1]. Unless it is followed by a full QM treatment, it leaves the following questions unanswered to most students:

- Why do nearly half the nuclei orient themselves with the spin *opposite* to the main magnetic field, which is the least energetically favorable direction of all (in fact they don't – a QM calculation shows that the random distribution is only slightly skewed by the applied field, [1]).
- Why do long radio wave pulses not just equalize the population in the two energy levels?
- What happens if the radio waves are slightly off-resonance?
- How do the radio waves reduce the phase spread in the transversal plane (create coherence)?

Certainly QM correctly answers these questions and describes magnetic resonance, but it is overly complicated for the vast majority of MRI students, and it is not necessary since MR is a relatively simple classical phenomenon (visualizations based on classical mechanics answers the questions intuitively). Some students may certainly benefit from an additional description in terms of QM eigenstates. Having understood the classical explanation first helps greatly, however.

[1] Hanson, LG. Is Quantum Mechanics necessary for understanding Magnetic Resonance? Concepts in Magn Reson A, 32A (5), 329, 2008.
[2] Feynman RP *et al*. Geometrical representation of the Schrödinger equation for solving MASER problems. Journal of Appl Phys, 28(1), 49, 1957.
[3] The Java Compass, http://www.drcmr.dk/MR
[4] The Bloch Simulator, http://www.drcmr.dk/bloch