

Susceptibility effects in MRI and ^1H MRS

the spurious echo artifact and susceptibility measurements

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Abstract

When performing magnetic resonance (MR) experiments, a strong homogeneous magnetic field is often preferred, especially in clinical applications. However, all objects that are placed in the magnetic field will disturb the field homogeneity and cause local magnetic field gradients. In the human body, which consists of a large number of tissues and organs of different shape and susceptibility (the ability to become magnetised), the field distribution becomes very complex. To minimise magnetic field inhomogeneities in the studied region, shim gradients, of linear or higher order, are locally optimised for each measurement.

In clinical MR the trend is towards higher field strengths, from 1.5 T to 3 T and beyond, and this leads to increased susceptibility effects, both in MR imaging (MRI) and MR spectroscopy (MRS). To have control of the susceptibility effects, and achieve high accuracy in phantom studies, it is valuable to have an easy and accessible method for measuring the susceptibility value of the phantom materials. A method which utilises MRI for susceptibility measurements was significantly improved by using an echo planar imaging sequence instead of the standard implementation of a spin echo sequence. An increased sensitivity and accuracy provides a possibility to detect smaller susceptibility differences, to be more flexible in choice of reference liquid or to decrease the sample volume. An automated evaluation method based on model fitting was also developed and this increased the accuracy even further. Finally, the volume susceptibility of two plastics, commonly used in phantoms, was determined.

For small volume ^1H MRS in susceptibility influenced regions, the spurious echo artifact has become a problem. It is, however, seldom recognised as a susceptibility artifact. In this thesis a k-space description was introduced and the causes and conditions of this artifact were studied. When the shim gradients are optimised for a small volume, the possibility of achieving a good local shim, *i.e.* a locally homogenous magnetic field, is increased. An imaging technique was developed, the WSI-scan (water suppression imaging), which visualises how the global effects of the locally optimised shim might shift the water resonance in some regions outside the water suppression bandwidth. When regions of unsuppressed water overlap with the excitation regions of the volume selection, the probability of a spurious echo artifact increases significantly.

To destroy any outer volume signal strong spoiling gradients are implemented in the volume selection sequences. By using the new modified k-space concept it was possible to demonstrate all magnetic configurations and their relative positions prior to acquisition in one single k-space map. This tool showed to be powerful not only for describing the artifact formation but also for evaluating the effective spoiling of unwanted magnetic configurations and it was applied to two volume selection methods, PRESS (point resolved spectroscopy) and STEAM (stimulated echo acquisition mode). The k-space description was verified by *in vitro* experiments where the magnetic configurations of PRESS were separately refocused into spurious echo artifacts.

This thesis shows that shim gradients are not only likely to shift water resonances of the brain outside the water suppression band, they might also refocus unwanted, and spoiled, magnetic configurations into a spurious echo. The k-space concept, the WSI-scan and the susceptibility measurements all provide important tools for evaluating strategies and prerequisites for high quality ^1H MRS of small volumes.

Keywords: MRI, ^1H MRS, susceptibility, spurious echo, artifact, artefact