Design Optimisation of an Field Free Point Magnetic Particle Imaging Scanner

G. Bringout[1], T.M. Buzug[1]

[1]Institute of Medical Engineering, University of Lübeck, Lübeck, Schleswig-Holstein, Germany

Abstract

Introduction
Magnetic Particle Imaging (MPI) is a new imaging technology aimed at the imaging of a tracer in the human body. First published in 2005 [1], the number of scanner prototypes is growing and there is always more room for optimisation in each new scanner design.

The imaging principle is based on the non-linear magnetisation of magnetic nanoparticles. Placed in a magnetic field they can be used as a tracer material. In a high speed 1D MPI Device, a sinusoidal signal containing a single frequency generate a time-varying magnetic field via the drive coil. Without any tracer in the field of view the receive chain record only the generated signal. With some tracer in the field of view, the receive chain record a different signal, which spectrum contains harmonics from the transmitted signal. Those harmonics are many orders of magnitude smaller than the main frequency and represent our useful signal.

In order to get a spatial encoding, a time-independent field is added to the drive field via the selection coil, in order to saturate the tracer, i.e. to disable any respond, anywhere in the field of view except in a volume, called the Field Free Point (FFP). The FFP is moved by the drive field. This principle is shown in Figure 1.

A 3D FFP MPI scanner includes a minimum of 4 coils sets: 1 selection coil set and 3 drive coils sets (1 per dimension). In order to extend further the field of view 3 focus field coils sets may be added.

During the design of a scanner, the shielding and the coupling between the different coils are of key importance, as the purity of the signal directly depends on those effects. Thus, the interactions between the different elements have to be understood, studied and optimized.

Use of COMSOL Multiphysics®
We propose to use a COMSOL Multiphysics® simulation to be able to calculate otherwise hard-to-obtain values, as:
- the impedance of each coil in air,
- the impedance of each coil in a scanner,
- the shielding efficiency between the drive and the selection coils.

With those quantities, we will be able to adapt the scanner design before the construction, by including the coupling between the coils and the effectiveness of the shielding in the design process.

Results
We successfully calculated the impedance and efficiency of each coil separately, the coupling factor between two drive coils and the influence of a shielding cylinder on the drive coils. Those results allowed us to validate our drive coil design.

Conclusion
The simulation of the scanner allows us to optimise the system before construction, which was done before through many prototyping iterations. Rough calculation can be now studied more precisely with COMSOL Multiphysics® in order to reduce the cost of the systems and increase the performance.

Reference

[1] Gleich B, Weizenecker J (2005) Tomographic imaging using the nonlinear response of magnetic particles. Nature 435:1214-1217

Figures used in the abstract

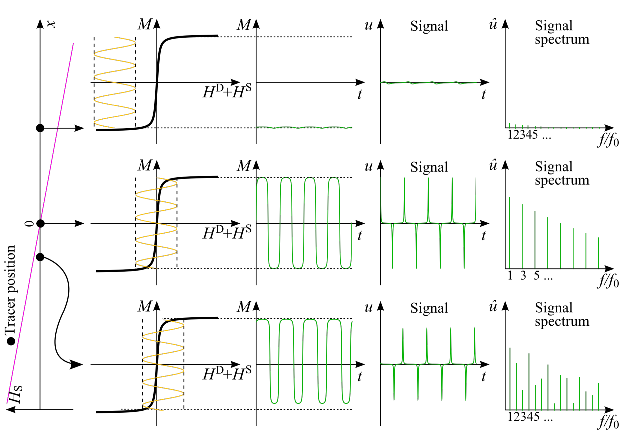

Figure 1: Top: The amplitudes from the drive field (Hd - yellow) and the selection field (Hs - pink) is sufficient to saturate the particle and thus prevent any useful signal to be generated. Middle: In the FFP, the useful signal spectrum is only composed of odd harmonics. Bottom: Outside the FFP, the useful signal spectrum is composed of odd and even harmonics.