with the periodic excitation. The usual applications of MRE include a measurement of the shear modulus in a living tissue or gel-like substances.

The goal of this project was to develop an MRI technique to image a periodic motion in fluids for studies of cavitation, turbulence, thermoacoustics, and fluid flow in media. Although a fluid does not have any shear strength that a gel does, it can still oscillate via a rotational motion in the eddy currents in a turbulent liquid, in a flow through granular/porous media, by a strong acoustic field in a gas or by the motion of cavitating bubbles.

In this project, the concept of MRE was applied to measure the displacements at a range of gradient frequencies with the goal to obtain power spectra of the oscillations. We used a set of the oscillating gradient waveforms (16 Hz–10 kHz) during the preparation part of the sequence with the Z-storage of X- and Y-components of the transverse magnetization with the subsequent use of the spiral SPRITE imaging as a readout sequence. A major problem with applying the ideas of MRE to liquids is the presence of flows that, in case of oscillating gradients, will contribute a non-zero phase. To cancel the flow effect, velocity-compensated symmetric oscillating gradient waveforms were used. The technique was applied to studies of cavitating liquids and a gas in a working thermoacoustical device.

O27 Observing Diffusion-Diffraction Patterns in Heterogeneous Specimens Using the Double-PFG NMR Methodology

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Diffusion-diffraction patterns arising from restricted diffusion are extremely important for characterizing pore morphology. In conventional single-PFG (s-PFG) NMR experiments, pore size can be directly inferred from the minima of $E(q)$ profiles; however, these diffraction troughs are lost in s-PFG when (a) compartments are polydisperse in size, (b) when locally anisotropic pores are randomly oriented and (c) when pores are inhomogeneous. These scenarios are predominant in many porous media found in nature.

The double-PFG (d-PFG) methodology1 is emerging as a powerful technique that can potentially overcome the inherent limitations of s-PFG NMR. Recent theoretical contributions2 have provided exact solutions for restricted diffusion in d-PFG NMR, and predicted the existence of zero-crossings of the signal, $E(q)$. These zero-crossings were predicted to persist even when pores are highly heterogeneous in size or shape.

Here, we experimentally challenged the predictions of the novel theory. We conducted s- and d-PFG NMR experiments on controlled porous media in which the ground truth is known a priori. Water-filled microcapillaries with well known nominal inner diameters (ID) of various sizes were mixed to construct specimens with increasingly broadening polydispersity. Alternatively, microcapillaries were cut or crushed into very small shards to achieve a random orientation. Scanning
Electron Microscopy (SEM) verified that these cylindrical pores were indeed randomly oriented. The resulting porous medium was highly inhomogeneous with a line width of $\sim 0.5\text{kHz}$; therefore, all s- and d-PFG experiments on randomly oriented pores were conducted using bipolar gradients.

Our findings [3] show that indeed, when pores are characterized by a distribution of either size or orientation, the diffusion-diffraction minima in s-PFG disappear. On the contrary, when d-PFG NMR experiments were performed, the zero-crossings persisted for both polydisperse and randomly oriented specimens. For the polydisperse specimens, we found that the $q$-value of the zero-crossing and its rate of return to the ambient background noise level can be used to infer on the average size of the distribution and its width. For randomly oriented porous media, the zero-crossings were experimentally observed for several different IDs, and the accurate sizes could be extracted, but only when using bipolar gradients.

Our results suggest that bipolar d-PFG NMR is the method of choice for studying heterogeneous specimens. The zero-crossings can be used to measure pore size and infer on the presence of restricted diffusion, a difficult task considering the presence of internal gradients. Our results validate the theory and demonstrate that novel microstructural features can be obtained using bipolar d-PFG NMR.


**O28** Improving Estimates of Nuclear-Spin Relaxation Time ($T_1$) in Surface-NMR Experiments

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Surface nuclear magnetic resonance (NMR) is a relatively novel and powerful geophysical technique for investigating hydrological characteristics of shallow aquifers from the Earth’s surface in a non-invasive way. Large current loops of approximate 100 m diameter are laid on the ground to transmit electromagnetic pulses into the subsurface. These pulses excite spins of proton and ground water molecules out of their equilibrium state in the Earth’s magnetic field. The spin response is recorded on either coincident or offset surface receiver loops of similar dimension. The amplitudes of the response signals recorded after single-pulse excitation provide estimates of water-content in the shallow subsurface. Another important parameter is the NMR relaxation time $T_1$, from which information on pore structure or even hydraulic conductivity can be inferred under favourable circumstances. $T_1$ data are conventionally acquired using a scheme that involves two sequential pulses of electromagnetic energy, the second of which is phase-shifted by $\pi$ relative to the first. We show that variations of the excitation field with distance from the transmitter introduce a significant