

# Platform for the Development of Robust Magnetomotive Ultrasound Imaging Algorithms

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## Summary:

In this contribution, we present a platform for the development and evaluation of Magnetomotive Ultrasound (MMUS) imaging algorithms for tissue mimicking materials. The presence of biological disturbances such as respiration or mechanical vibrations in in-vivo experiments interferes with MMUS imaging, which has to be considered for robust algorithm development. An electrodynamic shaker-based approach can be used instead of electromagnets to mimic magnetically induced displacements and biological disturbances to provide enhanced data for MMUS algorithm development and evaluation.

**Keywords:** Magnetic Drug Targeting (MDT), superparamagnetic nanoparticles (SPIONs), Magnetomotive Ultrasound (MMUS), local cancer treatment, ultrasound imaging.

## Motivation

Magnetic Drug Targeting (MDT) with superparamagnetic nanoparticles (SPIONs) is an emerging cancer treatment method for a new local chemotherapy. A promising real-time imaging modality for monitoring the spatial distribution of SPIONs within tumorous tissue during the enrichment is Magnetomotive Ultrasound (MMUS) imaging [1]. A recent review of MMUS can be found in [2]. The basic idea behind MMUS is to induce mechanical displacements in the  $\mu\text{m}$  range within the SPION-laden tumorous tissue by using a time-varying magnetic excitation field. Over the past two decades, various magnetic excitation fields have been studied in tissue mimicking phantoms or in-vivo, including harmonic, pulsed, linear up-chirp, and frequency-shift keying [3]. An overview of phantom manufacturing can be found in [4]. However, the presence of biological disturbances such as respiration or mechanical vibrations in in-vivo experiments interferes with MMUS imaging. In order to include these additional disturbances in the development and evaluation of MMUS algorithms, we have realized an electrodynamic shaker-based platform, which allows the separate mechanical generation of magnetic excitation fields and different biological disturbances within a tissue mimicking phantom.

## Experimental Setup

Common MMUS experimental setups require a very strong electromagnet to magnetically induce mechanical displacements in the  $\mu\text{m}$  range within a phantom. Without biological disturbances, only the internal SPION-laden tissue together with the surrounding tissue will move. Biological disturbances can instead be considered as global movement across both the SPION-laden and SPION-free tissue. Fig. 1 shows a schematic overview of the new MMUS platform. Internal movement can be generated using a shaker and a U-shaped element around the phantom and attached to the surfaces of the phantom parallel to the  $xy$ -image plane. Global movement can be mimicked by using another shaker to move an ultrasonic transducer. To reduce the complexity of in-vivo experiments to one-dimensional biological movements, the ultrasonic transducer can individually move either in  $x$ ,  $y$  or  $z$  direction. Displacements are generated using two Tira TV 51110 vibration systems in combination with a Tektronix AFG3102 arbitrary function generator and are recorded using a Micro-Epsilon optoNCDT 1420 triangulation sensor. Ultrasound data is collected by means of an Ultrasonix SonixTouch ultrasound scanner in combination with a L9-4/38 ultrasonic transducer.

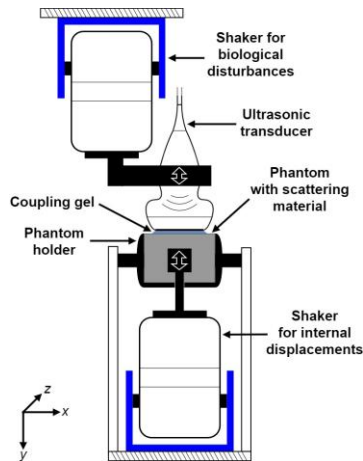


Fig. 1. Schematic overview of the platform for mimicking magnetically induced displacements and biological disturbances for MMUS experiments.

### Experiment and Results

To demonstrate the working principle of the new development platform, we performed an experiment using a disturbed linear up-chirp and a MMUS algorithm explained in [5]. This MMUS algorithm uses a phase-based displacement estimator and cross-correlation filtering for each pixel. The excitation and disturbance generated by the shakers are shown in Fig. 2.

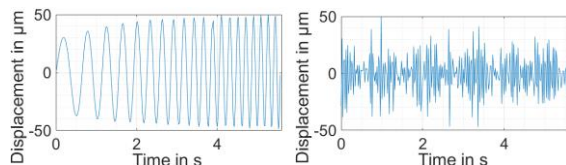


Fig. 2. Linear up-chirp excitation from 1 Hz to 6 Hz (left) and Gaussian noise disturbance (right).

The ultrasound imaging method selected was a clinically scanned B-mode with a center frequency of 6.6 MHz, 58 frames per second, mechanical index of 0.53, and thermal index of 0.37. Fig. 4 shows a B-mode image of the utilized phantom with scattering material. For comparison, a phase-based displacement estimation of a selected pixel with and without disturbance is depicted in Fig. 3.

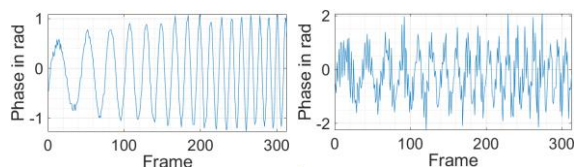


Fig. 3. Phase-based displacement estimation without disturbance (left) and with Gaussian noise disturbance (right).

The final MMUS image after evaluating each pixel for maximum displacement is illustrated in Fig. 4. It shows decreasing movement from the excitation through the surrounding area to the surface. The movement on the surface could be confirmed using the triangulation sensor.

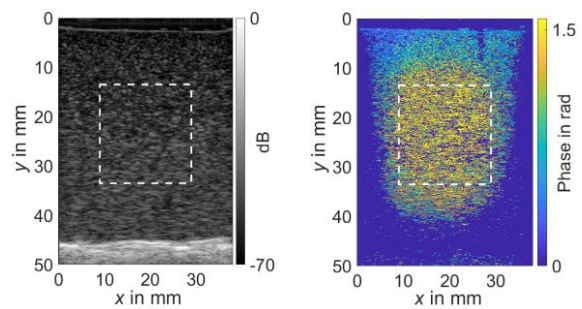


Fig. 4. B-mode image of utilized phantom (left) and MMUS image (right). The dotted box indicates the location of the attached U-shaped element.

### Conclusion and Outlook

This contribution demonstrates a new shaker-based platform for MMUS algorithm development. It could be shown that one shaker allows mimicking very low internal displacements in the  $\mu\text{m}$  range, and that an additional shaker can be used to add disturbance on top. Finally, it was possible to mimic common MMUS setups and to perform MMUS imaging of disturbed internal displacement. This platform enables to study and develop new MMUS algorithms under new conditions. Future research will focus on different excitations and disturbances. In addition, an ultrasound-based method to determine the contours will be investigated to better differentiate between tumorous and healthy tissue.

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