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## MRI Compatible Ultrasound Transducers for Simultaneous Acquisition of Coregistered Ultrasound to MRI Data

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### Abstract

Magnetic resonance imaging has become an important part of radiological diagnostics as it shows high resolution volumes of human tissue without any radiation exposure. Beside the high costs for MR imaging the greatest disadvantage of this technology is that it is not real-time capable which leads to possible motion artifacts.

Whereas Ultrasound is the most common diagnostic tool in radiology as it is real-time capable and cost effective. Therefore a combination of both modalities is obvious, not only to reduce motion artifacts in MR imaging but to save costs by reducing time in the MR scanner through coregistering ultrasound and MR images for deformation analysis.

This work presents the manufacturing and measurement results of MR compatible ultrasound transducers for motion compensation and deformation analyses for clinical interventions under MRI conditions, based on ultrasound volumes acquired by a full MR compatible 180° rotating 8 MHz phased array.

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## 1. Introduction

It is well known that not real time capable medical imaging methods are showing motion artefacts due to breathing and movement of the patient during the examination. The first step of our approach to improve this was to combine real time ultrasound simultaneous to MR imaging, [1]. This allows to detect and track the motion during the MR image is acquired. With this information it is possible to calculate retrospective an image without motion artefacts as shown in earlier publications [1-3]. Therefore the ultrasound transducers must be completely MRI compatible, which means that both modalities must not disturb each other during the examination.

In the second step these ultrasound transducers have been enhanced by a disposable adhesive pad system and a full MRI compatible motor for 3d motion tracking while the transducer is fixated on the body. This allows the acquisition of volumetric deformation information, coregistered to the MR data, not only for motion compensation but also for deformation calculation of the MR data in real time after the image has been taken [4]. Tang et al. [5] already reported an improved breast biopsy by combining both modalities with a 2d transducer for additional ultrasound information during the MRI-guided biopsy. Whereas the presented work allows to bring the patient from the MRI scanner room to an examination room while the fixated transducer still acquires ultrasound volumes (Fig. 1). Based on this, the physician is able to biopsy under real time MR images which are calculated from the consecutive acquired ultrasound data.



Fig. 1 MRI compatible ultrasound system for improved breast biopsy

This allows to biopsy under MRI conditions, where nearly all tumors are visible, whereas in ultrasound images around 30% of the tumors are invisible. Another benefit is that the time consumption in the MR scanner could be reduced by half which reduces the costs for a MRI-guided biopsy dramatically. Furthermore the access path to the tumor is limited within the MRI tube wherefore the most optimal path cannot be taken.

In this work the development, fabrication and measurement results of different MRI compatible ultrasound transducers for motion tracking and deformation analysis are presented.

## 2. Materials and Fabrication

To use ultrasound probes in strong magnetic fields, first of all it must be ensured that all components are non-ferromagnetic. That means that iron (Fe), nickel (Ni) and cobalt (Co) comprising parts could not be used. Therefore all parts have to be examined for these materials.

Especially piezoelectric materials are often plated with nickel or it is used as coupling agent for gold layers.

Backing materials as well as acoustic matching layers are also often filled with metal particles to increase the density and with that raise the acoustic impedance.

The last part relates to the shielding, wiring and housing including construction parts like screws and clamps.

Another important fact refers to the dynamic field where conductive structures are leading to eddy current artefacts.

There are different possibilities to avoid or minimize eddy currents. As a general rule all conductive materials which are not absolutely necessary should be avoided. Small structures with small masses like wiring and connection pcbs don't disturb the field significantly, whereas shielding normally has to be done on a larger area with higher mass.

### 2.1. Shielding Concept

We found that the MRI system doesn't influence the ultrasound system in the way it does conversely. In most cases we reached noise free ultrasound images with the standard cable shielding and a thin metal coating inside the probe housing. On a less positive note, the MRI System has such a high sensitivity, that it receives the ultrasound harmonics up to 125MHz (Fig. 4). To take this into account a special shielding concept consisting of different thin layers of various materials in combination with a low pass filter in the transmitting path of the system. The aperture could be shielded by a metal filled polymer which is also used as acoustic matching layer, as reported by Gerold et al. [6].

### 2.2. MRI compatible motor

Especially for breast biopsies as much as possible information of deformation in different tissue layers is needed to calculate the deformation of the MR image based on ultrasound data. To have regard to this we decided to acquire full volumes with a  $180^\circ$  per second rotating transducer at an angular resolution of  $0.1^\circ \pm 0.05^\circ$  (Fig. 2). The motor consists also only of non-ferromagnetic materials and is driven by piezo elements based on the travelling wave principle. It had been tested successful under MRI conditions while acquiring simultaneous ultrasound volumes.



Fig. 2. (a) Section view of 8 MHz rotating ultrasound transducer; (b) acquired ultrasound slices; (c) calculated Volume

### 2.3. Adhesive pads for ultrasound transducers

To ensure that the position of the transducer doesn't change during the MR image is taken or the patient is being brought to the biopsy room, a disposable adhesive cap (Fig. 3) has been developed. It keeps the transducer in position during the examination and the biopsy. The adhesive pad had also been tested for biological safety for use in medical environments.

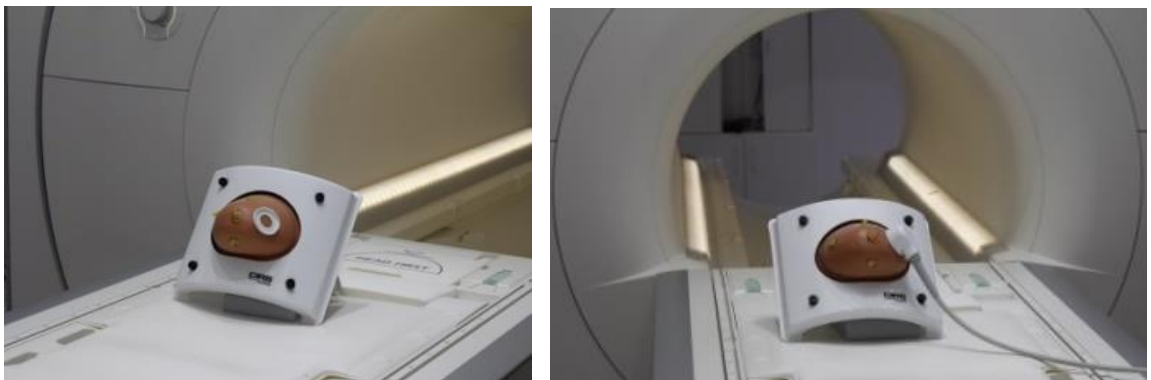


Fig. 3(a) Breast phantom with disposable adhesive cap; (b) fixed transducer

### 3. Measurements and application

To ensure signal integrity the disturbances had been measured in different setups at an EMC laboratory to get a better idea of the emitted signals. With the first prototype, we were able to reduce the emission above 55 MHz to the noise floor (Fig. 4a)

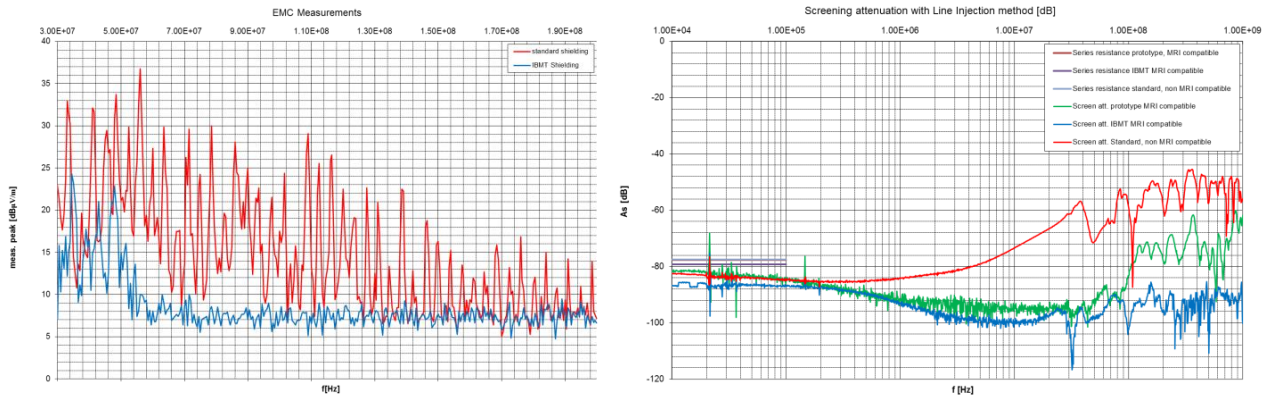


Fig. 4. (a) EM emission of probe and cable; (b) screening attenuation with line injection

Based on this information a special shielding concept with the intention of industrial fabrication has been developed and verified by line injection measurements. It showed screen attenuations of -94dB at 64 MHz (1.5T) and -96dB at 127.5 MHz (3T) (Fig. 4b).

With this setup different transducers between 3.75 MHz and 8 MHz center frequency have been built and tested at 1.5 Tesla and 3 Tesla tomographs without significant interferences (Fig. 5).

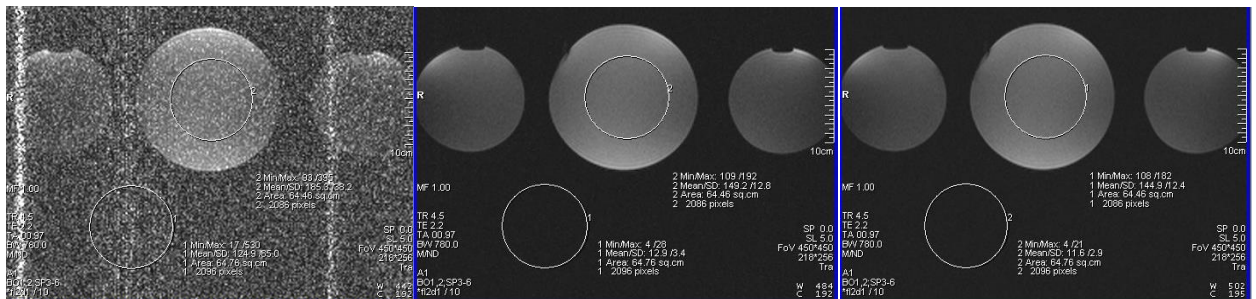


Fig. 5. (a) MRI Phantom, standard shielding, ultrasound transmission on; (b) IBMT shielding; (c) ultrasound system off.

Whereas MR images with standard US cable show strong noise artefacts, the special shielded Transducers causes approximately the same SNR than the MR system with a turned off ultrasound system.

Also important is that the conductive mass of the transducer does not lead to eddy currents and field artefacts. Although the shielding has conductive structures, the artefacts could be minimized by reducing the effective mass with the multi-layer shielding concept (Fig. 6)

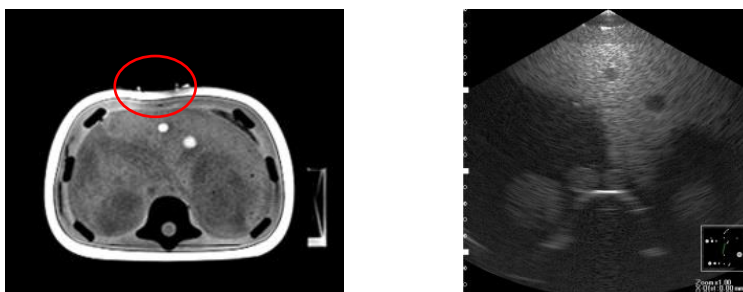


Fig. 6. Multimodality Phantom with attached ultrasound probe (a), MRI scan ; (b) simultaneous acquired ultrasound scan;

#### 4. Conclusion

Emission of the ultrasound transducer and system has been determined. Based on that information a shielding concept had been developed and verified. It has been shown that simultaneous acquisition of MRI and ultrasound data is possible, based on the multilayer shielding concept for cable and transducer just as filter networks for the transmission path of the ultrasound system. This has been used successfully for motion compensation as well as deformation analyses for real time MR imaging based on coregistered ultrasound data to improve clinical intervention like breast biopsies.

The presented technology could also be used for surgical interventions or as guidance for radiotherapy.

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