Fully Integrated Whole Body 3T MRI System for Parallel RF Transmission

I. Graesslin[1], P. Vernickel[1], J. Schmidt[1], C. Findelklee[1], P. Roeschmann[1], U. Katscher[1], C. Leussler[1], P. Haaker[1], K-M. Luedeke[1], J. Keupp[1], P. Börnert[1], H. Dingemans[2], G. Mens[2], K. Blom[2], J. vd. Heijden[2], P. Harvey[2], and J. Overweg[1]

[1]Philips Research Europe, Hamburg, Germany, [2]Philips Medical Systems, Best, Netherlands

Introduction

Wave propagation effects in RF fields are a primary cause of inhomogeneities in body MR imaging at field strength of 3T and above. RF shimming based on multi-channel RF transmit (MULTIX) technology [1-4] is a very promising approach to compensate for these effects. However, the miscellaneous challenges of the MULTIX approach, such as patient safety, and compatibility with conventional MR imaging techniques, still require adequate hardware design considerations. In this study, a design comprising an eight-channel transmit/receive system fully integrated into a commercial 3T whole body MR scanner is presented. Patient safety issues are addressed, and conventional imaging techniques are supported. First phantom- and in vivo experiments proof the concept of the present implementation.

Methods and Design Considerations

A sketch of the present MULTIX system architecture is shown in Fig. 1. For full control of spatio-temporal variations of the B1 field, the control of amplitude and phase of each RF channel is required. Furthermore, all RF channels must be accurately synchronized in time [5,1] to avoid artifacts. To fulfill these requirements, a scalable control and data acquisition system was employed (CDAS Freewave, Philips Medical Systems), which provides a sub-nanosecond synchronization accuracy of the complete control hardware. To reduce the system size and to ease an integration into existing installations, an integrated eight-channel solid-state RF power amplifier (AN8140, 5kW peak, Analogic Corp., Peabody, MA) was employed for parallel amplification of the independent transmitter channels. To ensure patient safety, a pick-up coil for each transmitter element provides continuous monitoring of RF amplitude and phase [6]. All coils are connected to dedicated monitoring inputs on the transmitters, and all RF power modules are switched off by the RF amplifier shutdown unit in case of a detected channel failure.

The RF power signals are routed via high-power transmit/receive switches to the respective elements of a multi-channel body coil (MBC) [7], which consists of eight transmit/receive TEM resonators. A front-end-interface (IF) routs the eight RF receive signals of the MBC to two four-channel receiver boards (Rx 1/2). Alternatively, conventional receive surface coils can be connected to the system via a coil interface to support existing MR hardware. Furthermore, other multi-channel transmit/receive coils, in particular Tx/Rx head coils, can be connected to the coil interface.

The system also provides an imaging mode emulating, a circularly rotating B_1-field of the MBC, as present in a standard body coil. In contrast to [4], this mode was realized entirely software-based, making additional RF amplifier superfluous, and reducing space requirements.

To evaluate the performance of the present configuration, two applications of MULTIX technology, namely RF shimming and an accelerated spatially selective excitation, were evaluated. Phantom and first in vivo experiments in healthy volunteers were performed. Written informed consent was obtained from the volunteers.

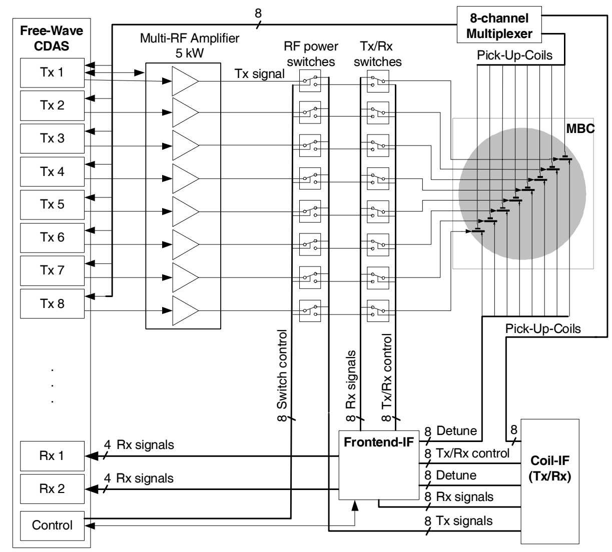

Fig. 1: Simplified block diagram of fully integrated eight-channel Tx/Rx MULTIX system architecture that supports an eight-channel Tx/Rx body coil or local Tx/Rx coils.

Results

The results of the phantom experiments, which included different prototypes of multi-channel transmit/receive head coils as shown in Fig. 2, are shown in Fig. 3. A 3D spatially selective RF pulse could be accelerated by a factor of two. First in-vivo whole-body results including RF shimming are shown in Fig. 4. All in vivo experiments were completed successfully proving the concept of the present design.

Discussion and Conclusion

The present MULTIX design was successfully integrated into a commercially available 3T MR system (Achieva, PMS, The Netherlands). All additional RF electronics and system control could be integrated into one single rack in the existing technical room. The modular concept of the employed hardware eases the maintenance in case of hardware failure and reduces thermal inter-channel variations, resulting in improved image quality. Other advantages of the current design include the software-based implementation of a circular B_1-field emulating a conventional body coil to support existing MR protocols. The current design also offers improved patient safety monitoring and overcomes the limitation of previous multi-channel power-monitoring units (PMUs), which monitor the maximum peak and average power, but do not take phase deviations or channel failures into account. The system has proven to be flexible and to allow an easy operation and exchange of multi-channel Tx/Rx (head) coils connected to the Coil-IF.

In conclusion, the current MULTIX hardware design represents a versatile experimental platform to study new methodological concepts and hardware approaches in the rapidly evolving field of multi-element transmission.

Fig. 2: A Tx/Rx head coil with eight TEM elements, consists of two rings of four elements each (3D- or z-segmented).

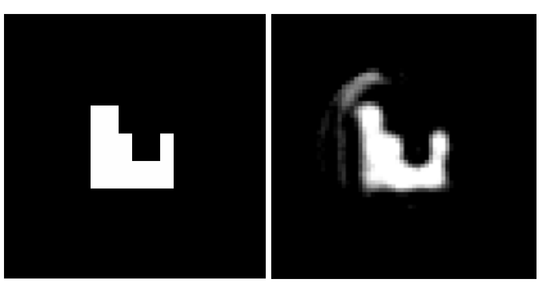

Fig. 3: Example of a 3D excitation pattern accelerated by a factor of two.

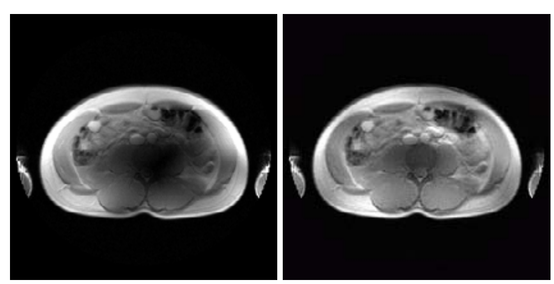

Fig. 4: Comparison of an un-shimmed (left) and shimmed (right) in-vivo experiment of a transversal view of the abdominal region.

References

[1] Ullmann P, et al. [2005] MRM. 54:994-1001
[2] Zhu Y, et al. [2005] ISMRM 13:14
[3] Setsompop K, et al. [2006] MRM 56:1163-1171
[4] Graesslin I, et al. [2006] ISMRM 14:129
[5] Seifert F, et al. [2002] ISMRM 10:162
[6] Graesslin I, et al. [2006] ISMRM 14:2041
[7] Vernickel P, et al. [2006] ISMRM 14:123