Whole Body 3T MRI System with Eight Parallel RF Transmission Channels

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Introduction

Dielectric resonance effects diminish the quality of body MR images at main fields at 3T or above. Parallel RF transmission techniques bear the potential of compensating for these effects through RF shimming. Such techniques have been studied in simulations [1], and first multi-channel transmit systems were presented recently [2-4]. Furthermore, such systems enable advanced parallel transmission imaging techniques like [5-7], e.g., to accelerate multi-dimensional RF-pulses. This paper describes the first MRI prototype system based on a modified clinical MR scanner, which features whole body imaging at 3T using genuine eight-channel transmitter/receiver (Tx/Rx) technology.

Methods and Discussion

A system with the capability of fully controlling spatio-temporal variations of the B_1 field must have independently controllable transmit channels in terms of amplitude and phase. To avoid artifacts, the transmit channels must be accurately synchronized in time [2,3]. In order to achieve this, a scalable control and data acquisition system (CDAS, FreeWave spectrometer) is used, which can be configured with multiple Tx/Rx channels in a single rack. The RF transmission signals for the eight channels are generated by independent transmitters (Tx1-Tx8) as shown in Fig. 1. All transmitters are synchronized with sub-nanosecond accuracy. Amplitude and phase of individual channels are controlled via individual solid-state RF amplifiers (AN8132, 8kW peak, Analogic Corp., Peabody, MA). Safety precautions are taken into account by implementing an RF amplifier shutdown unit (SDU), which turns off all amplifiers immediately in case a single amplifier fails. This is required to circumvent safety hazards due to a potential increase of local SAR under unfavorable conditions. Circulators protect all amplifiers against reflected or coupled power from the coil elements. The reversely directed power is absorbed by 50 Ohm loads connected to these circulators. Each channel is equipped with its own transmit/receive switch. The RF power is sent to a multi-element body coil (MBC), which consists of 8 TEM resonators useable in transmit and receive mode. Eight parallel signals are received with the MBC and routed to individual receiver boards. Alternatively, standard receive surface coils can be used for signal reception. Each TEM resonator is equipped with a pickup coil to monitor the current in each element for safety reasons. The system also allows imaging with a conventional body coil and a circularly rotating B_1-field. In this "single channel mode", the RF-paths are reconfigured by electro-mechanic RF switches. A single RF-amplifier, controlled by an additional transmitter board (Tx), in combination with an RF power splitter and phase shifters provides the signals for the generation of a circularly polarized B_1-field. This mode assures system operation of all standard imaging protocols without safety issues associated with multi-Tx systems in clinical routine. Both imaging modes were used to acquire phantom ($\varnothing$ = 40cm) images. A T1-weighted FFE sequence was used for the single channel mode. On the other hand, spatially selective patterns with 32×32 pixel were excited in parallel in the multi-channel mode. Reduction factors between 1 and 8 have been applied, corresponding to spiral k-space trajectories between 16 and 2 revolutions. A modified spin echo with a non-selective refocusing pulse was used. The sensitivities were acquired with a non-selective sequence separately for each array element.

Results

An eight-channel Tx/Rx body coil and associated electronics to support parallel transmission with up to eight independent channels was integrated into a 3T MR system (Achieva, PMS, The Netherlands) and put into operation. This system offers a multi-channel transmit and a standard single channel-imaging mode. Examples for the imaging results of the MRI experiments in both modes are shown in Fig. 2 and Fig. 3.

Conclusion

In this paper, the successful integration of an eight-channel Tx/Rx whole body imaging system, using a scalable system architecture, is presented. Such a system forms the basis for solving RF homogeneity issues due to dielectric resonances, which has the potential to deteriorate image quality at high fields. Furthermore, spatially selective excitation might be the key for a new field of diagnostic applications.

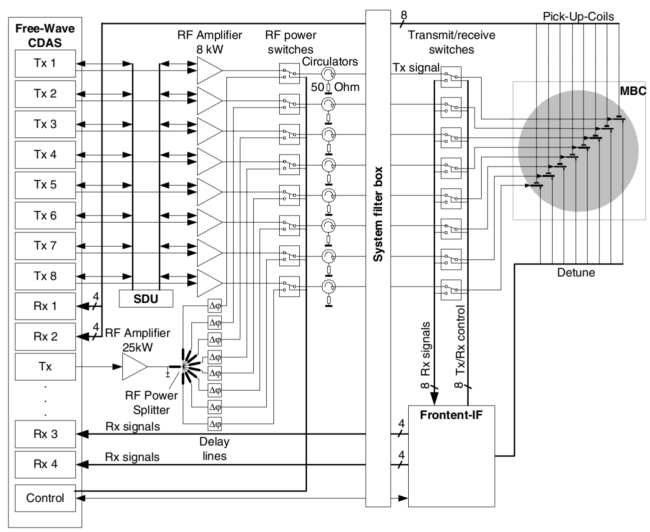

Fig. 1: Simplified block diagram of eight-channel Tx/Rx MR system architecture with two operation modes.

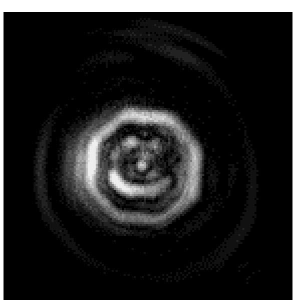

Fig. 2: Example result for a multi-dimensional RF pulse. Eight independent transmit elements and a 4-fold reduction have been applied, i.e., a spiral k-space trajectory with 4 revolutions for a pattern with 32×32 pixel.

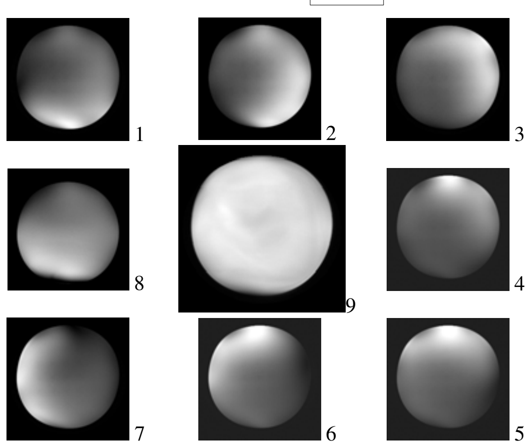

Fig. 3: The eight single transmit sensitivities (1-8) of the phantom were obtained by exciting the parallel transmit channels sequentially in the multi channel mode. The phantom was excited homogeneously (9) using the "single channel mode" via transmitter Tx.

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