Plug and play multi transmit head coil with integrated receiver arrays for clinical 7T MRI.

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Introduction

MRI at high magnetic field strengths like 7T has shown great potential in high resolution imaging, particularly in the human brain. In fact, sensitivity of the proton spins may no longer limit the spatial resolution that can be obtained in a reasonable scan time. Therefore, acceleration techniques are very effective at 7T and result in MRI with superb detail. However, the B1 field at 7T is non-uniform in the human head, resulting in a limited field of view with non uniform contrast in the brain. Using a multi transceiver coil array, B1 uniformity can be regained. So far these transceivers have been optimized for B1 uniformity and minimized RF power deposition, therefore not exploiting the full benefit of dedicated receiver coils that are generally available in a higher number, provide more SNR and have improved SENSE capability. When splitting up the transmitters from the receivers, the transmit coil size will increase, providing reduced tissue load dominance therefore more prone to mutual RF coupling between the elements. As a consequence the impedance at the coil input substantially relates to the current density and phase of the other elements, making conventional RF shimming strategies inaccurate. Fortunately pick-up probes have been suggested [2,3] to counteract for RF coupling, making the coupled multi transmit setup less sensitive to mismatched coils. We therefore developed a fixed-tuned 8 element stripline array with an inner diameter that fits a 16 channel receiver head array. This setup including 8 integrated pick up coils is fully interfaced to a clinical 7T MR system, providing capability of multi transmit with automated coupling matrix detection while preserving full capabilities in MR detection.

Methods

Fig 1: An 8 channel transmit/receive coil in combination with a 16 channel receive array

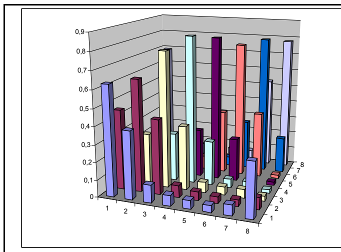

Fig 2: The coupling matrix between the transmit channels as measured in a volunteer. Note how the coupling decreases as the distance between the elements increases.

An 8-elements stripline array was mounted on a Plexiglas cylinder (inner diameter = 28cm). Each element consists of two striplines (2 x 8 cm in length), which are connected in parallel using a half lambda cable to provide a balanced network and minimize current density variations over the total length of 17 cm. The distance between the ground plane and main conductor of the element is 2 cm, in which a 1 cm pick-up probe was mounted. For each 8 elements, both the cable of the pick-up probe and double stripline element were passed through a ceramic tuned cable trap and interfaced to the MR system (i.e. pickup probes directly, and transmit elements via a transmit receive switch). A commercially available 16 channel head array (Nova Medical) was used as a receiver, shifted in the multi transmit array and interfaced to the MR system as well. Figure 1 shows the setup.

Receiver coil characteristics were determined using proton density MR images obtained interleaved with the 8 channel coil as a transceiver and with the 16 channel receiver coil as commonly used in the MR system (reference scan). B1 maps were obtained for each transmit channel using the double TR method [1]. A full 8 x 8 coil coupling matrix was obtained in a separate measurement using the pickup probes as receivers during transmission with each channel sequentially. Convergence was tested by running the procedure two times, while updating the coupling matrix and hence counteract the coupling.

To demonstrate in vivo use, MR images have been obtained from a healthy male volunteer in two sessions, either with the 8 element coil as a transceiver or as a transmitter, while receiving with the 16 channel receiver coil. Channel decoupling was not used in these measurements.

Results and discussion

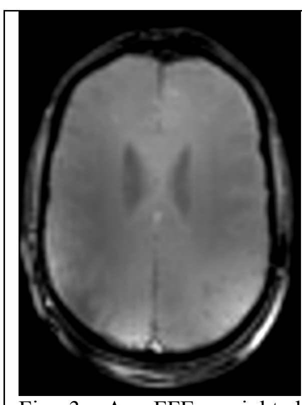

Fig 3: An FFE weighted image obtained using the 8 channel transmit/receive coil.

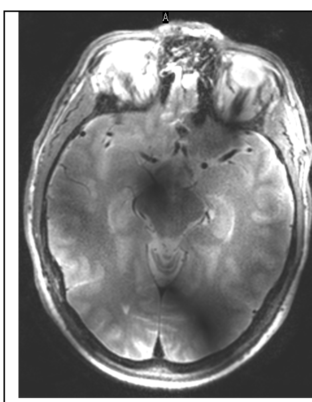

Fig 4: A slice from a PD weighted TSE series obtained with the 8 channel transmit coil using the 16 channel receive array. A SENSE factor of 2.5 was used

RF coil coupling as measured on the bench using a network analyser (S12) was approximately -10dB for all nearest neighbours and -13dB for the next neighbour. Unloaded Q values of each element are about 300, while loaded no less than 200. Therefore tissue load dominance is not obtained, and with the relatively high Q values making the system prone to RF coupling. Loaded with a human head, and fully integrated to the MR system, 2 runs of measuring the 8 x 8 coupling matrix was obtained in a few seconds. The resulting coupling matrix is shown in figure 2. B1 field maps were obtained in 2 minutes, while a full 3D reference scan was obtained in 1 minute. A slice from a FFE image obtained with the 8 channel transceiver is shown in figure 3. A TSE image using a SENSE factor of 2.5 was obtained using the 8 channel coil as transmit array and the 16 channel coil as receiver. RF shimming was not optimal in this case as is clear from the dark void in figure 4.

Conclusion

In this work we have demonstrated the design and implementation of a 7T coil setup for optimized transmit as well as receive in the human head. By merging the benefits of multi transmit for uniform B1 with multi receive for optimized SNR and acceleration, full potential of 7T MRI can be obtained. Combined with full integrated pick-up probes, interfaced to the clinical platform, and with calibration procedures that take less than 5 minutes, we think that this setup will bring 7T MRI closer towards clinical use.

Reference [1] Yarnykh VL. Magn Reson Med 2007;57(1):192-200. [2] Scott et al ISMRM 2007, [3] Vernickel et al ISMRM 2007.