An Eight Channel Transmit/Receive Body Coil for 3T

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Introduction

Multi-channel transmit MR systems bear the potential of compensating signal intensity variations occurring at higher field strengths due to dielectric resonances. Methods like RF shimming [1] and local excitation [2] in combination with Transmit Sense [3] can be applied to compensate for these effects. Moreover, methods like Transmit Sense [3] can be used to facilitate the excitation of arbitrarily shaped pattern [2]. The implementation of these methods adds new requirements to the MRI hardware, especially with respect to the number of RF transmit channels. This work describes the implementation and testing of a decoupled eight-element transmit/receive body coil for 3T and its integration into a standard clinical MRI scanner.

Methods

The eight-element coil was built to perform whole body imaging at 3T using eight independent transmit channels. The transmit elements of the multi-element body coil (MBC), designed as TEM resonators, were mounted equidistantly in the RF screen. The dimensions of the TEM elements were chosen to excite the standard imaging volume homogeneously. The conductor structure was implemented in PCB technology to obtain a good reproducibility for the different elements. Special care was taken to avoid eddy currents. The resonators were tuned to 127.7MHz and matched to 50Ω. Each transmitter had to be matched separately due to the cylindrical arrangement of the RF transmitters and the asymmetric shape of the body. The matching procedure was performed for a human volunteer with average weight and size and verified for a variety of test phantoms and persons. The electromagnetic decoupling of the coils was achieved by using a capacitive end ring [4]. The end ring is connected to the elements by an additional capacitor per element (Fig.1). The elements can be detuned by switching diodes in the centre of each element. The receive signals are directed to low noise amplifiers (LNA) using Tx/Rx switches. The noise impedance of the preamplifiers is 50Ohm. Therefore, the matching for the transmit and receive mode was the same. The receive signals of the eight elements are processed individually and can be combined according to the user's requirements. Each TEM resonator is equipped with a figure-eight pickup coil to monitor the current in the element selectively for patient and system safety reasons. The MBC can be driven by a standard single channel power amplifier and an 1-to-8-channel power splitter. The optimal phase distribution for the coil elements ($\varphi = k\pi/4$, $k = 0 - 7$) was adjusted to obtain a circularly rotating B_1-field. The single channel mode enables to use standard single transmit protocols for imaging. Alternatively to the single channel mode, the MBC can be driven by eight independent waveform generators and amplifiers (AN8132, 8kW peak, Analogic Corp., Peabody, MA). In this multi channel mode, RF shimming and Transmit SENSE can be demonstrated. Both driving modes were tested in MR imaging of a cylindrical phantom (∅ = 40 cm, standard copper sulphate solution) in a Philips 3T Achieva system (Philips Medical Systems, Best, NL). A T1-weighted FFE sequence (TR = 8ms, TE = 2.3ms, $\alpha = 15°$) was used to demonstrate imaging of the phantom for the single channel mode. The multi channel mode was used to measure the transmit sensitivities of the coil. For this purpose, all eight parallel channels were driven sequentially using the same imaging parameters. The eight receive signals for both modes were combined using a sum of squares algorithm in the image domain.

Results and Discussion

The mismatch S_{11} of the individual channels is better than –12dB for different sizes and positions of phantoms and human volunteers. This permits a robust matching of the transmitters and assures that at least 93.5% of the power reaches the transmit coil elements. The coupling S_{nm} (n,m = 1 – 8, $m \neq n$) between the coil elements is smaller than –15dB indicating a good separation of the coils transmit sensitivities. The coil performed well in both imaging methods. Fig.2 shows the result of the single channel transmission experiment. The phases and amplitudes were properly matched to obtain homogeneously excited images. The remaining intensity modulation was caused flow in the phantom. The eight single transmit sensitivities are presented in Fig3. The transmit sensitivities are linear independent, as indicated by the scattering parameters.

Conclusion

A novel multi-element body coil was developed and integrated into a Philips 3T Achieva system. Initial imaging experiments demonstrate the excellent performance of the coil. The new eight-channel Tx/Rx MRI scanner platform offers the possibility to carry out a variety of multi-channel transmit experiments.

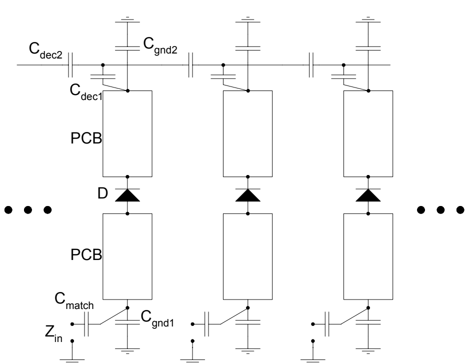

Fig.1 Circuit model of the eight channel body coil. The capacitor C_{match} is used to match the impedance of each coil to 50Ω. The diodes D are used to detune the coils. Capacitors C_{dec1} and C_{dec2} are used to decouple the elements. The TEM element is connected to the RF screen using the capacitors C_{gnd1} and C_{gnd2}.

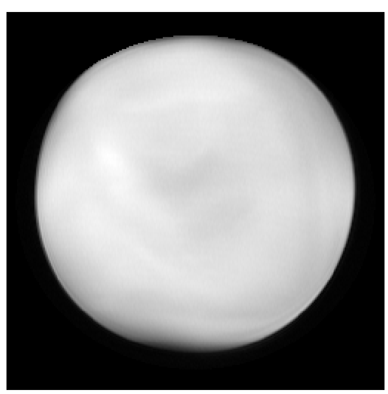

Fig.2 Phantom image using the coil driven in birdcage manner. Equal amplitudes and a phase distribution of $\varphi = k\pi/4$ ($k = 0 - 7$) was used to excite a circular rotating B_1 field. The intensity modulation is cause by flow in the phantom.

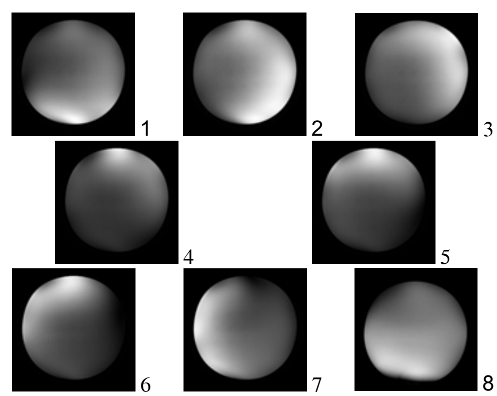

Fig.3 The eight single transmit sensitivities of the phantom were obtained by exciting the parallel transmit channels sequentially. The good separation of the channels indicates a good suitability for applications like Transmit Sense.

References: [1] Ibrahim TS., Lee R., Baertlein BA., Abduljalil AM., Zhu H, Robitaille PM., Effect of RF coil excitation on field inhomogeneity at ultra high fields: a field optimized TEM resonator, JMRI 19(10):1339-47, 2002, [2] Pauly J., Nishimura D., Macovski A., A k-space analysis of small-tip-angle excitation, J. Magn. Reson.; 81: 43-56., 1989, [3] Katscher U., Börnert P., Leussler C., van den Brink J., Transmit SENSE, MRM 49, 144-150, 2003, [4] Jevtic J, Ladder networks for capacitive decoupling in array coils, Proc. ISMRM 9: 17, 2001,