

7T MR System Design Approach for Research Applications

M. Morich¹, M. Knopp², G. DeMeester¹, K. Nieman¹, D. Blakeley¹, L. Eastwood¹, J. Patrick¹

¹Philips Medical Systems, Cleveland, Ohio, United States, ²The Ohio State University, Columbus, Ohio, United States

Introduction

There are potential advantages and challenges associated with the design of 7T MR systems. System design considerations must promote the anticipated advantages and address the challenges. The goal is the creation of an MR platform, which realizes the potential of 7T MR imaging building on the clinical utility already established at 3T. While a primary goal is head ¹H imaging and fMRI capability, spectroscopy and studies of alternate nuclei are also of key interest. We describe a new 7T MR system design intended to foster the advancement of these research applications.

Methods

The Philips design approach placed emphasis first and foremost upon the goal of a 7T system with software and control capabilities equivalent to our current clinical systems. The system is based around a 7T 900mm bore superconducting magnet that is iron room shielded for fringe field reduction. Clinical Philips 3T Achieva system components served as a baseline. Where appropriate, unique components were designed specifically for 7T operation. A separate RF room shield is utilized and includes a unique RF vestibule area that extends beyond the end of the magnet and patient handling system to allow for a lower field subject preparation area. System covers are designed to integrate the magnet and RF room as one unit.

The patient handling system is detachable, has minimized magnetic attraction force, and allows remote subject positioning much like the 8T system at The Ohio State University. The patient handling system controls are located at the end most distant from the magnet. The tabletop also has provision for interface of RF coils that allows positioning of a subject in the coil, on the patient handling system, in the vestibule area. These measures allow for the user to minimize field exposure as the vestibule area has a static field below 0.1T.

The allocation of components in the available bore space was given special consideration. The third order resistive shims are a separate structure from the gradient coil to minimize mechanical and magnetic coupling. The body-access self-shielded and reinforced high performance gradient coil has integral second order resistive shims and self-shielded Z0 and Z2 shims. Resistive shims are controlled via a 14-channel shim power supply subsystem. We excluded passive shims from the gradient coil to maximize gradient coil mechanical strength and minimize potential temperature related field drift associated with passive shims. A separate reinforced patient bore tube is used and combines several functions, including provision for minimum passive shim iron, bore lighting and subject isolation from other bore components. All bore components, including patient support structures, are independently mounted in a manner to minimize vibration transmission.

Both TEM and Birdcage ¹H T/R brain coils were analyzed previously [1]. Our current approach utilizes the birdcage coil as described. It is anticipated that RF coil developments will be key to useful MRI and MRS at 7T. The control and data acquisition system, based on the Achieva 3T multi-channel system, was adapted using a separate frequency translator subsystem. The broadband radio-frequency power amplifier (4kW) is a 7T specific component and the system design allows for up to two of these units with independent transmit control on the two channels for combined or separate operation.

Components common to the clinical 3T Achieva system are the gradient amplifiers, operators console, reconstructor, mains distribution and water-cooling subsystems. System software, including sequences/methods and reconstruction, is based on the Achieva 3T platform and modified appropriately for control of 7T unique components and sequence optimization for 7T imaging.

Results

The described 7T system was integrated in Philips Medical Systems, Cleveland, for development purposes. To our knowledge this is the first such system in a factory setting. The system was principally shimmed using superconducting shims integral to the magnet. A small amount of passive shims was used (~35 grams of iron), which was pre-calculated based on a bare field plot in the magnet factory and corrected for the site and iron shield. Using the pre-calculated shim distribution and superconducting shimming the final result after system integration was <5 ppm peak-to-peak on 45 cm DSV. It was determined that the components mounted in the bore had minimal affect on the shimming. The fringe field was measured and matches predictions.

A limited subset of MR sequences were selected for initial human imaging and acoustic noise verified to be within safe levels with typical ear protection measures. Appropriate peripheral nerve stimulation and SAR controls are implemented in the software. An IRB was put in place to allow for human scanning. Initial human ¹H images of the brain have been obtained with the integrated system using a single channel T/R coil to start. The expected dielectric effects are observed. We anticipate future RF developments to mitigate these effects. Work will continue toward optimizing the system for MR research use at specific sites.

Conclusions

Operation at 7 tesla places substantially different and more demanding constraints upon the system designer than that of 1.5T or even 3T systems. When considering the needs for 7T operation, we find that approximately 70% of our 7T system hardware components are either modified or completely redesigned versus our 3T systems. However, and importantly, the software and methods base is largely being re-used (albeit methods remain to be optimized for 7T).

References

[1]. Gordon D. DeMeester, et al. ISMRM, Kyoto 2004, p. 35