A Mechanism to Produce Translational and Rotational Motion of a Phantom Inside an MR Scanner

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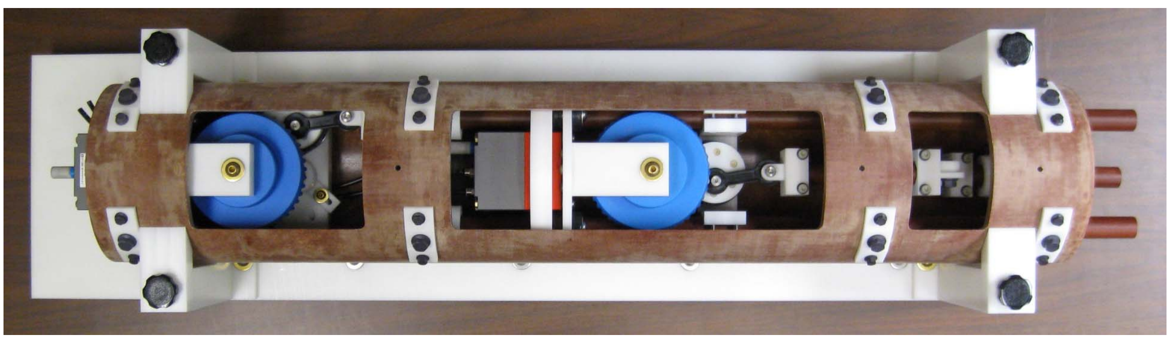
Objectives

Our group is developing a computer controlled motion simulator to provide a reference for developing and validating prospective real-time motion correction methods for brain MRI. The objective of the simulator is to provide 2 controlled degrees of freedom motion (+/-10 mm of translation along the Z axis and +/-10 degrees of rotation about X at 1 Hz, to +/-1 mm of translation along Z and +/-1 degree of rotation about X at 10 Hz) of a high resolution spherical phantom inside a head RF coil, capable of operation in an unshielded 7T MR scanner. Here, we report on the drive mechanism developed for the motion simulator.

Methods

A top view of the prototype drive mechanism for the motion simulator is shown below. The mechanism includes 2 nearly identical drive assemblies, 1 for translation and 1 for rotation. Each drive assembly consists of a custom non-ferrous air motor (Globe Air Motors B.V.) driving a 3:1 nylon bevel gear set followed by a 1.8:1 plastic timing pulley set that drives a slider-crank mechanism. The air motors have an effective range of ~ 150-600 rpm. As initially configured, this results in drive rod motions of ~ 0.5-2 Hz. The pulley set can be reversed to achieve motions of 1.5-6 Hz; the large pulley can be replaced to reach 10 Hz. The translation drive assembly drives two rods that connect to the phantom to effect horizontal displacement. The translation drive rods also carry the entire rotation drive assembly, enabling independent control of translation and rotation. The initial configuration allows for +/-1 mm and +/-10 mm of displacement of the drive rods. Linear bearings for the drive rods, flange bearings for the gear and pulley shafts, and self-aligning double joint bearings for the connecting arms are plastic (IGUS Inc.). The entire drive system is mounted in a phenolic LE tube (107 cm long, 20 cm O.D.) supported on 2 cradles, which enables the drive system to be manually rotated about the Z axis and locked in place so that the phantom can be manipulated in a variety of orientations. Ports are positioned at 45 degree increments around the circumference of the tube where the translation drive assembly and all bearing blocks mount so that alignment and shimming can be done from the outside of the tube. In practice, the drive mechanism will be coupled to another section of phenolic tube that will primarily contain bearing blocks and extensions for the 3 drive rods. Thus, the motion simulator can be readily lengthened as necessary to adapt to a variety of scanners.



Results

Initial evaluations of the prototype were conducted in a GE Eclipse 3T MR scanner (312 cm bore length) using GRE-EPI phase images (single slice coronal images; 96x96 matrix, 333 ms TR, 50.5 ms TE) of a spherical phantom (18 cm O.D.) in a quadrature head RF coil. Movement of the rotation motor on the translation drive rods produced phase artifact when the rotation motor was within 110 cm of the center of the phantom, but not when the translation motor was 140 cm from the center of the phantom. The air motors functioned well even near the center of the scanner. The forces generated when the nonferrous metal rotation motor was moving in the high magnetic field produced some loading of the translation motor. With the rotation motor removed from the tube, and the translation drive rods moving over a 2 cm range at approximately 1 Hz, no perceptible phase or magnitude distortions were seen with the end of the tube 25 cm from the center of the phantom and the drive rods extending approximately 10 cm beyond the end of the tube.

Discussion/Conclusions

The initial testing of a drive mechanism for a computer controlled motion simulator demonstrated good performance inside a 3T MR scanner with the drive rods moving very close to the imaging volume. The next steps in the development of this motion simulator are (1) addition of a high resolution spherical phantom, a prototype of which is presently in use in this project, (2) addition of non-contact displacement sensors to monitor the translation and rotation of the phantom, and (3) computer control of the air motors. The motion simulator will be useful in developing prospective motion correction methods as well as in other situations where a motion reference is needed, such as comparing the motion sensitivity of different imaging methods.

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