A Transceive Surface Coil Array for MRI of the Human Prostate at 4 T

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Introduction

Magnetic resonance imaging and spectroscopy (MRS) have shown tremendous promise in the detection of malignant prostate cancer [1]. Due to the position of the prostate near the center of the torso, MRS studies have generally required invasive endorectal radio frequency (rf) coils to achieve sufficient signal to noise ratio (SNR) for detection of citrate; the primary surrogate marker of pathology. However, a recent comparison between surface and endorectal coils at field strengths of 1.5 and 3 Tesla [2] showed no significant difference in the ability to detect prostate cancer by MRS. The use of non-invasive surface coil arrays instead of endorectal coils for prostate imaging provides several considerable advantages including a non-deformed prostate image, increased patient comfort and therefore compliance, fewer contraindications to imaging due to hemorrhoids, or other rectal medical complications, the elimination of the need for qualified medical staff for the endorectal procedure, as well as potentially improved RF and static field homogeneity for more reliable spectroscopic imaging. Improved homogeneity and signal penetration has been theoretically described [3] through varying the phase and magnitude of the rf transmit field. This method is known as field focusing (or B_1 shimming) and is experimentally verified in this study.

Methods

The complete apparatus along with the driving network is shown in Fig 1 A. The coil consists of 10 surface coil elements as shown in Fig B with a combination of overlap and capacitive nearest neighbour decoupling. There are 3 different driving schemes employed in this study. The only changes in phases between the 3 drving schemes involve the top and bottom panels (6 surface coil elements in total). For the circularly polarized scheme (C) the entire top panel is driven 180˚ out of phase with the bottom panel (with the side elements being +/- 45˚ relative to the flat panels). For driving schemes A and B the octogon pair and the 4 square elements are shifted by 180˚ respectively.

All imaging data were obtained using a 4 T Varian Unity INOVA whole-body MRI/MRS system (Palo Alto, CA, USA) interfaced to Siemens Sonata Gradients and Amplifiers (Erlangen, Germany). In order to reduce contrast in the prostate for assessing image homogeneity, a proton density weighted fast low angle shot (FLASH) sequence was used to acquire all anatomical images (FOV_x = 40 cm, FOV_y= 28 cm, TR = 11 ms, TE = 35 ms, slice thickness = 0.5 cm, tip angle = 60˚, N_{RO} = N_{PE} = 256, with 10 averages per image). The total imaging time for each image was approximately 28 s. A non-weighted sum of squares method was implemented for image reconstruction. Human torso data were acquired from one human volunteer (male, height = 188 cm, and mass = 80 kg).

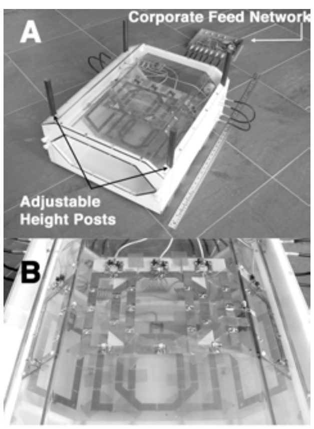
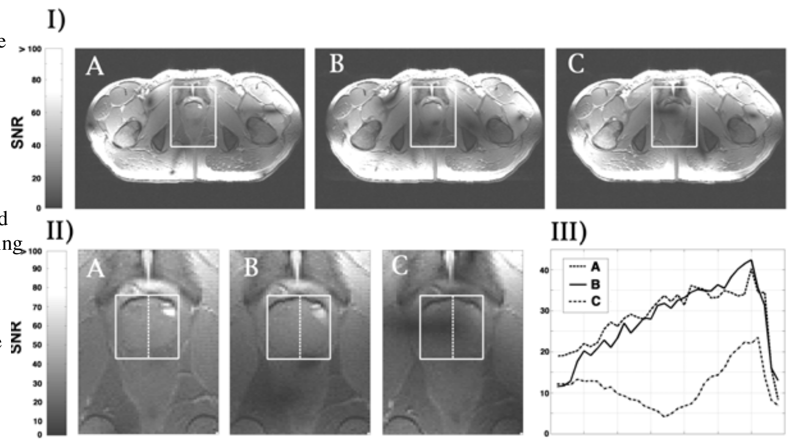


Fig. 1: (left) A) The transceive prostate surface coil array accompanied with driving corporate feed network. B) A blowup of the individual surface coil elements within the array.

Fig.2 (right) The SNR anatomical images of the torso of the three driving schemes (A,B, and C). I) The full field of view images of the torso for all driving schemes as indicated. II) A blow up of the white box outlined in each image I) corresponding to the general prostate volume of interest. The SNR along the dashed line encompassing only the prostate gland in II) is shown in III) corresponding to each driving scheme.



Results and Discussion

A novel torso transceive surface coil array was designed and constructed. The use of *field focusing* driving schemes allowed full field of view imaging of the torso while maintaining high SNR and better image homogeneity within the prostate VOI compared to a circularly polarized drive scheme (as shown in Fig. 2 II). The current study provides experimental proof that *field focusing* increases SNR and produces homogeneous transmit profiles verifying previously proposed theoretical predictions [3] at 3 T. Specifically, the predicted region of low SNR in the prostate region for the circularly polarized scheme was experimentally demonstrated at 4 T. Both focused driving schemes (A and B) yielded similar SNR in the prostate (Fig 2 III), however driving scheme B produced phase incoherence just anterior to the prostate gland, which has the potential to degrade image quality in patients with varying sizes.

A patient accessible transceive surface coil array for pelvic imaging at 4T has been designed, and constructed. The implementation of *field focusing* driving schemes improved SNR and image homogeneity and is expected to improve the performance of both spectroscopic and conventional imaging techniques used for cancer detection and diagnosis.

References

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