

DESIGN OF A RECEIVER ARRAY FOR MRI-GUIDED TRANSRECTAL PROSTATE BIOPSY

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Introduction

MRI Transrectal prostate biopsy requires tracking of the biopsy needle interleaved with the updating of the image of the targeted lesion, in view of the tissue movements during the intervention¹. Reliable tracking and fast, high resolution imaging require an optimised receiver design. The combination of pelvic and balloon endorectal coils, used in diagnostic imaging, is not compatible with the intervention, while the sensitivity of the pelvic array alone is low in the region of interest. Biopsy probes with an incorporated solid surface coil have been proposed², but they suffer from a small field of view due to acceptable coil sizes and inevitably restrict probe movement. A novel external receive coil was designed to provide an improved signal from the prostate region and from the fiducial markers incorporated in the probe. The design was produced based on volunteer subjects and optimised for use with an MRI compatible remote manipulator³ developed for this procedure.

Methods

Design. High resolution cross-section sagittal and transverse MR images of the pelvic anatomy were acquired for a subject in prone position (Figure 1). An asymmetric array of 3 anterior and 3 posterior trapezoidal loops was devised to follow closely the exterior body contour, with each loop tapered toward the perineal body. Signal sensitivity was maximized by orienting the normals to the planes of each loop toward the vertical (y-direction). However, to compensate for the small angle with y at the midpoint, the central pair of trapezoids formed a figure-of-eight coil (Figure 2). The design accommodated the transrectal biopsy probe, through one of the loops, and the manipulator (Figure 3).

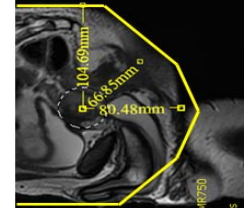


Figure 1. Coil design in relation to anatomy.

Evaluation. The sensitivity of the coil and the RF field homogeneity were evaluated to characterize the performance

of the array. According to the Theorem of Reciprocity, the sensitivity to the y-component of RF magnetization is proportional to the y component of magnetic field generated by unit current flowing in the coil. This was computed by integration of field calculated by the Biot-Savart law along the path of each of the coil loops using a combination of C and MatLab codes. The inductances and mutual coupling between the elements were simulated using FastHenry software. The resonant frequency of the coil was tuned to 63.8 MHz. The array was compared with a standard pelvic coil comprising 4 rectangular elements placed at the front and 4 at the back of the patient. The frontal elements were positioned at the same height as the perineal body, while the posterior ones higher than the anus to accommodate the probe and the manipulator, resulting in an offset between the two arrays of about 150 mm along z.

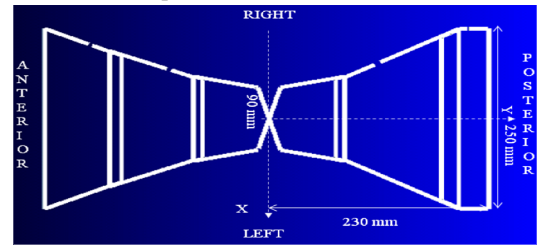


Figure 2. The array in a planar configuration.

Result

Figure 4 shows the sensitivity maps of the proposed and pelvic coils in the sagittal and axial planes, indicating the main regions of interest. Figure 5 shows the field inhomogeneity along a 5 mm slice parallel to y-axis and through the middle of the prostate. An overlap of about 1/6 of the length of the long side of a trapezoid was found to minimize the mutual inductance between neighboring elements.

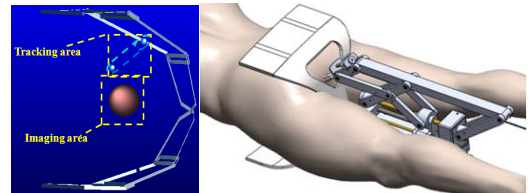


Figure 3. Coil in place while performing transrectal prostate biopsy. The areas of interest are outlined.

Discussion

The results show that the sensitivity of the proposed coil is appreciably higher than that of the pelvic coil. In both regions of interest the values are about 3 times higher. Also, in the region of the prostate the field homogeneity is better, as seen from the field contours in Figure 4 and further illustrated in Figure 5.

Conclusion

The results indicate that the proposed coil achieves significant improvements in sensitivity over the whole region of interest, with consequent improvements in needle tracking and high quality imaging of the target lesions. High quality intraoperative imaging will also be aided by the high homogeneity in the region of the prostate.

References

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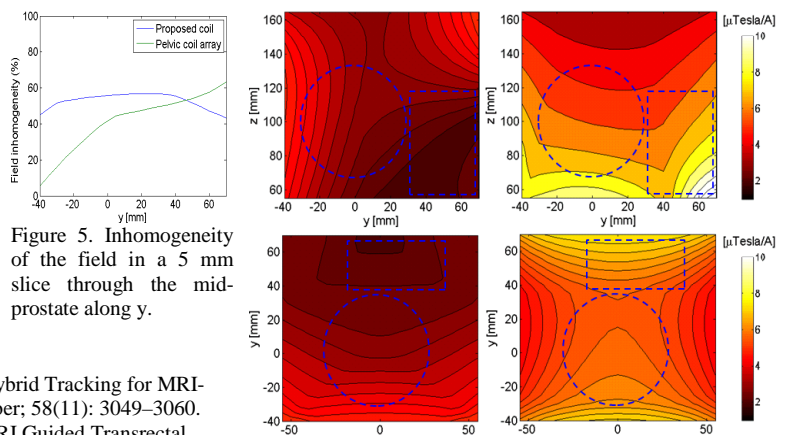


Figure 4. Sensitivity maps of pelvic (left) and proposed coil (right) in sagittal (above) and axial (below) planes. Circle=target region; Rectangle=marker tracking region.

Figure 5. Inhomogeneity of the field in a 5 mm slice through the mid-prostate along y.

