Optimization of Internal MRI Coils Using Ultimate Intrinsic SNR

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Introduction

Internal coils are widely used in MRI applications for both diagnostic and interventional studies [1]. Their high SNR characteristics make them more preferable in certain applications when compared to conventil external coils. Although many studies exist for the optimization of external coils to obtain increased SNR, an optimization study for internal MRI coils can also be made. In this study the methods for optimization of internal MRI coils are demonstrated. A cylindrical geometry with a fixed radius is assumed for the coil shape. As a sample opion, the endorectalMRI coils are optimized, implemented and tested in both phantom and patient studies. The Intrinsic SNR (ISNR) [2] of the optimum design is compared to Ultimate Intrinsic SNR (UISNR) for internal MRI coils [3] to demonstrate its measure of performance.

Methods and Results

Optimization of the internal MRI coils is a complex problem which requires considering many different variables such as size, geometry and the EM properties of the coils. For the sake of simplicity a heuristic approach is adopted in this work, and the optimization problem is divided into two sub problems; cross-sectional optimization and length optimization. For the cross sectional optimization two different coil geometries which are known to have an improvement over a conventional loop endorectal coil geometry, are considered. Then the geometrical properties of these two coils that resulted in SNR improvement is combined in a single coil design to obtain further SNR improvement. For the length optimization the ISNR variation of a rectangular loop coil is investigated. The length value that maximizes the performance of the coil with respect to UISNR is calculated. For the length optimization a rectangular loop coil with lengths between 2cm and 12 cm is simulated using the simulation program FEKO. The ISNR values are computed for each length and divided by the UISNR corresponding to the same model geometry. As it is seen in Figure1 for each point of interest a different coil length is optimal. However it can roughly be stated that a 4cm coil gives the best performance for all points of interest. Therefore the length of the optimized coil should be chosen as 4 cm. For the cross sectional optimization, single-channel strip-conductor and phased array designs were tested in a gel phantom model on a GE 1.5 T scanner. A fast spin echo imaging sequence was used to obtain axial images. A 0.5 S/m conductivity value was obtained by adding 2.2 g/liter of NaCl to the gel solution. The ISNR distribution of the coils was analyzed using a MATLAB (version 6.5,MathworksInc., Natick, MA) program. To show the relative advantage of the new designs over conventional loop design, the ISNR values of the single-channel strip-conductor coil and the dual phased array coil were divided by the ISNR of the rectangular loop coil. The maximum improvement obtained by the dual phased array coil compared to the conventional coil was 55% at a point of interest 3.2 cm away from the coil center. For the single-channel strip-conductor design, the maximum improvement of 35% was obtained at 2.5 cm. To achieve further improvement a third design is proposed as a combination of two previous designs as seen in Figu3. During implementation it was observed that the strip pole of the loop can be used to decouple the two channels of the coil. Therefore the inner conductor cylinder was removed from the design. The width and shape of the strip was modified in this design to force the currents on the two loops to flow on paths orthogonal to measure of decoupling, s12 parameter between to loop coils is measured using a two channel network analyzer. An s12 value of -22 dB was obtained with this method. Figure3 shows the optimized design. Figure 4 shows the performance variation inside the phantom obtained by dividing its ISNR to UISNR for this coil geometry. When the 2D performance map is sampled along the direction where its maximum we see that a maximum performance of 85% is achieved at a location of 6cm. At 4.5 cm which is the furthest point of the prostate in the average sense, the performance drops to %72. This result reveals that this design is an optimum design for imaging a location of 6 cm away from the center since it reaches a performance of 85%. Also it is very close to optimum for 4.5 cm since it fulfills the %72 percent of the maximum achievable ISNR at that point of interest. After the phantom studies the optimized coil is built with slight moications in order to run patient studies. A flexible plastic hose is used as a coil housing to increase patient comfort Figure 5 shows an axial prostate image obtained by a GE Signa 1.5 T system using a T2 weighted FRFSE sequence with the parameters TE=119ms, TR=2900ms FOV=16cm x 16cm BW=25kHz

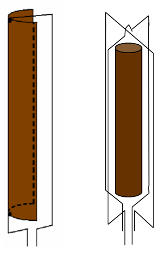

Figure 1 Strip-Conducto(left) and Dual phased array(right) coils' cross sectional geometries

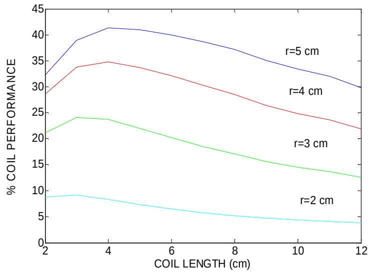

Figure 2 Coil Performances for coils with different lengths

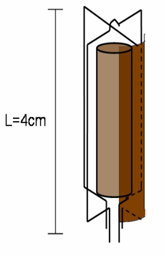

Figure 3 Optimized Coil

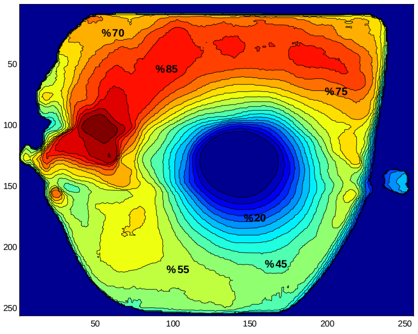

Figure 4 Peformance map of the optimized coil

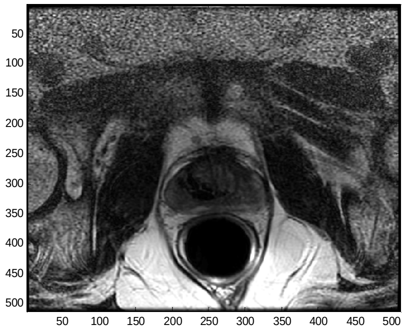

Figure 5 Axial Prostate Image

Discussions

One of the modifications was the shift of the coil's sensitive region in order to cover the prostate. This shift required that the loops are connected to the scanner with additional coaxial lines which may result in SNR decrease. On the other hand for practical purposes the matching and decoupling circuitry is placed at the end of these coaxial extension lines instead of the proximity of the loops as it was in phantom studies.

Conclusion

In this work some general methods for the optimization of the internal coils are introduced. As a sample optimization that demonstrates the validity of the method, the endorectal coils are optimized. The optimized endorectal coil is built and tested in phantom studies and compared with UISNR for internal MRI coils. Maximum coil performances of 85% and %72 are reached at 6 cm and 4.5 away from the coil center. This comparison revealed that for certain point of interests the coil is very close to optimum. Patient studies are also performed to prove the clinical usability of the coil. Similar optimization techniques can be applied to different type of internal coils.

References: [1] Krieger et al. Design of a Novel MRI Compatible Manipulator for Image Guided Prostate Interventions Ieee Transactions on Biomedical Engineering, 2005;52(2):306-313 Edelstein et al.[2] The intrinsic signal-to-noise ratio in NMR imaging. Magnetic Resonance in Medicine 1986;3(4):604-618. [3] H.Celik et al.Evaluation of internal MRI coils using ultimate intrinsic SNR.MRM. 2004 Sept; 52(3):640-649