Design of a double tuned TxRx ^{1}H/ ^{31}P endorectal prostate coil for 7T

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Introduction

With ^{31}P MR spectroscopy it is possible to sample signals of compounds involved in energy and phospholipid metabolism. The introduction of whole body MR systems with a field strength of 7T provides unique opportunities to perform ^{31}P MRS in the human body with improved spectral and spatial resolution. A major disease is cancer in the prostate which can be approached by an endorectal coil for optimal SNR. . In this work we present the design and calculated the values for electrical components for a double tuned ^{1}H/ ^{31}P endorectal prostate transmit - receive coil for a 7T MR system and compared the SNR to single resonant coils.

Materials and Methods

The housing of the coil is based on the Medrad endorectal coil design (Medrad Pittsburgh, PA). For endorectal use and in order to keep patient discomfort to a minimum the number and size of the used components needs to be small. Based on the trap circuit and the aim for a minimum number of components we calculated the values for these different components in a double tuned circuit. (red box in Figure 1). To prevent signal leak from one connection to the other, filtering needs to be applied. ^{31}P and ^{1}H frequency filters need to be positioned in the feeding cables for these nuclei outside the endorectal coil housing, minimizing the number of components inside. By using the appropriate cable lengths the filter properties are translocated to the coil connections (Figure 1).

Apart from the double tuned circuit, two single tuned circuits (^{1}H and ^{31}P) were also designed to evaluate potential performance loss of the double tuned coil. The SNR on both frequencies was compared. In case of ^{1}H this SNR was calculated by dividing the mean of the signal on the standard deviation of the noise of a gradient echo image. In case of ^{31}P spectra were acquired with a single pulse of a phosphate buffer and the SNR values were compared by dividing the integral of the ^{31}P singlet by the standard deviation of the noise.

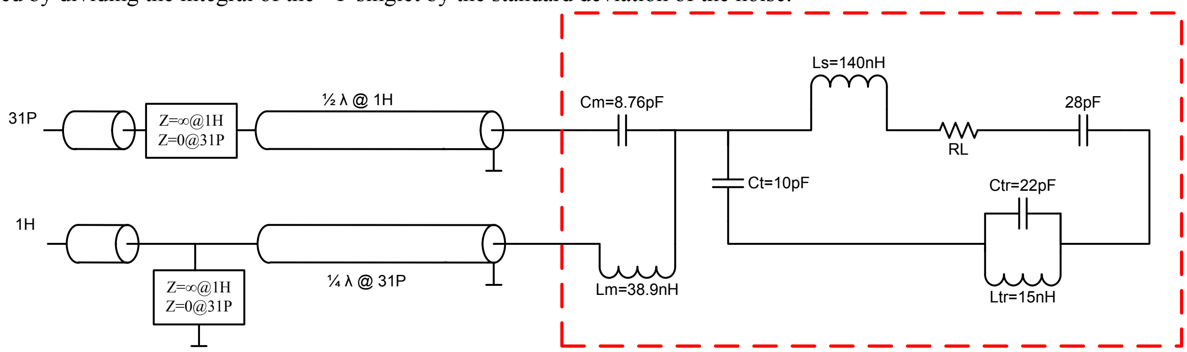

Figure 1 Double resonant trap circuit with the calculated components for the transmit receive ^{1}H/ ^{31}P prostate coil for 7T including the filtering outside endorectal coil housing.

Results and Discussion

The first prototype of the coil was built and tested on a glass sphere with a phosphate solution on a 7T animal MR system ClinScan (Bruker Biospin, Ettlingen, Germany). After gradient echo imaging with conventional pulses with small flip angles (background image of figure 2), 3D ^{31}P spectroscopic imaging revealed phosphate signals in the phantom (spectral maps overlaid on background image in figure 2), illustrating the functionality of the coil. The component values in the actual prototype were slightly adapted from the calculated values while building the coil, enabling better tuning and matching on both frequencies.

Compared to the single resonant coils, the prototype double tuned coil had a lower SNR on ^{31}P and ^{1}H of respectively 30% and 14%. These losses indicate that either signal leak is not prevented optimally by the proposed filtering solution, or the choice of coil component values may decrease the performance of the coil at ^{31}P.

The double resonant endorectal coil design for both transmit and receive of ^{1}H and ^{31}P signals has the advantage of being positioned as close to the organ of interest as possible, which is optimal in receive mode for maximum SNR. In transmit mode however, the inhomogeneous B1 field demands the use of adiabatic pulses for homogeneous excitation.

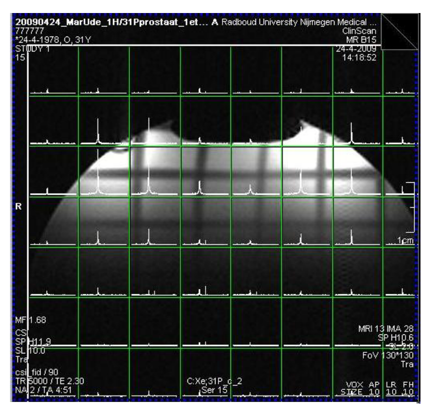

Figure 2 First results of transmit receive ^{1}H/ ^{31}P prostate coil for 7T.

Conclusion

In conclusion, we developed a prototype double tuned TxRx loop coil with components that can be put into the housing of an endorectal balloon coil design. Although the SNR for the current prototype was not optimal yet , this design can be used as a model for a double tuned ^{1}H/ ^{31}P endorectal prostate transmit receive coil with respect to all the limitations involved in these coils. The next steps are to improve SNR and perform a safety validation of RF deposition of the coil design before the first in vivo use [1].

Reference: 1. Klomp DW, Bitz AK, Heerschap A, Scheenen TW. Proton spectroscopic imaging of the human prostate at 7 T. NMR Biomed. 2009 Jun;22(5):495-501