Efficient Design of a novel Double Tuned Quadrature Headcoil for Simultaneous ^{1}H and ^{31}P MRI/MRS at 7T

C. Findeklee[1], C. Leussler[1], M. Morich[2], G. Demeester[2]

[1]Sector Technical Systems, Philips Research Laboratories, Hamburg, Germany, [2]Philips Medical Systems, Cleveland, Ohio, United States

Introduction

Double tuned coils are used for imaging and spectroscopy at high fields. TEM- and Birdcage designs have been shown using separate feeding ports for both nuclei [Zha03], [Kin04], [Due91]. These designs consist of two combined coils, which have to be decoupled geometrically or by filtering. In this work, a single quadrature coil is used in two different modes. Both signals use the same feeding port. A new design method was used to predict appropriate dual resonance capacitors.

Methods

A 7T birdcage headcoil as presented in [Leu04] was modified to a double-resonant coil. The capacitors in the ring sections were removed and additional capacitive branches were placed from the end of the rods to the shield. This provides additional TEM modes to the birdcage spectrum. A CONCEPT-model [CON] for Method-of-Moments simulations was generated (Fig.1). The resonance capacitors were derived using the method presented in [Fin04]. The bare coil was simulated without capacitors. The admittance matrix with respect to the capacitor ports (green printed in Fig. 1) was evaluated at the two target frequencies 120.75 and 298.032 MHz and extrapolated by

$$\boldsymbol{Y} \approx s^{-1}\boldsymbol{L}^{-1} + s^{0}\boldsymbol{G} + s^{1}\boldsymbol{C},\quad \boldsymbol{L}^{-1} := \omega_1\omega_2\frac{\omega_2 \mathrm{imag}\boldsymbol{Y}_1 - \omega_1 \mathrm{imag}\boldsymbol{Y}_2}{\omega_1^2 - \omega_2^2},\quad \boldsymbol{G} := \mathrm{real}\left(\boldsymbol{Y}_1 + \boldsymbol{Y}_2\right)/2 \text{ and } \boldsymbol{C} := \frac{\omega_1 \mathrm{imag}\boldsymbol{Y}_1 - \omega_2 \mathrm{imag}\boldsymbol{Y}_2}{\omega_1^2 - \omega_2^2}.$$

Different sets of resonance capacitors were tested by changing the diagonal elements of the capacitive matrix *C*. The complex resonance frequencies $s = \sigma + j\omega$ were calculated by solving the eigenvalue equation

$$s\begin{bmatrix} \boldsymbol{G} & \boldsymbol{C} \\ \boldsymbol{Id} & 0 \end{bmatrix}\begin{bmatrix} \vec{\underline{U}} \\ s\vec{\underline{U}} \end{bmatrix} = \begin{bmatrix} \boldsymbol{L}^{-1} & 0 \\ 0 & \boldsymbol{Id} \end{bmatrix}\begin{bmatrix} \vec{\underline{U}} \\ s\vec{\underline{U}} \end{bmatrix}.$$

Results

From the simulations, 15pF for the four rod-capacitors and 3.9pF for the connections to the shield were chosen to build up a lab model of the double tuned resonator. Fig. 2 shows the modeled transversal fields of the resonant modes at 120 and 284 MHz. Variable capacitors have to be inserted in rods and shield connections in order to tune the coil exactly to the target frequencies. Omitting the last resonance capacitor in a rod (negative z-direction) provides a feeding port, where two lumped matching circuits of the same topology could be located to support both resonant frequencies (shunt reactance in parallel to the coil and one reactance in series to the 50 Ohm port). A single matching network was derived from two matching circuits at both resonance frequencies (Fig. 3). Fig. 4 shows the successful matching of the loaded lab model.

Conclusion

A new simulation technique was successfully used to tune a novel double tuned headcoil for simultaneous ^{1}H and ^{31}P MRI/MRS at 7T. A dual frequency matching was implemented to use only one port of a single coil for two resonances.

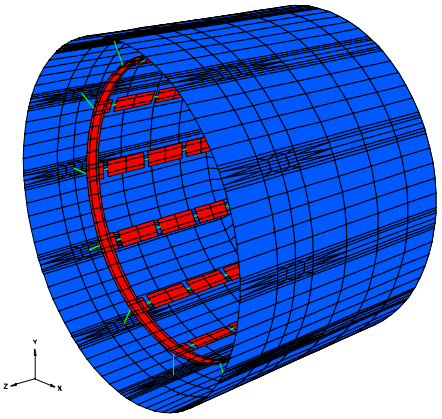

Fig. 1 MoM model of the coil

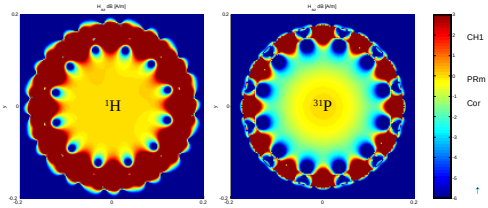

Fig. 2 Transversal fieldplots in the center plane

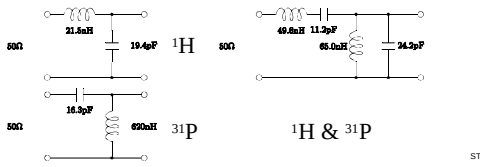

Fig. 3 Simultaneous matching for two frequencies

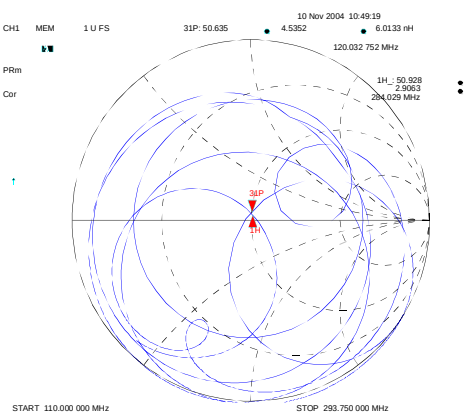

Fig. 4 Measured reflection of double matched feeding port of the loaded coil

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