A Dual Tuned RF Coil for 3T MRI

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INTRODUCTION

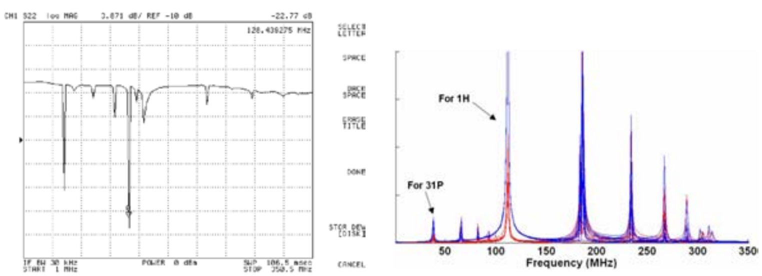
Magnetic resonance spectroscopy (MRS) has the capability of detecting phosphorous in-vivo, providing an opportunity to quantify Phosphomonoesters (PME) and Phosphodiesters (PDE). Both PME and PDE are intermediates of membrane phospholipids turnover and therefore play an important role in human brain development. In addition, these metabolites are implicated in many brain diseases involving membrane defects. While infant studies involving 31P spectroscopy are capable of elucidating the evolution of phospholipids turnover in early brain maturation, the low signal to noise ratio (SNR) of such techniques has prevented it from being frequently used. This could be partially remedied by using efficient RF coils to reduce imaging time. These efforts are necessary because of the low SNR of these nuclei (due to their low natural abundance) and because of the low field strengths of clinical magnets. For infant imaging, a design has been selected [1] for computational analysis. It is shown that a better understanding of various resonance modes corresponding to the two nuclei detectable by this coil is attained. One way to enhance the SNR in these studies is to use computational electromagnetic field techniques, such as finite difference time domain (FDTD), to guide optimization of such coils.

METHODS

A 16 rung birdcage design has been used to build the dual tuned RF coil [1]. It has a diameter of 18 cm and a length of 19 cm. The coil consists of three connected low pass birdcage coils, which are referred to as inner and outer structures. The outer structures are two low pass birdcage coils with a 127.74 MHz resonance frequency, and the inner structure is a low pass birdcage coil with a 51.4 MHz resonance frequency. The value of the outer structures' and inner structure's capacitors is 4.1 pF and 26 pF, respectively. The shield is placed 3 cm away from the rungs. The coil was tested for its 31P and 1H resonance capabilities. The B_1 field map and resonance pattern of the coil have been probed in three ways: calculation with FDTD, bench test with a spectrum analyzer, and imaging with a GE Signa 3T scanner.

RESULT AND DISCUSSION

As shown in Fig. 1 computed and measured resonance modes agree rather closely. Ability to generate homogeneous B1 at two different frequencies is demonstrated. The resonance modes demonstrate ability of this coil to produce pure modes at 51.4 MHz for 31P and 127.74 MHz for 1H for operation at 3T. In all dual tune coils, the possibility exists for higher frequency current to flow on the low frequency section. If this is an out of phase current it will drastically reduce the SNR of the HF modes. FDTD computations allowed selection of matching and tuning capacitances to eliminate this problem. Upon incorporation of FDTD results, a high SNR for 1H and 31P was measured. The axial image shown in Fig. 4 was obtained utilizing this optimization. FDTD computation in the central axial and coronal/sagittal plane, shown in Fig. 3, demonstrates the extremely high homogeneity of the 1H B1 field within the region of interest of the coil. 31P spectra were acquired from a phantom within the central region of the coil with an expected SNR.



Measured resonance modes (top left) and FDTD calculate modes (top right) of coil.

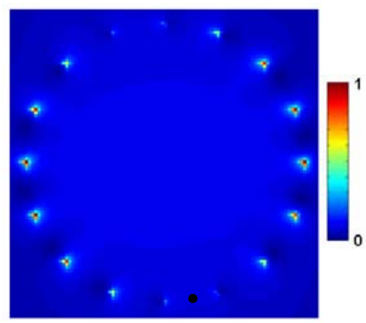


Figure 2: Normalized B_1^+ field distribution, throughout the central axial slice of the coil. The excitation feed point is designated with a dot. A two-period symmetric current distribution is clearly seen on the coil's wires.

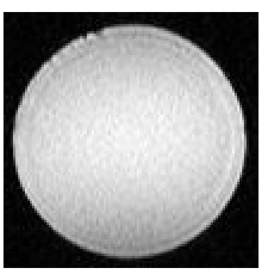


Figure 4: MR image of uniform saline spherical phantom generated with coil operating in quadrature excitation. As predicted with the FDTD simulation, the image is extremely homogeneous.

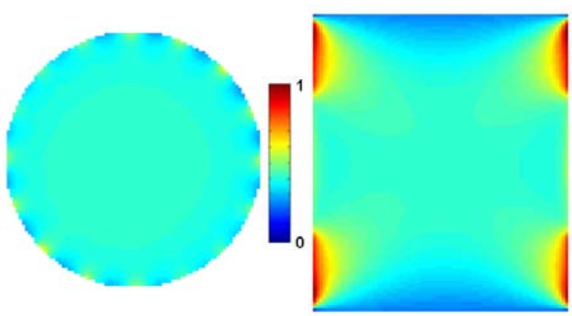


Figure 3: Normalized B_1^+ field distribution, with the coil operating in two-port quadrature excitation, through the coil cavity, in the central axial (left) and central coronal/sagittal (right) slice of the coil. The coil is clearly able to produce excellent field homogeneity throughout the cavity's region of interest.

CONCLUSION

A dual tuned RF coil was built and analyzed for the ability to generate pure resonance modes at two distinct frequencies. FDTD analysis guided the process of tuning, matching and selection of the correct mode for imaging, and showed excellent accuracy with experimental verifications. The coil was tested successfully with phantoms on the bench and in the scanner.

REFERENCES

1. Murphy-Boesch J, et. al. J Magn Reson B. 1994 ;103(2):103-14.