A Quadrature Head Coil for a 0.3T Permanent MRI System

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Introduction

A design approach to improve the SNR of the quadrature head coil in vertical field MRI systems is presented. The quadrature coil consists of a solenoid and a saddle coil, and the human head is simulated as a uniform conducting cylinder. The geometries of two coil elements are optimized to achieve the highest weighted combination of SNR at some specified points in the imaging volume. To obtain a homogeneous sensitivity distribution, the weighting factors assumed to be in inverse proportion to the SNR limit at those control points. A prototype quadrature head coil is developed by the optimization results and in-vivo images are acquired.

Methods

The schematic of the quadrature coil are shown in Figure 1, in which L_1, L_2 and θ will be determined by an optimization procedure. The proposed imaging volume is a cylinder with a 20 cm diameter and a 16 cm length. The noise resistance of each element coil can be calculated by (1), where $\boldsymbol{E}(\boldsymbol{r})$ is the electric field generated by a unit RF current flowing in that coil. Assuming that the signals from two element coils are quadraturely combined with a same gain, the SNR of the combination signal at a specific point $\boldsymbol{r}$ can be approximately calculated as (2), where R_1, R_2, $\boldsymbol{b_1}(\boldsymbol{r})$ and $\boldsymbol{b_2}(\boldsymbol{r})$ are the noise resistances and the magnetic fields generated by a unit RF current of two element coils respectively, C is a constant that does not relate to the coil geometries. To achieve a homogeneous sensitivity distribution in the imaging volume, the weighted combination of SNR at some specified points is selected as the target function of the optimization, which is expressed by (3). The weighting factor W_k is in inverse proportion to the SNR limit at the point $\boldsymbol{r_k}$, as indicated by (4) [1].

$$R = \sigma \int \left| \boldsymbol{E}(\boldsymbol{r}) \right|^2 dv \quad (1) \qquad SNR(\boldsymbol{r}) = C \frac{\left|\boldsymbol{b}_1(\boldsymbol{r})\right| + \left|\boldsymbol{b}_2(\boldsymbol{r})\right|}{\sqrt{R_1 + R_2}} \quad (2) \qquad f = \sum_{k=1}^{K} W_k SNR(\boldsymbol{r}_k) \quad (3) \qquad W_1 : W_2 : \cdots : W_k = \frac{1}{SNR_{\max}(\boldsymbol{r}_1)} : \frac{1}{SNR_{\max}(\boldsymbol{r}_2)} : \cdots : \frac{1}{SNR_{\max}(\boldsymbol{r}_k)} \quad (4)$$

Results

A MATLAB program is employed to optimize the geometry parameters of the quadrature coil. Twenty points in the imaging volume are specified. The results of the optimization are L_1 =8 cm, L_2 =22 cm and $\theta = 160^{\circ}$.

A prototype quadrature head coil is constructed for a 0.3T permanent MRI system with the optimization results. The coil is made of 10 mm wide, 0.1 mm thick copper tape. Both coils are tuned to 12.68 MHz and matched to 2000 Ω, and are attached to high input resistance preamplifiers. A four-port decouple network is applied to achieve a good isolation between the two element coils [2]. In-vivo experiments are carried out with the quadrature head coil. A transverse head image is shown in Figure 2a. The sequence employed is a spin-echo sequence with following parameters: TE=33 ms, TR=480 ms, slice thickness=6 mm, FOV=24 cm, 256×192 acquisition matrix. As a comparison, images acquired by the solenoid coil and the saddle coil independently with the same sequence parameters are illustrated in Figure 2b and Figure 2c respectively.

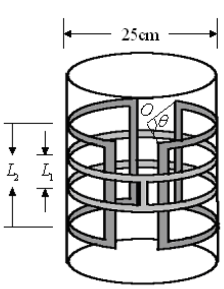

Fig. 1: Coil geometries

Fig. 2a: Quadrature mode

Fig. 2b: Solenoid mode

Fig. 2c: Saddle mode

Reference

[1] Xu Chu, et al., Submitted to the ISMRM 13th scientific meeting, 2005

[2] R.F. Lee, et al., MRM, 48, 203-213, 2002.