Counter Rotating Current Coil for 3-D Eye Growth Study of Infant Rhesus Monkeys

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Introduction.

Limited signal-to-noise ratio and the resulting insufficient spatial resolution during in vivo MRI very often necessitate the development of application-specialized coils or arrays. We report on the development of a clinically practical surface coil with sufficiently high SNR and large FOV suitable to perform MRI studies of monocular form-deprivation effects on the pattern of peripheral refractive errors and eye shape in developing rhesus monkeys [1]. In this on going work, a monocular form-deprivation was imposed in infant rhesus monkeys by securing a diffuser lens in front of one eye. MR images are acquired from both eyes near the end of the diffuser rearing period using control (normal) and refractive errors imposed monkeys. Refractive errors and also correlation between the interocular differences in peripheral refractive error and the interocular differences in vitreous chamber depth are studied. Influence of vision induced alteration in axial length on shape of the posterior globe and the pattern of peripheral refractive errors is also a subject of this investigation. The coil presented here is based on the concept of counter-rotating current planar resonator [2] and was designed to be used as receive-only coil. Its size was optimized to that of a monkey's oculars which, depending on the age of the monkey, are in the range of 10 to 15-mm in diameter.

Method and Results.

In this work we used the designs' principles of loop-gap [3] and planar-pair loop-gap [4] resonators, which have been previously demonstrated as very useful in magnetic resonance. Our design consists of two modified split-square resonators connected by two narrow strips. Tuning capacitor can be added across the middle gap of such structure. In addition, we have used a double-sided structure concept in order to introduce distributed capacitance in the coil, and to minimize and confine stray electric fields to the substrate that otherwise would lead to additional dielectric loss in the body. In such a counter-rotating current design (CRC), each "loop resonator" consists of two split-squares rotated 180° counter one another. This resonator has two different rf modes, however for MRI application it should resonate at required mode when the rf currents in each loop flow in opposite directions as shown in Fig. 1a. The coil can be also treated as two directly connected horse-shoe resonators [5]. The split-squares have a 28-mm by 26-mm outer dimensions, 20-mm inner diameter and 18-mm opening dimensions and the spacing between loops is 2 mm.
Double-sided copper high frequency laminate with a dielectric constant ε=2.2 and thickness of 0.381 mm was used for the surface coil material. The coil and electronic circuit layout was patterned using computer controlled milling machine LPKF PhotoMat C60.

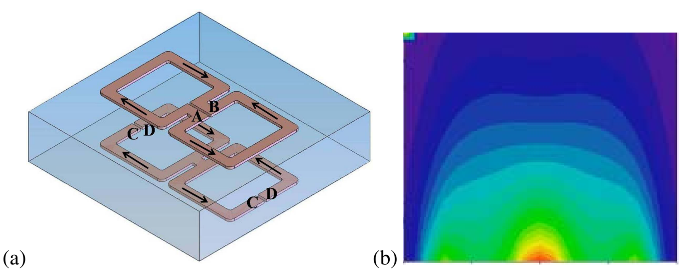

Fig. 1. (a) A sketch of the 300 MHz counter-rotating current coil. Varactor based tuning and matching circuit was connected on one side to the coil across the middle gap through A and B gap points. (b) Calculated coil sensitivity contour map.

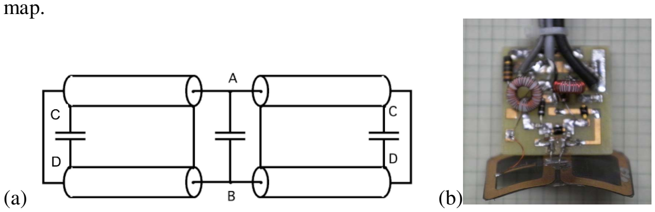

Fig. 2. (a) An equivalent circuit of the coil. Coaxial line sections represent distributed capacitance between A-B and C-D gaps (see Fig. 1a). (b) A picture of the coil together with tuning/matching varactor based circuit board.

The calculated sensitivity contour map using the Biot-Savart approach is shown in Figure 1b. Despite the simple coil form, the resonant frequency of the coil has a complicated dependence on the resonant circuit elements. An equivalent circuit is depicted in Fig. 2a. In Fig. 2b, a picture of the coil and coil/circuit board mounting is shown.

This electronic circuit board attached to the coil is for tuning and matching to 300.26 MHz and 50 Ω, respectively, and also for active detuning during RF transmit pulse. Dc power supply placed outside of the scanner shielded-room allows for remote tuning and matching process due to the varactors (see Figure 1b) included in the circuit. Active detuning circuit is based on two PIN diodes.

The signal-to-noise profile of the surface coil as compared to the S205 Bruker volume coil and to a single loop coil of similar size is shown in Figure 3a.

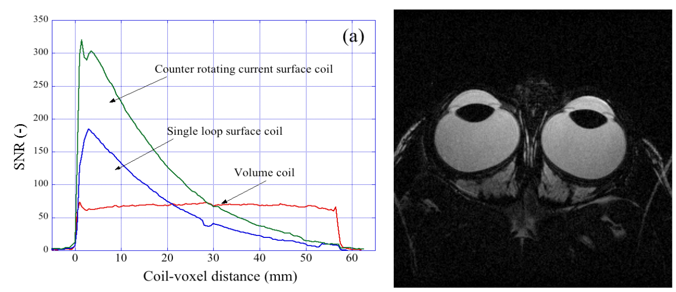

Fig. 3. Comparison of SNR profiles for single loop, CRC and volume coils (a). Images of an infant monkey eyes acquired using a surface coil (b).

Pulse sequence applied was SE and image parameters presented in Fig. 3b are as follows: 3D RARE acquisition, RARE factor 32, TR 1 s, TE 170 ms, scan time NEX1 8 minutes, FOV 5 x 5x 3, matrix 256 x 256 x 60. No anti-aliasing was used. For each set of imaging data, sixty 0.5mm thin slices were taken.

Discussion and Conclusion

Comparing at 1 mm slices, the SNR of the single loop and volume coil are ~180 and ~70 respectively; while our planar counter-rotating current (CRC) design has a higher SNR of 300. Superior performance over the volume coil up to 3 cm deep and a 60% improved SNR compared to single loop coil is illustrated in Fig. 3a. For the project, it is highly desirable to shorten the scanning time during which the monkeys (infants) are placed under anesthesia**.** Using volume coils, image acquisition for one monkey is almost 2 hours. Single loop coils reduces this time to 1 hour. The CRC coil allows for image acquisition to be completed in less than 1 hour for each monkey imaging. This SNR along with sufficiently large FOV and depth meet the requirements for the duration of the project, which will follow the growth of the monkey with changing eye ball sizes using time scan as short as possible.

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