A circularly polarized birdcage coil with a single port

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Introduction

Birdcage coils [1,2] have been widely used in magnetic resonance imaging (MRI) because of their good B_1 field homogeneity and high signal-to-noise ratio (SNR). The quadrature (QD) birdcage coil shown in Fig. 1(a) can improve the SNR by a factor of $\sqrt{2}$ over that of a linear birdcage coil (Fig. 1(b)). This is because the two orthogonal ports of the QD birdcage coil receive the circularly polarized B_1 field. However, the implementation of the QD birdcage coil is more difficult than that of a linear birdcage coil, because the QD birdcage coil makes it difficult to isolate the two ports and needs to be connected to a QD hybrid circuit. Here, we have designed a circularly polarized birdcage coil with a single port and investigated its RF characteristics by using an RF simulator. We have also fabricated the designed coil and evaluated its SNR and uniformity of phantom images at 1.5 T.

Method

Coil Design: A schematic diagram of the designed coil is shown in Fig. 2. The structure of the coil was based on an 8-rung high-pass birdcage coil. Two orthogonal capacitors, denoted by $C+$ and $C-$, were placed on the end ring of the coil. A port was placed on the end-ring capacitor between $C+$ and $C-$. The values of $C+$ and $C-$ were set to be greater and less than the value of the end-ring capacitors (C), respectively. The coil was 300 mm in diameter and 300 mm in length. Copper sheet conductors (10 mm wide and 0.2 mm thick) were used for the coils. The designed coil was tuned for 1.5 T (63.85 MHz). $C+$, $C-$, and C were 35.4 pF, 31.2 pF, and 33.3 pF, respectively. *Simulations:* The characteristics of coils were numerically simulated by using our own program based on electromagnetic method of moments and impedance analysis [3]. This program can calculate the impedance and sensitivity of coils with loads. The load was 200 mm in diameter and 127 mm in length. The conductivity and relative permittivity of the load were 0.3 S/m and of 60, respectively. The sensitivity of the coil was defined by the circularly polarized B_1 field strength generated by the coil when a signal of 1 W was applied to the coil. *Measurement:* Images were acquired by using the SE sequence on a HITACHI 1.5T ECHELON Vega. The transmission of the B_1 field was by means of the body coil. The sequence parameters were: TR/TE=500/30 ms, BW=38.3 kHz, slice thickness=5 mm, FOV=250x250 mm, Matrix size =256x128, NEX=1, and scan time =64 s. A cylindrical phantom (200 mm in diameter and 127 mm long) was used. The phantom was filled with 10 mM NiCl solution. The SNRs of the images were calculated from the ratio of signal mean value to standard deviation of noise. Image uniformities were calculated with the NEMA method.

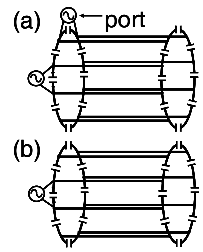

Fig. 1 QD (a) and linear (b) birdcage coils.

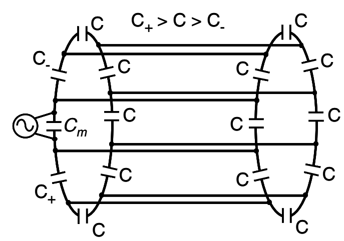

Fig. 2 Circularly polarized birdcage coil with a single port.

Results and Discussion

Figure 3 shows the simulated impedance and sensitivity characteristics of the designed coil with the load placed at the center of the coil. The sensitivity was measured at the center of the coil. Two impedance peaks were observed near the resonance frequency of 1.5 T (63.85 MHz). However, the designed coil showed the maximum sensitivity of 1.81 $Am^{-1}W^{-1/2}$ at 63.85 MHz between the two peaks. The sensitivity of the linear birdcage coil tuned for 63.85 MHz was 1.26 $Am^{-1}W^{-1/2}$. These results indicated that the designed coil improved the sensitivity by a factor of $\sqrt{2}$. Figure 4 shows the simulation results of the sensitivity maps for a linear, QD, and circularly polarized birdcage coils. The sensitivity of the circularly polarized birdcage coil had a more uniform distribution than that of the linear birdcage coil, and was very similar to that of the QD birdcage coil. Figure 5 shows one-dimensional sensitivity profiles of the coils in Fig. 4. The 1D sensitivity profile of the circularly polarized birdcage coil was identical to that of the QD birdcage coil. This result suggests that the circularly polarized birdcage coil operates as well as the QD birdcage coil. Figure 6 shows axial slices of the phantom images measured by using the linear and the circularly polarized birdcage coils. The contrast of the images was enhanced for clarity. The circularly polarized birdcage coil improved the SNR by a factor of 1.13 and the image uniformity from 33.5% to 20.7%, compared with the linear birdcage coil. The improvement in SNR was less than $\sqrt{2}$. This is because the impedance matching of the coil was not optimal.

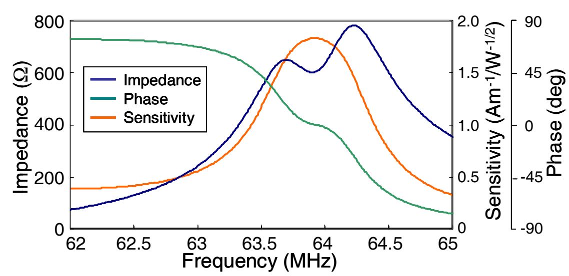

Fig. 3 Simulation results of the impedance and sensitivity characteristics of the circular polarized birdcage coil.

Conclusion

A circularly polarized birdcage coil with a single port was designed and fabricated by adjusting the values of orthogonal capacitors. RF simulations demonstrated that the coil has a highly uniform sensitivity distribution and improves SNR by a factor of $\sqrt{2}$ like the QD birdcage coil does. The technique of circular polarization with a single port is also applicable to low-pass birdcage and TEM coils [4].

References [1] C. E. Hayes, et al., J. Magn. Reson. 63, 622-628 (1985) [2] J. Tropp, J. Magn. Reson. 82, 51-62 (1989)
[3] H. Ochi, et al., SMRM 11th Annual Meeting, 4021 (1992) [4] J. T. Vaughan, et al.,Magn. Reson. Med. 32, 206-218 (1994)

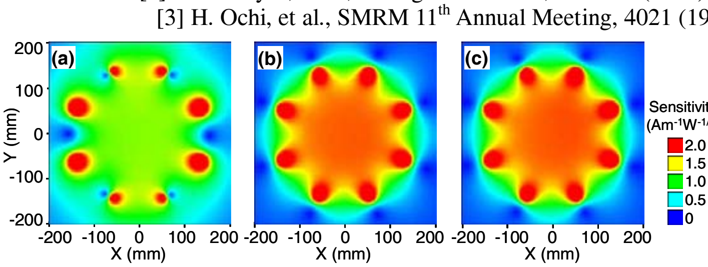

Fig. 4 Simulated results of the sensitivity map for a linear (a), QD (b), and circularly polarized (c) birdcage coil.

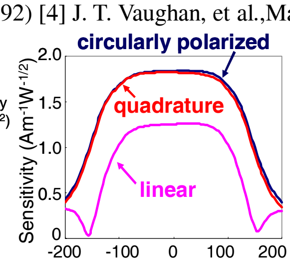

Fig. 5 1D sensitivity profiles of the coils shown in Fig. 4.

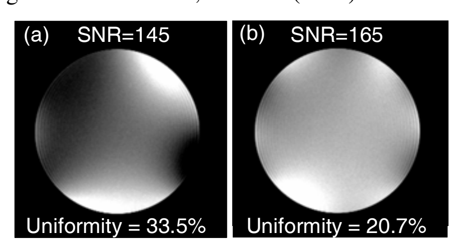

Fig. 6 Phantom images using the linear (a) and the circular polarized (b) birdcage