The "rung pair" birdcage coil that has the transmission line resonance mode

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Introduction

Birdcage coils [1] are used commonly in MRI as cylindrical volume coils. They have many excellent properties: good B_1 homogeneity, quadrature driving features, and good efficiency. These contribute to reducing RF power. Double-tuned birdcage coils were proposed and used, for example, $^{1}H/^{31}P$ imaging of a human brain [2]. However, in ultra-high-field MRI (>3 Tesla) scanners, the self-resonance frequency of birdcage coils decrease, and difficulty occurs with frequency tuning [3]. Transmission line resonators have been proposed as an alternative to the birdcage coils [3] and used at a very high frequency. A double-tuned transmission line resonator was also created by alternatively tuning each of two rungs at two different frequencies. The MRS and MRSI measurements of another nucleus (^{31}P, ^{13}C, or ^{23}Na) have gradually become more important because ultra-high-field MRI scanners have become available. We herein describe a "rung pair" birdcage coil for use as a double-tuned cylindrical volume coil.

Method

Figure 1 shows our coil design. The coil consists of two end rings, 16 outer rungs, and 16 inner rungs. The inner and outer rungs form pairs. A double-tuned (^{13}C and proton) head coil for 3T MRI scanners has been designed. The length of the coil is 220 mm, and the outer and inner diameters of the coils are 276 and 334 mm, respectively. The conductive rod diameter is 8 mm. The capacitors have been placed in the center of each of the 32 rungs. The structure of the coil resembles a birdcage coil and also a transmission line resonator. However our structure differs from a birdcage coil on the point that it has a rung pair at each of the 16 circumference points. Our structure also differs from the transmission line resonator because its outer RF shield has been constructed using end rings and 16 outer rungs. The moment method has been used for impedance and sensitivity calculations of the coil [4]. In the calculation, the inner 16 capacitors have been set to 12 pF, and the outer 16 capacitors have been set to 17 pF. The feeding point is set parallel to one of the outer capacitors.

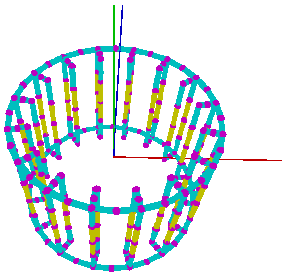

Fig. 1: rung pair birdcage coil structure

Results

Figure 2 shows the impedance characteristics of this coil. Low-pass birdcage mode resonances were observed from 30 to 110 MHz. Transmission line mode resonances were observed from 125 to 145 MHz. The uniform resonance frequency of the birdcage mode is at 32 MHz, which is close to the ^{13}C resonance frequency of the 3T MRI scanner. The uniform resonance mode of the transmission line resonator mode was observed at 128 MHz, which is the proton resonance frequency of the 3T scanner. If additional 16+16 capacitors are placed in each end ring, the resonance frequency of the birdcage mode becomes much higher. Even in this condition, the frequency of the transmission line resonance mode does not change so much. For example, ring capacitors of 250 pF make the 32 MHz resonance frequency of the birdcage mode 52 MHz. The transmission line resonance frequency does not change.

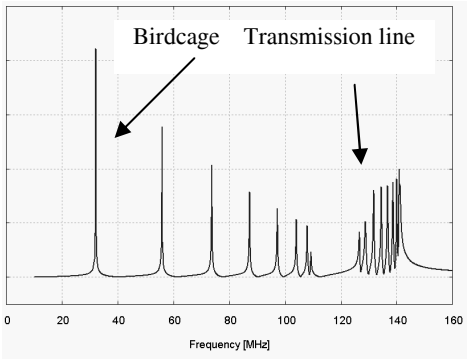

Fig. 2: Birdcage modes and transmission line resonance modes

Discussion and Conclusion

The reason this coil structure has both birdcage and transmission line resonator characteristics can be explained as follows. In the birdcage mode, the current flows in each rung pair in the same direction, as if each rung pair is only one rung. In contrast, in the transmission line resonator mode, the current flows circularly in each rung pair. It is as if each rung pair is one resonance loop. Figures 3 and 4 show the axial sensitivity profile of the birdcage mode and the transmission line resonator mode, respectively. This sensitivity calculation assumes the quadrature driving of the coil.

We have demonstrated that our coil structure has not only a low-pass birdcage mode but also a transmission line resonance mode. This coil structure has two resonance frequencies that have uniform sensitivity. A trial production of this coil and evaluations are underway.

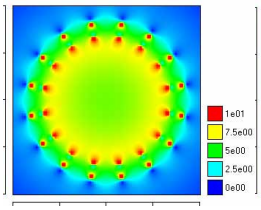

Fig. 3: Axial sensitivity of 32 MHz resonance

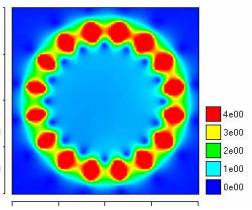

Fig. 4: Axial sensitivity of 128 MHz resonance

References

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