Comparison of B1 Field Homogeneity for Shielded Birdcage, TEM and Microstrip Volume Coils at 300MHz

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Introduction:

Because of the inherent advantage of improved SNR, ultra-high field (3T~9.4T) MRI technology and applications have been accelerated these years. However many engineering challenges have arisen from high-operation frequencies. One major challenge is the difficulty of designing large-size RF coils with high-resonance frequencies. In addition, it has been shown that the homogeneity of the radio frequency (RF) magnetic field, B1, will progressively decrease in large samples with increasing B1 frequency. This is mainly caused by the dielectric resonance phenomenon [1]. Due to distributed element and intrinsic shield, TEM [2] and microstrip [3] volume coils can be used for very high field. Improved birdcage coil with tight RF shield, widening rung, etc. also can be used and reported at 7T [4]. In order to reveal which one has better B1 homogeneity these three kinds of volume coils were simulated and compared by FDTD method in this work.

Methods:

Shielded birdcage, TEM and microstrip volume coils were modeled, and the numerical Maxwell solution were calculated for these models to find the steady state RF field using FDTD method. All the coils have identical dimensions (26cm i.d. x 25cm length), and all are open on both ends. Each coil consists of 8 rungs. They are all numerically tuned to 300MHz and driven linearly. The phantom used in this work is an 18 cm diameter sphere (relative permittivity is 51.898, conductivity is 0.553) which can be used to represent average brain tissue at 300MHz [5]. A region of interest (ROI), 66×66×65 cm was divided into a mesh of 2,265,120 Yee cells, where the basic element of 3D meshes in FDTD method is 5 mm/cell in each dimension.

Results and Discussion:

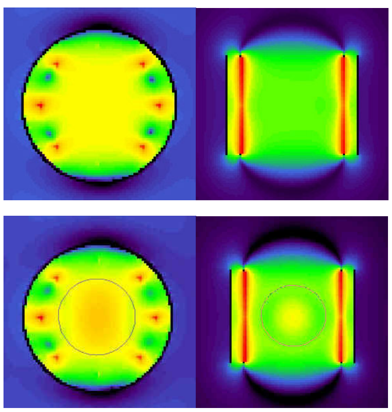

Fig 1:B1 field of unloaded (top) and loaded (bottom) shielded birdcage coil

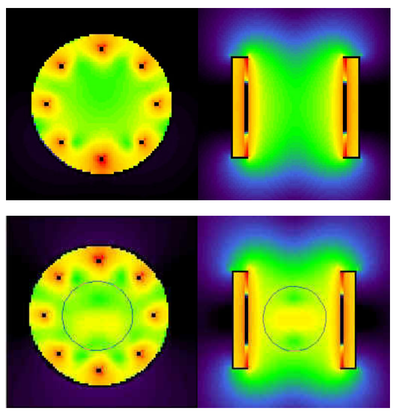

Fig 2: B1 field of unloaded (top) and loaded (bottom) TEM coil

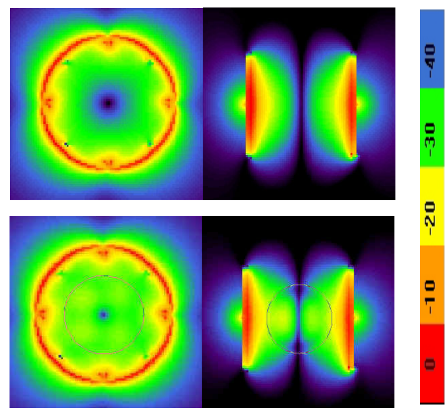

Fig3:B1 field of unloaded (top) and loaded (bottom) microstrip volume coil

The distributions of the RF magnetic field (B1) magnitude on the central axial plane (left) and central sagittal plane (right) in the shielded birdcage coil (Fig 1), TEM coil (Fig 2) and the microstrip volume coil (Fig 3) were illustrated above. The B1 field distributions inside all coils indicate that the coils are at the right resonance mode. Within the transaxial plane, the variation over 20cm distance is about 14% for birdcage coil, 23%for TEM coil, and within the sagittal plane, the variation over 20cm distance is about 19% for birdcage coil, 34% for TEM coil. Because the penetration of microstrip is limited even though the distance between the strip conductor and the ground plane was selected large enough comparing with 0.64cm in reference [3] (1cm in this work), the B1 intensity at the region near microstrip resonant elements was much stronger than that in the center region (almost 10 times). The dielectric resonance phenomenon is obvious for all three coils when loaded with phantom (the bottom of three figures). Although it may degrade the quality of final image, it also can compensate the inhomogeneity when the intensity of intrinsic B1 field at the center is less than that at the periphery (Fig 3). This characteristic can be used as a guide for high field RF coil design. The leakage of magnetic field outside of microstrip volume coil in Fig 3 (right) is caused by the gap between the ground plane and the floating plane [3].

The simulation results indicate that the birdcage structure has better B1 field homogeneity than TEM and microstrip coils. But the radiation loss is another aspect which would affect quality factor of coils. Compared Fig 1 with Fig 2, the B1 magnitude outside of the shielded birdcage coil seems larger than that outside of the TEM coil. It may represent that the radiation loss of the shielded birdcage coil is more than that of the TEM coil.

Acknowledgement:

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References:

[1] Barsuss, H., et al., NMR Biomed. 3, 31, 1990
[2] Vaughan JT, et al., Magn Reson Med, 32: 206-218, 1994
[3] X. Zhang, et al., J of Magn Reso. 161: 242-251, 2003
[4] R.D. Watkins, et al., the 11th Proc. of ISMRM, p424, 2003
[5] C.Gabriel et al., Internet document; URL: http://www.brooks.af.mil/AFRL/HED/hedr/reports/dielectric/home.html