7T Head Coil with Two Independent T/R Channels

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Introduction

Birdcage head coils are widely used at 1.5T and 3T due to their high transmit/receive (T/R) power efficiency. For a birdcage T/R head coil at 7T, B_1^+ field distribution in the head is very non-uniform due to wavelength effects in tissue medium. Using two independent transmit channels to drive the two birdcage modes one can slightly improve B_1^+ uniformity, but further improvement is needed. One solution is to use yet more T/R channels together with other types of less-efficient coil elements. The drawback of this approach is the increased complexity, cost and technical difficulties of RF hardware and SAR management. Here we propose a modified 7T T/R head coil that maintains the simplicity of two T/R channels but with improved RF shimming capability. Simulations show that this head coil can improve B_1^+ uniformity in the head considerably more than a conventional birdcage head coil alone with two independent T/R channels.

Methods

Figure 1(a) shows the FDTD model (XFDTD software package, Remcom, Inc., State College, PA)[1,2] of the proposed head coil. The coil is made of two parts: a 16-element highpass birdcage coil and a single ring coil. Like a conventional birdcage coil, the birdcage is tuned to the uniform B_1^+ mode at 298MHz by adjusting the capacitor values in both end rings. The single ring coil is placed in the mid-plane of the birdcage coil. Evenly distributed capacitors along the ring conductor are used to tune the ring coil to 298MHz for a mode with a sinusoidal current distribution. As the ring coil is at the center of birdcage coil, its effect on the resonant mode of the birdcage coil is negligible and thus independent T/R for each coil is possible. Two independent transmit channels are used to drive the head coil, one channel for the birdcage coil and the other for the ring coil. For each channel, a quadrature hybrid and a 180° phase shifter are used to split the RF power equally to four ports with progressive phase shift of 90°. Thus each coil is fed in quadrature. When there is no RF input power for the ring coil, the head coil acts like a conventional birdcage coil, which has all the benefits of a birdcage type of head coil. When there is RF input power for the ring coil and birdcage coil, the generated B_1^+ of the ring coil can be used to improve overall B_1^+ uniformity in the head. For the FDTD coil model, the birdcage coil has diameter of 30cm and end ring center-to-center distance of 20cm. A RF shield is used and has diameter of 35cm and length of 25.5cm. For the ring coil, the diameter is 32cm and width of 1.5cm. For the birdcage coil, four-port feed is placed in the top (superior) end ring. For the ring coil, four-port feed is placed along the ring conductor evenly. A human head model is used to load the proposed head coil and to conduct $|B_1^+|$ shimming simulations over three center orthogonal slices of the head[3].

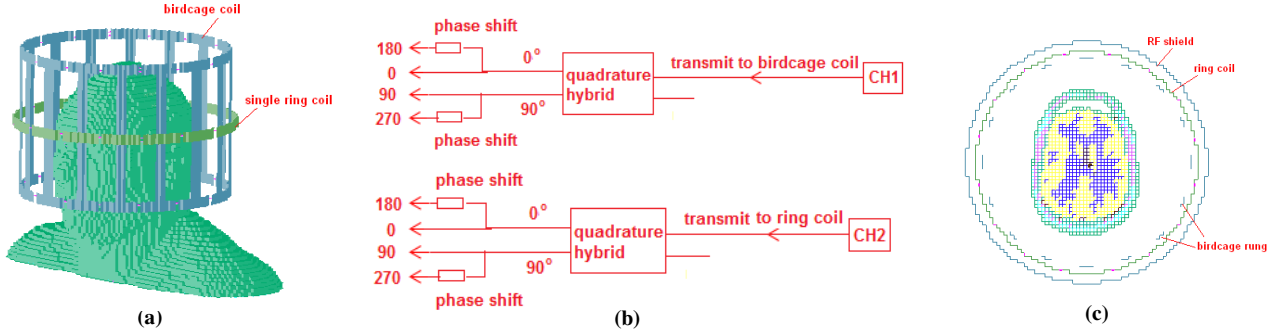

Figure 1. (a) Proposed two channel head coil with human head model (RF shield is not shown); (b) Four-port quadrature feed for each coil part; (c) Center transverse slice of the head model for $|B_1^+|$ shimming.

Results

Figure 2 shows the comparison of $|B_1^+|$-field distributions over three center orthogonal slices of the head model for a conventional birdcage head coil and for the proposed two-channel head coil. The normalized $|B_1^+|/|B_1^+|_{avg}$ is plotted, where $|B_1^+|_{avg}$ is the average $|B_1^+|$ over the center slice. Optimal $|B_1^+|$ shimming is done by minimizing $|B_1^+|$ standard deviation in the selected slice. $|B_1^+|$ shimming for center sagittal and coronal slices is done over the respective slice area within the head volume coil. The values of $|B_1^+|$ standard deviation (normalized to mean value, no units) and the ratio of maximum $|B_1^+|$ to minimum $|B_1^+|$ in slice are also given. In the center transverse slice, conventional birdcage coil with quadrature feed has $|B_1^+|$ standard deviation of 0.205. For conventional birdcage coil with two-channel shimming, $|B_1^+|$ deviation is reduced to 0.188 (~8% improvement). For the proposed birdcage + loop head coil with two-channel shimming, $|B_1^+|$ deviation is further reduced to 0.079, (~61% reduction from conventional birdcage with quadrature feed, or ~58% reduction from two-channel shimming with conventional birdcage coil). $|B_1^+|$ bright spot in the slice center region is well shimmed. $|B_1^+|$ shimming over the center sagittal and coronal slices also show significant improvements of $|B_1^+|$ uniformity.

Conclusions

Here we demonstrate by simulation the feasibility of a 7T T/R head coil with only two-channel T/R and with improved uniformity. Compared with a conventional two channel birdcage T/R head coil, the proposed head coil with extra resonant ring structure in the mid-plane is more effective for two-channel $|B_1^+|$ shimming. Complexity (SAR control, general hardware) is reduced compared to schemes with >>two T/R channels.

References

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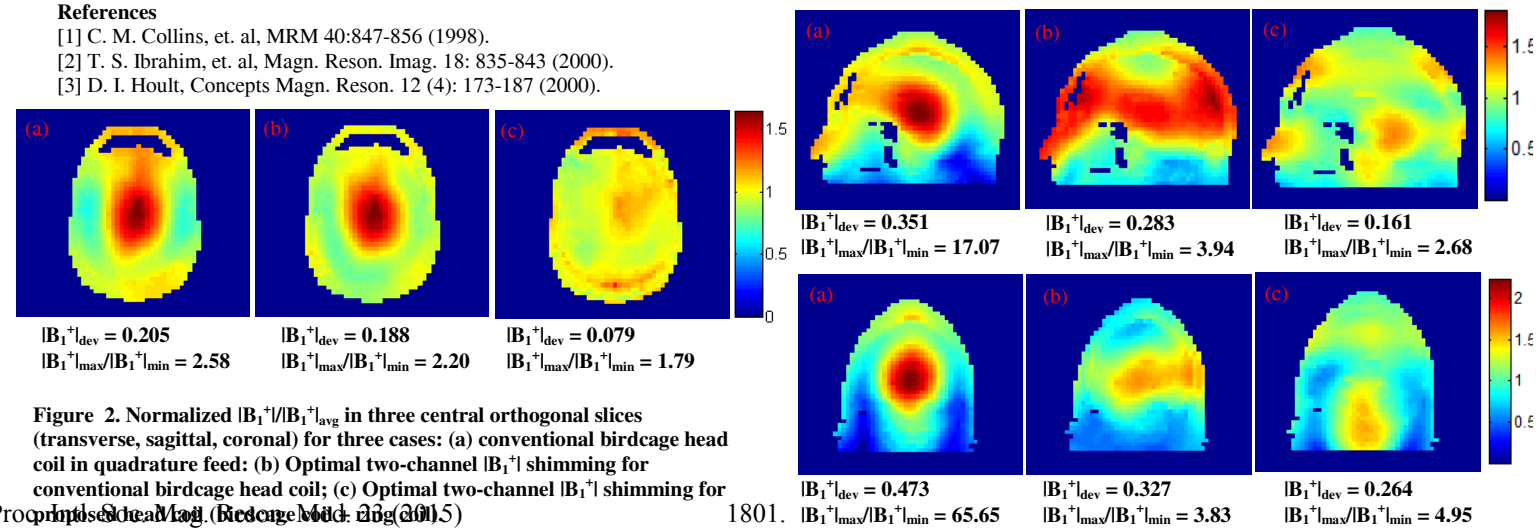

Figure 2. Normalized $|B_1^+|/|B_1^+|_{avg}$ in three central orthogonal slices (transverse, sagittal, coronal) for three cases: (a) conventional birdcage head coil in quadrature feed: (b) Optimal two-channel $|B_1^+|$ shimming for conventional birdcage head coil; (c) Optimal two-channel $|B_1^+|$ shimming for proposed head coil (birdcage + ring coil).