Quadrature Transmit Coil for Ultra High Field MRI

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Introduction

At ultra high fields such as 7T, B_1 field distribution is dominated by the tissue dielectric effects. A transmit coil with uniform B_1 remains a challenge compared to 1.5T or 3T. Therefore, all types of RF coil structures are being explored for 7T, such as loops, TEM strips, wavelength dipole [1], travelling wave coil concepts [2], radiative coil antenna [3], stepped impedance resonators [4], and even non-resonance microstrips [5]. Here we suggest a new type of volume transmit coil for 7T and above - a birdcage structure with discontinuous (or broken) rungs. Simulations show that such a coil structure, when tuned properly, can generate similar B_1 to that of a birdcage volume coil. It provides a new and more flexible way of making volume transmit coil for ultra-high fields MRI.

Methods

To start with, a conventional 16-element highpass birdcage head volume coil is modeled using the FDTD method (XFDTD software package, Remcom, Inc., State College, PA). The shielded head coil has the diameter of 30cm and length of 20cm (end ring center-to-center distance). Figure 1 shows the loaded coil model with a heterogeneous human head model (part of the RF shield is shown). The birdcage coil is tuned to the resonance of 298MHz (7T proton). To model a coil with discontinuous rungs, as an example, we break each rung in the middle such that the birdcage coil is divided into two halves. Each half is basically an end ring structure connected with multiple radiative strips. Each half can be tuned to a resonance which has similar B_1-field as that of a birdcage coil. Two halves can be fed in quadrature together similar to the birdcage coil.

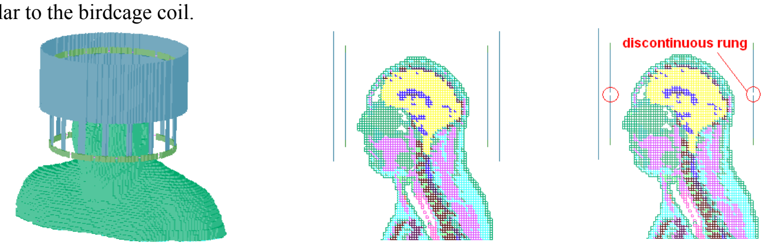

Figure 1. Left: loaded regular birdcage head coil model; (middle) regular birdcage coil with continuous rung connected to two end rings; (right) coil discontinuous rungs, each part of the rungs is connected to one end ring.

Results

In Figure 2, we plot the normalized $|B_1^+|/|B_1^+|_{center}$ in three center orthogonal slices (transverse, sagittal, coronal) of the head for the regular birdcage coil and the volume coil with discontinuous rungs, where $|B_1^+|_{center}$ is the average $|B_1^+|$ over the center transverse slice. Only areas within the head volume coil are plotted. Both coils are 2-port feed in quadrature. For the coil with discontinuous rungs, one port is placed in each half. As seen, $|B_1^+|$ uniformity is very similar for both coils, while the coil with discontinuous rungs has a little higher $|B_1^+|$ in portions of anterior and lateral regions. One of the advantages of quadrature birdcage coils is one can use two independent transmit channels to perform B_1-shimming to further improve $|B_1^+|$ uniformity. Figure 3 shows the shimmed $|B_1^+|$ (normalized to slice average) in the same three slices for both coils with two independent RF sources. As seen in Table 1, where $|B_1^+|$ standard deviation (divided by average $|B_1^+|$, no unit) is calculated, coil with the discontinuous rungs has a better shimming result than that of the regular birdcage coil. For example, in sagittal slice $|B_1^+|$ standard deviation is reduced further by 22% for the proposed volume coil compared to the regular birdcage coil.

Conclusions

Here we demonstrate the feasibility of a new volume transmit coil for ultra-high fields MRI. Comparing with a regular birdcage coil, the coil with discontinuous rungs is more flexible to build. The discontinuous locations in the rungs can be chosen to generate best B_1 for a specific use, or two parts of the birdcage coil can be separated further to provide enough space for other uses, such as placing a receive coil array or visual stimulus devices, etc.. Rung discontinuity can be chosen at interleaved rungs for possible multi-nuclear coils. This coil is also applicable for B_1-shimming with two independent transmit channels. It is possible to make the radiative strips longer, in a large diameter or flexible for various imaging purposes at different anatomies such as head or torso at 7T and above.

References

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[4]. C. Akgun, et. al., proc. ISMRM 2011, 3815.
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	Transverse	Sagittal	Coronal
Regular birdcage	0.21	0.37	0.29
Coil with discontinuous rungs	0.18	0.29	0.26
Improvement%	-14%	-22%	-10%

Table 1. Comparison of shimmed $|B_1^+|$ standard deviation for two head coils with two independent transmit channel B_1-shimming.

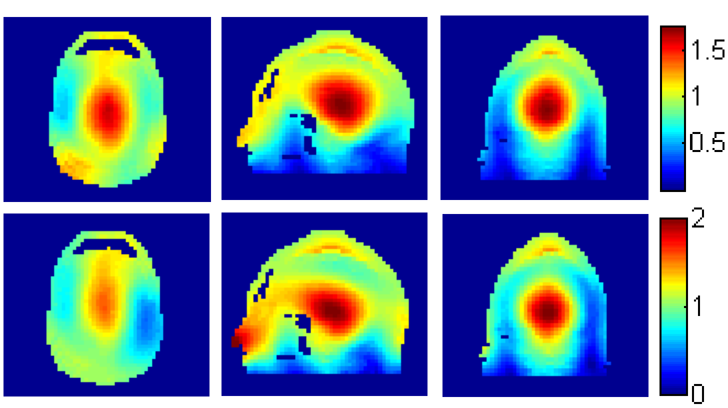

Figure 2. Normalized $|B_1^+|/|B_1^+|_{center}$ in three central transverse slices for a regular birdcage coil (top row) and coil with discontinuous rungs (bottom rung). Both coils are two-port quadrature feed.

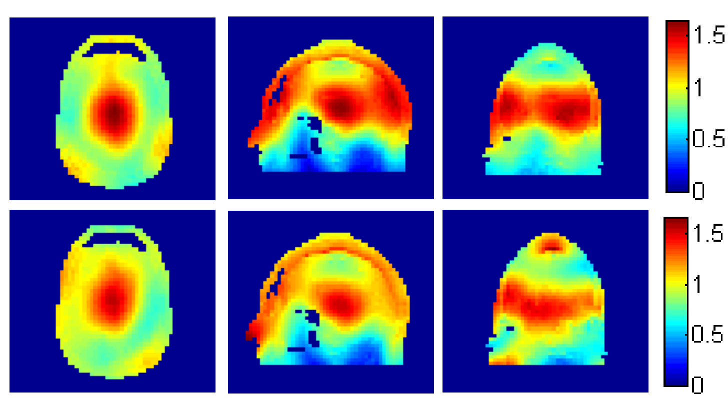

Figure 3. Best uniform $|B_1^+|/|B_1^+|_{avg}$ in three central transverse slices for a regular birdcage coil (top row) and coil with discontinuous rungs (bottom rung). B_1-shimming with two independent transmit channels are used.