A Head Coil Design Using a Single Coil Structure of Dual Operation Modes for Homogeneous Volume Excitation and Parallel Signal Acquisition in High Field Imaging

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Introduction: Scientific and clinical applications of head imaging have significantly increased due to recent advancement of high field technology. The high resolution measurement in these applications, especially in the studies on brain metabolism using proton spectroscopic imaging, requires a highly efficient head coil design to achieve both good homogeneity in RF excitation and high sensitivity in signal reception. This challenge is usually approached using the combination of a transmit-only volume coil and a receive-only phase array coil with actively decoupling circuits. In this study, we propose a novel coil design with a single coil structure of different T/R operation modes for head imaging at high fields. The coil is used as a volume coil to generate a homogeneous B_1-field in the transmitting phase and is configured to an 8-channel surface-coil array for SNR enhancement in the receiving phase. Compared with other head coil structures, this coil design offers higher efficiency in imaging performance and coil implementation.

Methods and Materials: The major coil structure is shown in Fig. 1. Two grounded washers machined from PCB provide the support structure for 32 copper rungs. These rungs form a basic 16-leg TEM coil structure with the 16 outer rungs grounded for shield. An end-ring is connected to the top of inner rungs and shielded out of the ground layer. In the transmitting phase, the 16 inner rungs are driven to generate currents for RF excitation. In the receiving phase, the connection between rungs is reconfigured using diode-controlled circuits and every two of 16 inner rungs form a surface coil loop. Eight channels are implemented for parallel imaging. The T/R mode control circuits in the unfolded coil structure are shown in Fig. 2. The coil size for a 3T system is 8" in length and 10" in diameter.

Results and Discussion: A 16-leg TEM coil produces 9 observable resonance modes and the second lowest mode is used to generate a homogenous B_1 field. The frequency differences between the expected mode and adjacent modes are about 4~5MHz for a 3T coil. Due to this proximity, mode mixing will considerably reduce the RF efficiency of the transmitting coil. An extra end-ring is introduced in this structure to degenerate the resonance modes close to the expected mode. It is found that all the unwanted resonance modes are more than 50MHz away from the expected mode with this end-ring. The RF homogeneity is less affected by the mode mixing and the bench test shows that the B_1 field is flat over 80% of the coil volume. The field produced by end-ring currents will not enhance the RF heating in sample because the ring is shielded out of the sample region. To implement an array structure for signal reception, a simple way is to connect each inner rung to a low input impedance amplifier and 16 channels will be available for parallel acquisition. However, the SNR performance will suffer from the weak coupling between a single rung and the sample. For this reason, it is necessary to construct a different coil unit in the receive array structure with sufficient sensitivity coverage in the sample region. Such surface coil loops can be implemented by connecting two inner rungs as shown in Fig. 3. Table 1 gives the measurement on the percent drop of loaded Q from unloaded Q using different connection strategies. The loop connection in Fig. 3(c) and the control circuit in Fig. 2 are used to implement 8-channel phase array for parallel imaging.

Conclusion: A head coil design with different T/R operation modes is implemented for high field imaging. This coil offers the capability of homogeneous volume RF excitation and high-sensitivity parallel signal acquisition in head imaging. Higher efficiency is achieved in coil implementation, RF excitation and signal acquisition in comparison to other head coil designs.

Coil loops	Q drop from loading
Full Volume coil	64%
Single rung	16%
Coil loop in Fig. 3(a)	28%
Coil loop in Fig. 3(b)	39%
Coil loop in Fig. 3(c)	52%

Table 1. Q drop measurement from loading

References:

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3. J.T. Vaughan, et. Al., "Radio Frequency Volume Coils for Imaging and Spectroscopy", US Patent, # 5557247, Sep. 17, 1996.

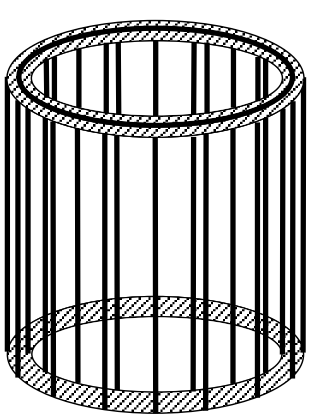

Fig. 1

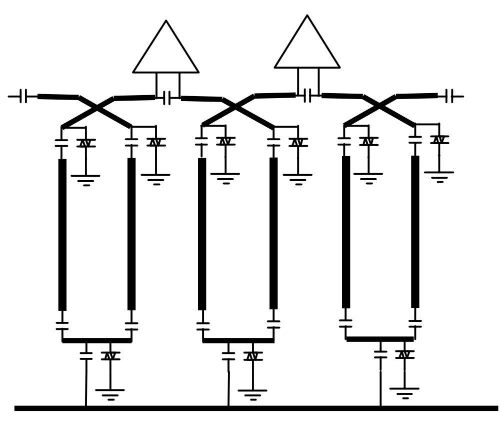

Fig. 2

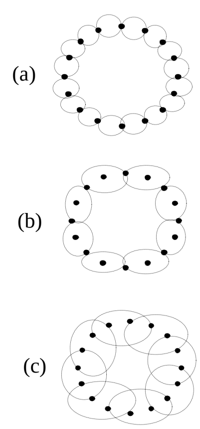

Fig. 3

Fig. 1. Major coil structure. The connection circuits between the end-ring and the rungs are not shown.
Fig. 2. T/R mode control circuits: The coil structure is unfolded on a flat plane. All diodes are actively switched on in the transmitting phase and off in the receiving phase. The triangle represents the low input impedance preamplifier. The end-ring and outer rungs are not shown in this figure.
Fig. 3. Formation of coil loops in array structure by connecting two inner rungs. The solid dots represent the inner rungs. The dashed lines give the loop connection between rungs. 16 channels are available in (a) and 8 channels in (b) and (c).