16-channel degenerate birdcage T/R loop array head coil for parallel transmit MRI at 7 T

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Introduction: Parallel transmit method has provided the potential to shape excitations with practical pulse lengths and mitigate B_1^+ inhomogeneity and B_0 inhomogeneity at high field. Increasing the number of transmit channels offers the flexibility for adjusting the phase and amplitude of each channel [1] and the degree of the freedom for improved pulse design and SAR. In this work, we developed a 16-channel T/R degenerate birdcage head coil in a single cylindrical row, with good decoupling (>15dB) between the next neighbors and high B_1^+ efficiency as compared with that of an 8-channel concentrically shielded T/R array coil.

Methods: The experiments were performed on the 7T system (Siemens Healthcare, Erlangen Germany) equipped with 8x1kW transmit channels, 32 receive channels and 70mT/m SC72 body gradients. The 16-channel loop array (Fig. 1) was routed with PCB sheets in a single row around a 304 mm dia, acrylic tube. The loop dimensions were 190mm x 60mm using 10mm trace widths. The adjacent rectangular elements were decoupled by adjusting the capacitor ratio between the ring and shared rung capacitors each of which used a high-power trimmer capacitor (60-0716-10016-600, Tronser Trimmers, Engelsbrand, Germany). Each element was tuned to the proton's Larmor frequency at 7T (297.2MHz) and matched to 50 Ω via a lattice balun. The latter also severed to isolate the differential potentials between the end-ring feed points and the coaxial cable shield. The output cables were connected to an interface box, comprising with cable traps, T/R switches, preamps (Siemens Healthcare, Erlangen), and patient table plugs.

The 16 channel coil was excited through a 16x16 Butler matrix [2] outside of the magnet bore. The Butler matrix distributed the transmit power to 16 elements with the appropriate phase to excite the modes associated with a birdcage coil (including 8 CP modes and 8 Anti-CP modes). Since an 8 channel parallel transmit system was used, 4 CP modes and 4 Anti-CP modes were selected for excitation with in a B_1^+ shimming mode. Figure 2 shows the B_1^+ profiles of the 8 modes were obtained by mapping using a pre-saturation pulse and turbo-FLASH readout [3]. The array was compared to a smaller (280mm diameter) 8-channel concentrically shielded transceiver array coil [4].

Results and Conclusions: The 16-channel degenerate birdcage had the average S12 coupling between nearest neighbors about -17dB and between the next nearest neighbors is about -15dB. The worst case inter-element coupling was -14dB loaded by phantom. The individual $B1^+$ magnitude maps of the 16-channel degenerate birdcage in Fig 2 showed the similar $B1^+$ profiles for each element and the sufficient decoupling between each element. The $B1^+$ efficiency of the uniform mode of the16-channel degenerate birdcage was not much higher than the 8-channel head coil, but for other modes the 16-channel coil generated more $B1^+$ field per input power, Fig 3. From Bloch simulation, the average transmit power of 16-channel coil was less than the transmit power from 8-chnnel coil, for 1 spoke pulse design (table 2). From the multi slice $B1^+$ maps (Fig 4), the B1+ field pattern of this 16-channel loop array showed a full coverage of the whole brain.

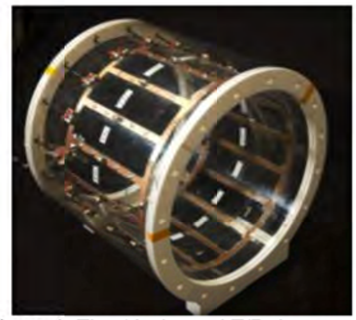

Figure 1. The 16-channel T/R degenerate birdcage head coil.

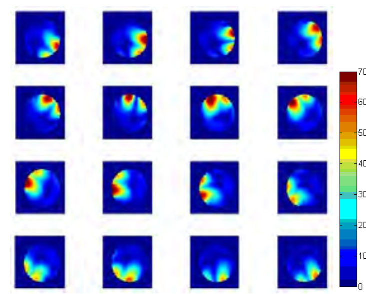

Figure 2. Individual B1+ maps of the 16-channel degenerate birdcage, unit : nT/V.

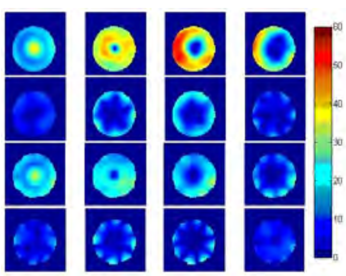

Figure 1. B1+ maps of BC modes, unit: nT/V. (1) 4 CP modes and 4 Anti-CP modes of the 16-channel degenerate birdcage by 16x16 Butler matrix. (2) 4 CP modes and 4 Anti-CP modes of the 8-channel array coil by 8x8 Butler matrix.

Sum of 8 transmit channel	8ch	16ch
Average power/1spoke (W)	75.04	73.75
Average power/4spokes (W)	62.80	64.04
Maximum voltage/1spoke (V)	215.65	226.28
Maximum voltage/4spokes(V)	728.95	640.25

Table 2. Transmit power comparison of the 16-channel degenerate birdcage and the 8-channel coil from the Bloch simulation of 1 spoke and 4 spokes.

B1 efficiency	8ch	16ch	Birdcage
Unform mode(TRA)	3.25	3.72	6.71
Other modes (Max)	3.28	5.28	/

Table 1. The B1 efficiency in the center slice of the transversal plane of 16-channel degenerate birdcage, that of the 8-channel array coil and that of the 16-leg birdcage with RF shield.

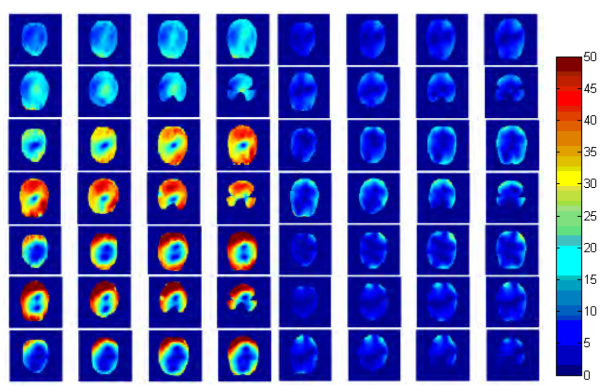

Figure 4. In vivo B1+ maps of 8 transmit BC modes from the 16-channel degenerate birdcage. 8 slices of the transversal plane of the brain was taken for each BC mode. The method consisted of two parts: qualitative part (low flip angle images acquisitions), and quantitative part (stepping through different flip angles of the pre-saturation pulse). The volume mapped was set to FOV = 24x24x16 cm^3, encoded over a matrix size of (x,y,z) = (64,64,32). The overall acquisition time was 3 minutes.

Reference: [1] N. Darji, et al., ISMRM, 19 (2011), 324. [2] V. Alagappan, et al., ISMRM, 16 (2008). [3] Lee, et al, ISMRM 2010, p2835. [4] V. Alagappan, et al., ISMRM, 17 (2009) 3008. **Acknowledgments:** NCRR P41 RR14075.