Non-resonance 16-element transceiver array for human head imaging at 7T

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Introduction: To overcome the B_1 inhomogeneity at high field MRI, parallel transmission [1] and B_1 shimming using multichannel transceiver arrays have been utilized to manipulate the B_1 profiles. This has presented a challenging issue for array element decoupling. Non-resonance RF method (NORM) using traveling wave for array coil design has exhibited its great advantages [2, 3], including intrinsic decoupling between NORM elements, multiple frequency operation, and homogeneous B_1 field along elements. In this work, a 16-element transceiver NORM array for human head imaging at 7T is modeled to investigate its performance in parallel imaging and parallel excitation at ultrahigh fields. The decoupling between array elements, B_1 field distribution and capability for multinuclear excitation and reception are simulated and evaluated using FDTD method. Also, the g-factor maps for 1D SENSE have also been calculated.

Material and method: Fig 1 shows the structure of the 16-element transceiver NORM head array. Each element was a NORM coil: a 20mm wide microstrip conductor being built on the surface of a 6mm thick, 32mm wide Teflon substrate with permittivity of 2.1 and loss tangent of 0.0003. The ground was built by adhering a single piece copper to the bottom of the substrate. With such a configuration, the characteristic impedance Z_0 was matched to 50Ω. Z_0 is independent of the length of the element, however for fitting head size each element was built to 23cm long. On one end of each element a series voltage source with 50Ω impedance acted as the feed coaxial cable, while on the other end a 50Ω impedance was used as termination for simplification. However in practical applications, the connection setup in Ref [3] should be used to guarantee both transmission and reception efficiency. Totally 16 NORM elements were equidistantly distributed along a cylinder with 23cm ID. The ground was connected together using copper tape to form a single piece ground. XFDTD (Remcom Inc.) was used to simulate the B_1 field distributions in unloaded case and analyze the decoupling for H^1 head imaging at 7T. The g-factor was also calculated. To demonstrate its multinuclear signal detection ability, B_1 field distributions of C^{13} and P^{31} using the same NORM array were also simulated.

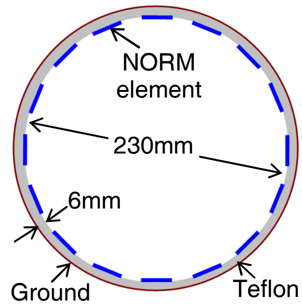

Fig. 1. The cross-sectional view of the NORM head array.

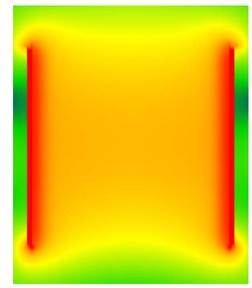

Fig. 2 Homogeneous B_1 profile of sagittal plane when fed simultaneously.

Results: The simulated decoupling coefficients among array elements are all better than -35dB when frequency ranging from 1 to 500MHz while the S11 are below -20dB. When fed simultaneously, homogeneous B_1 profile can be achieved, as shown in Fig 2. Well-defined B_1 profiles of the 16 individual elements shown in Fig 3 illustrates the unmatched decoupling performance of the proposed NORM array. Their combined B_1 pattern on axial plane when fed simultaneously (Fig 3a) is homogeneous. The g-factor maps for 1D SENSE reconstruction at different reduction factors are shown in Fig 4, and the mean and std of g-factors are listed in Table 1, illustrating feasibility and high performance for parallel imaging. With the presence of the human head, it is expected to achieve even better parallel imaging performance due to the highly asymmetric B_1 profiles [4]. To demonstrate the multinuclear signal detection feasibility, the axial B_1 profiles of the same NORM array for C^{13} and P^{31} at 7T are shown in Fig 5. The homogeneity and decoupling between elements are as good as those in the B_1 profiles of H^1, demonstrating multinuclear MRI/S capability of the same NORM array.

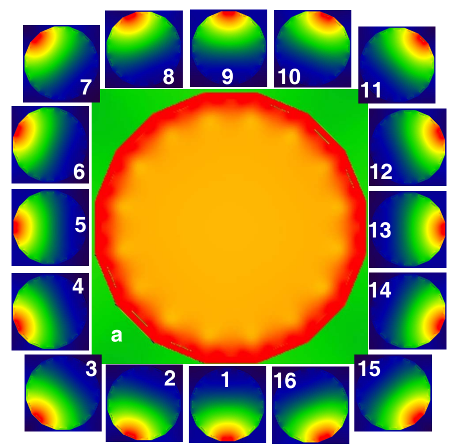

Fig. 3 B_1 profiles of 16 elements and the homogeneous B_1 when fed simultaneously. The numbers denote the element number.

Conclusion and discussion: In this work, the feasibility and great advantages of 16-element transceiver NORM array for human head imaging and multinuclear MRI/S at 7T have been demonstrated using FDTD simulation. The intrinsic decoupling between array elements makes it easy to use in both parallel transmission and acquisition. Homogeneous B_1 field along both the axial and sagittal planes can be achieved when fed simultaneously. For parallel imaging, it is expected to achieve high performance due to its good g-factor maps and superior decoupling performance. Especially at high field where dielectric resonance becomes dominant, loaded case in practical experiments will make sensitivity pattern highly asymmetric and help further improving parallel imaging performance [4]. Another unique advantage is that multinuclear MRI/S can be implemented by using the same NORM array structure. Although the resonance frequency has been changed greatly (from 298MHz to 120 and 75MHz), there is almost no change on the B_1 field homogeneity and the decoupling. This also implicates that the NORM coil array can be used for proton imaging at different field strength MRI, such as 7T, 3T and1.5T, without changing or "re-tuning" the array.

References: [1] Zhu Y, Magn Reson Med 2004; 51: 775-784. [2] Zhang X, et al, ISMRM 2008: p435. [3] Zhang X, et al, ISMRM 2009: p104. [4] Adriany G, et al, Magn Reson Med 2005; 53: 434-445.

Reduction factor	2	3	4	5	6
g-factor mean	1.08	1.22	1.43	1.85	3.06
g-factor std	0.11	0.16	0.26	0.68	1.92

Table 1 G-factors for 1D SENSE at different reduction factors.

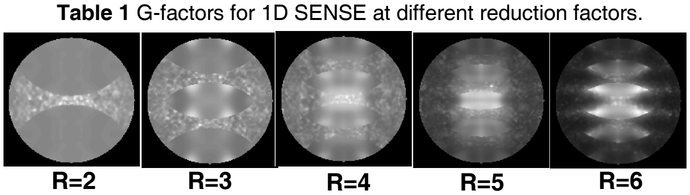

Fig. 4 g-factor maps for 1D SENSE at different reduction factors.

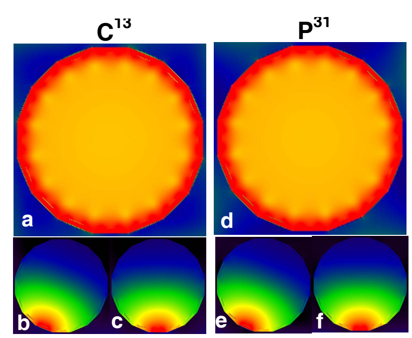

Fig. 5 Using the same array to generate RF fields of C^{13} (left) and P^{31} at 7T (right): (a) B_1 profile of C^{13} when fed simultaneous; (b,c) two individual B_1 profiles of adjacent elements for C^{13}; (d) B_1 profile of P^{31} when fed simultaneous; (b,c) two individual B_1 profiles of two adjacent elements for P^{31}.