Design and numerical evaluation of an 8-element quadrature transceiver array using single-feed CP patch antenna for parallel reception and excitation

Y. Pang[1], C. Wang[1], and X. Zhang[1,2]

[1]Radiology and Biomedical imaging, University of California San Francisco, San Francisco, CA, United States, [2]UCSF/UC Berkeley Joint Graduate Group in Bioengineering, San Francisco & Berkeley, CA, United States

Introduction: It has been demonstrated that a single-feed transceiver patch coil is able to generate a circularly polarized (CP) magnetic field, which can improve the MR sensitivity by 40% and reduce the excitation power by half compared with linear coils [1]. This single-feed quadrature patch coil has a simple structure similar to a conventional linear surface coil, which can be easily used for building quadrature transceiver arrays for both parallel imaging and parallel transmission. In this work, an 8-element quadrature transceiver planar patch array is designed and modeled at 298 MHz. Its feasibility is demonstrated and evaluated using FDTD simulation.

Material and method: The structure of 8-element quadrature patch array is shown in Figure 1. Each element was built as a nearly square ring microstrip patch antenna [2] using copper tape. The outer dimension of the ring was 12.2 cm by 12 cm, while the square slot cut was with side length of 4.4 cm. This square cutting was used to increase the path length of the surface current so as to reduce the resonant frequency to 298 MHz. The coaxial feed port (blue points in Figure 1) was along the diagonal and very close to the square slot. The 8 patch elements were equispaced distributed on the substrate and the distance between the neighboring elements was 4 cm. The ground was built by adhering a single copper sheet to the bottom of the substrate which was a piece of TMM 13I material with permittivity of 13.1. The XFDTD 6.4 (Remcom Inc.) was used to model this 8-element quadrature patch array, calculate the reflection and transmission parameters and evaluate the magnetic field distribution.

Results: The simulated S11 and the transmission parameters S21 to S81 are plotted in Figure 2. At 298 MHz the S11 is -8dB and the S21 to S81 are all better than -35dB. Also, the S11 of a single patch coil is plotted in Figure 2c where the shape is almost identical to that of Figure 2a. All these demonstrate excellent decoupling between patch elements. Figure 3 shows the B_1 field distribution of coronal plane at 10 cm above the array. 8 individual B_1 profiles are shown when driving independently, each with good sensitivity pattern. Their combined B_1 field has a homogeneous distribution when driving simultaneously. The axial and sagittal planes shown in Figure 4 demonstrate that the penetration of the patch array can reach 35 cm depth in unloaded case. The average B_1 at 5mm above array surface is 3.2e-6 T while that at 35 cm depth is 2.2e-7 T, which is 7% of the field strength at 5mm position. The B_1 field is a circularly polarized magnetic field as can be seen from Figure 5, in which the B_1 rotates with the time.

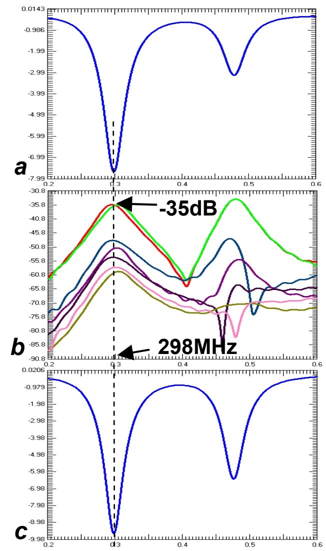

Fig. 2 XFDTD plots of (a) simulated S11 of the array, (b) simulated S21 to S81 parameters between port 1 and the other 7 ports; (c) simulated S11 of a single patch coil (non-array).

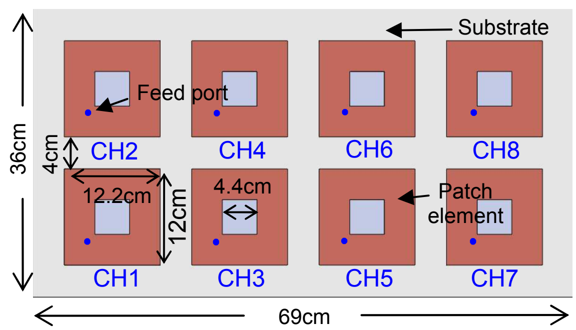

Fig. 1 8-element planar patch array model.

Conclusion and discussion: In this work, a novel design of quadrature planar array has been proposed using the nearly square ring microstrip patch antenna technique. Compared with the conventional quadrature coil, the structure of patch coil is simple and easy to be built as coil array. From the FDTD simulation results it can be seen that the penetration of patch coil is not worse than traditional loop coil. This quadrature array design is advantageous for parallel imaging because it can not only accelerate the imaging but also improve the SNR by 40% and reduce the RF excitation power during transmission. In practical design, the ring size and the position of the feed point need to be chosen carefully, because the ring size determines the resonant frequency while the feed point is related to the match impedance.

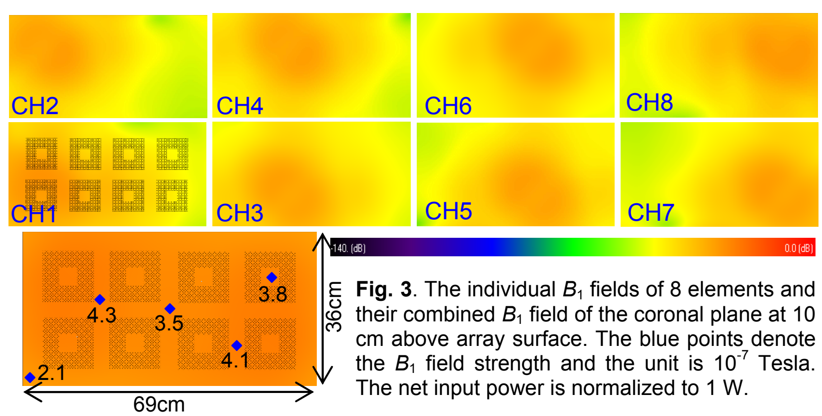

Fig. 3. The individual B_1 fields of 8 elements and their combined B_1 field of the coronal plane at 10 cm above array surface. The blue points denote the B_1 field strength and the unit is 10^{-7} Tesla. The net input power is normalized to 1 W.

References: [1] Zhang X, et al, ISMRM 2009: p3014. [2] Garg R, Microstrip Antenna Design Handbook (2001).

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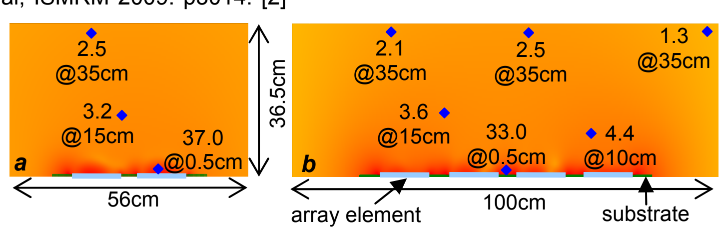

Fig. 4 (a) axial plane and (b) sagittal plane of the B_1 field near the center of the patch array. The blue points denote the B_1 field strength and the unit is 10^{-7} Tesla. The net input power is normalized to 1 Watt.

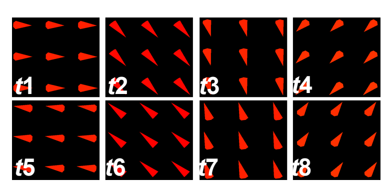

Fig. 5 CP magnetic field varies with time. *t*1 to *t*8 denote 8 discrete time point within one period, indicating quadrature or CP behavior of the patch array.