Double Tuned 31P/1H Elliptical Transceiver Phased Array for the Human Brain Studies at 7 T

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Introduction: The improved SNR at 7T provides significant advantages for both ^{1}H and lower gyromagnetic nuclei such as ^{31}P, ^{23}Na and ^{13}C (X nuclei). Double resonant volume head coils, based on both birdcage (1-3) and TEM (4) designs have been previously used at lower magnetic fields. However at 7T, transceiver phased arrays provide significant advantages for both B_1 homogeneity and transmit efficiency over volume coils. Similarly, phased arrays for reception provide additional SNR gains for peripheral locations for studies of X nuclei. Therefore, double tuned transceiver arrays may provide substantial advantages over conventional double tuned volume head coils. However, double tuned transceiver arrays are substantially more complicated than single tuned arrays since all individual coils must be decoupled at both resonance frequencies. We have developed a 16-element (8 elements at each frequency) split elliptical ^{31}P/^{1}H (120.7/298 MHz) 7T transceiver phased array. This design improved both coil's efficiency and homogeneity.

Methods: The array consisted of two concentric layers of evenly spaced rectangular surface coils circumscribing the head (8 coils per layer) separated by 1 cm, with the inner array resonating at ^{31}P frequency. The ^{31}P and ^{1}H arrays measured 10 and 9 cm in length, respectively. All the adjacent surface coils were decoupled inductively. To decouple ^{31}P and ^{1}H components of the phased array multiple ^{31}P and ^{1}H resonant traps were introduced into the individual surface coils in series. We also used novel double tuned cable traps to suppress shield currents at both resonance frequencies. To decrease radiation losses the array was shielded. The array was split in two parts with the bottom section having 10 (5 per layer) surface coils and the top portion – 6 (3 per layer) coils. Due to inductive decoupling no electrical connection between the two sections of the array was required. To accommodate different head sizes we constructed two different array tops (Fig.1), which when combined with the bottom (Fig.1) allowed the array's height to be varied (21 and 23 cm). The width of the arrays measured 19.5 cm. We compared the array with a double tuned ^{31}P/^{1}H TEM volume coil (^{1}H length – 13cm, ^{31}P length – 16cm, ID – 25cm). For comparison we also constructed similar in geometry and size ^{31}P/^{1}H transceiver array consisted of 8 double tuned surface coils (length – 9cm) utilizing common LC-trap design (5). All data was acquired on a Varian Direct Drive 7T human imaging system. The ^{31}P acquisition used a sparse Gaussian sampling scheme of 1219 encodes with a FOV of 240x240x240mm^3, with a TR of 0.5S and 4 averages (41min).

Results: For ^{1}H transmission, the transceiver array achieved 1.00±0.16 kHz of B_1 at a combined power of 3.37kW over an axial slice at the center of the coil (through the ventricles). The double tuned TEM required 6.41kW to achieve 1.00±0.25 kHz at the same location. The common LC-trap array was substantially worse and achieved 1 kHz of B_1 at ^{1}H frequency at 8.52 kW (projection since it was out of range for the amplifier) when optimized for ^{31}P performance. For ^{31}P transmission, the double layer ^{31}P/^{1}H transceiver array and the double tuned volume TEM coils achieved a mean B_1 over the head of 488 Hz at 1.75kW and 1.94kW, respectively. For ^{31}P reception, the transceiver array achieved up to a factor of 4 increase in SNR over the TEM volume coil over the periphery of the brain, and up to 20% higher SNR from central brain regions. Fig.2 displays a scout image and spectra from peripherally (A) and centrally (B) located voxels acquired with the TEM and the array. The spectra presented in Fig. 2 are plotted on the same vertical scale with identical processing.

Fig 1

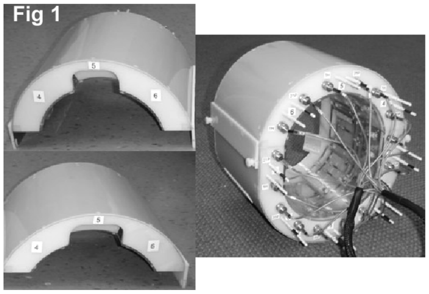
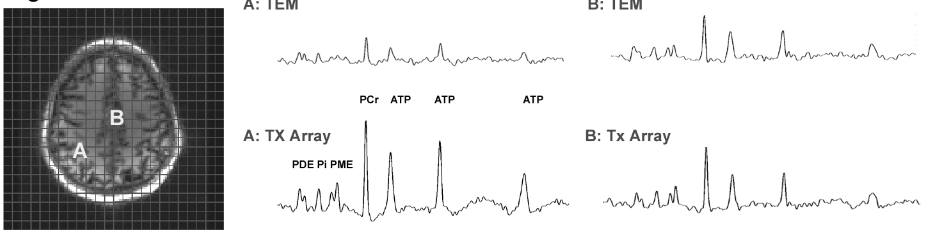


Fig 2



Conclusion: The double tuned transceiver phased array increased both B_1 homogeneity and efficiency for ^{1}H transmission in comparison to the double tuned TEM. For ^{31}P studies, in comparison to the TEM, the transceiver array provides similar transmission efficiency across the head; similar reception sensitivity for central brain locations (up to a 20% increase in SNR) and substantially greater reception sensitivity (up to a 400% increase) for peripheral locations.

References: 1) Rath AR, JMR 86:488-485, 1990. 2) Murphy-Boesch J et al, JMR B 103:103-114, 1994. 3) Shen GX et al, MRM 41:268-275, 1999. 4) Vaughan JT et al, MRM 32:206-218, 1994. 5) Schnall MD et al, JMR 65:122-129, 1985.