B1 Transmit Field Manipulation at 7 Tesla Using Controlled Decoupling of Array Coil Elements (CODACE)

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Introduction: At 7 Tesla, the short RF wavelength leads to cancellation effects in the human head for conventional volume transmit coils, producing a B1 Tx field with a distinct spatial B1 pattern, largely determined by the head's shape, which is highest in the center of the head but with low B1 areas in the temporal lobes and cerebellum (1). Dedicated off-resonance tuned surface coils have been proposed for manipulating the B1 Tx field and have been applied for body imaging at 3T (2). We extend this method to head imaging at 7T, and investigate how the surface coils already present in a receive array can be used to replace the dedicated tuned coils. We have developed a method where the receive array elements are manipulated during transmit to increase the B1 field in areas otherwise poorly served by standard birdcage and TEM volume coils. During transmit the receive coil's reactive impedance is manipulated with a modified T/R switch in the receive line which creates a preamp decoupling-type minimum in the response of the coil element. The frequency of the element's response minimum can be varied to control the amount of coupling to the TX coil, thus controlling the focusing of transmit RF into the region of interest. The receive coil operates as normal in receive mode.

Methods: All data were acquired on a 7 Tesla scanner (Siemens Medical Solutions, Erlangen Germany) with 32 receive channels. A close-fitting 32 channel receive-only head coil was used, with circular elements arranged in a soccer-ball type geometry, mounted inside a 28cm diameter and 20cm length transmit birdcage (3). An 8.5cm dia. coil on each side of the head was chosen for manipulation, due to their proximity to the anterior end of the temporal lobes. A T/R switch was constructed using a series diode and a diode shunted ¼ lambda coax to achieve switching of the receive coil either to the coil preamp, or to an adjustable capacitor connected to ground (Fig 1). The receive path through the T/R switch was designed to be ½ lambda so that the preamp decoupling of the receive coil would not be affected by the T/R switch during receive. The path length to the capacitive termination which is active during transmit was chosen so that the impedance of the termination was transformed to a low impedance at the coil's trap circuit, creating a decoupling type minimum in the coil resonance (similar to preamplifier decoupling) during transmit. The frequency of this minimum could be varied by +/- 30 MHz by setting the trimmer capacitor. This created a decoupling effect of between 0 and –22 dB. The decoupling strength was set to –12dB for both coils. The diodes in the T/R switch were biased with the systems standard bias signals.

The PIN diode detuning trap on the coil element was present but was not activated except for the comparisons to the normal use of the receive array. SNR comparisons were made using proton density gradient echo images (TR/TE/flip/slice = 200ms/4.07ms/20deg/3mm, 256x256, FoV=220mm) obtained in human scans using both the volume transmit coil in T/R mode and by transmitting with the volume coil and receiving with the 32 channel array. SNR scans were obtained both with and without the presence of the two T/R switches. Transmit coil tuning and match were optimized for each setup.

Results: A match of better than –25dB was obtained at each of the two input ports of the transmit birdcage with both the unperturbed setup and with the T/R switches creating partial decoupling for the two coils. Substantial adjustment of the tune and match circuit on the volume transmit coil was however necessary to achieve a good match in the two different configurations. The scanner transmit calibration was 256 volts for the standard setup with fully detuned receive array, and 280 volts when the two receive elements were partially decoupled. SNR maps for volume coil transmit and receive are shown in Figure 2. Substantial improvements in SNR are seen in the anterior parts of the temporal lobe, reflecting the higher transmit efficiency, and by reciprocity, higher receive sensitivity. SNR gains of up to 6 fold are seen in these volume coil T/R images, reflecting a B1 increase of over 2 fold. The increased B1 field in the anterior temporal lobe is accompanied by a B1 decrease elsewhere in the brain, particularly in the superior part of the frontal lobes and a region in the left posterior parietal/occipital cortex. When the local focusing method is applied in conjunction with array reception, a substantial gain is seen in the temporal lobe SNR, due to the increased local B1 TX field, which causes an increase in SNR for these low flip angle GRE images. SNR profiles through the anterior temporal lobe show SNR gains of up to 2.5 fold for volume TX and 32 channel RX.

Conclusions: We have demonstrated that it is possible to manipulate the local B1 transmit field of a standard birdcage coil through the controlled partial decoupling of specific receive coil elements. This increases the B1 TX field in specific regions which were otherwise poorly served by the transmit coil alone, but at the expense of B1 efficiency elsewhere. It is possible that control of other elements in the array could address these deficits and allow a more homogeneous transmit field, but coil interactions between an increasing number of partially detuned coil elements could prevent adequate control. The SAR implications of this approach as with other B1 shimming approaches need further evaluation before application to higher SAR sequences.

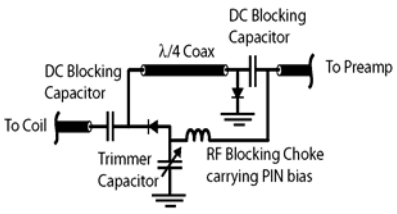

Fig. 1 T/R Switch Circuit Diagram

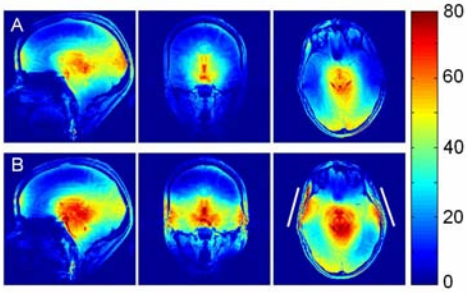

Fig. 2 SNR maps for volume coil transmit and receive showing the effect of A) all receive coils detuned and B) 2 receive coils partially decoupled (position of coils marked in figure)

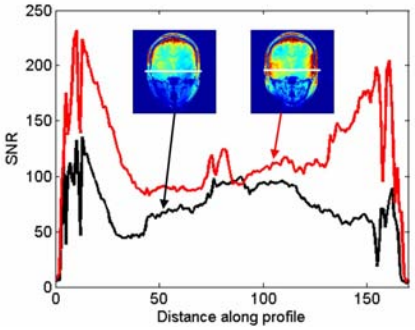

Fig. 3 SNR profiles for 32 channel array coil receive with (Red) and without (Black) B1 focusing, showing SNR gains of up to 2.5 fold in the temporal lobes

[1] Vaughan JT et.al. Magn Reson Med 46:24-30(2001) [2] Schmitt M, Feiweier T, Voellmecke E, Lazar R, Krueger G, Reykowski A, Proc. ISMRM 2005 Miami USA p331 [3] Wiggins GC, Triantafyllou C, Potthast A, Reykowski A, Nittka M, Wald LL, Mag Reson Med. 56:216-223 (2006)