Transmit B1 Field Pattern Control Using RF Current Source Technique

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Introduction Parallel excitation algorithms [1] that have the potential to optimize B_1 fields at high static fields or to enable volume selective imaging, require individual and independent control of RF current amplitude and phase on each transmit element. Coil element overlap or other passive decoupling techniques may be applicable for transmit decoupling but are limited to symmetrical and uniform loading. In this work a two-channel parallel excitation system incorporating the push-pull RF current source (CS) technique [2] was built and tested in a 3T clinical scanner to obtain B_1 field patterns within a head size volume without aid of other decoupling strategies. Phantom images show predictable B_1 patterns generated by controlling RF amplitudes and phases, demonstrating practical use of the RFCS drive and decoupling technique in a parallel transmit system. The proposed parallel system minimizes load dependent RF currents by forcing RF drive current and simultaneously blocking induced current by other elements.

Method A two-channel volume transmit and single channel receive coil was built in a symmetrical fashion as shown in figure 1. Two symmetrical saddle shaped loops (25.4 cm squared loop each) were implemented on a 25.4 cm diameter clear acrylic cylinder. Each loop was tuned at 127.7 MHz, and connected to the RFCS through a 50 ohm half wave length ($\lambda/2$) coaxial cable. The λ /2 cable effectively transfers RF drive currents from the drain terminal to the transmitting loop without perturbing terminal impedances at both ends, hence sustaining the suppression of induced currents as well as current mode operation. During the receive phase the two loops were matched and tuned to 50 ohm, and operated as a single channel receive coil via a PIN diode network. A 50 ohm coaxial cable was connected to the receive matching network through a 50 ohm lattice balun. During transmit phase the PIN diodes were short circuited with forward bias current thus creating open circuit terminals through the λ /4 cable at the loop terminal. This forced the receiver circuit to be decoupled from the transmitter. The constructed volume coil was tested in a 3T clinical scanner (Model GE signa, Milwaukee, WI, USA). The transmit RF pulse was derived from the scanner head coil port and attenuated by 30 dB. The transmit RF pulse was then input to the two channel controller. Each channel of the controller consisted of a variable phase shifter and a variable gain driver amplifier. The drive power feeding into the current source was calibrated during a pre-scan phase. A spherical mineral oil phantom (Model 2360034, GE Healthcare, Milwaukee, WI, USA) of 11.1 cm diameter was used to observe the B_1 field pattern. 2D axial images were obtained using a spoiled gradient echo (SPGR: TE min, TR 18, FA 60) sequence, under various RF phase and amplitude settings. With the same fixed amplitude on both channels, five images with different phase settings were acquired. Similarly, with a fixed phase on both channels, five images with different amplitude settings are presented. RF phase and amplitude on each channel were controlled by manually adjusting the phase shift and driver gain in the control unit.

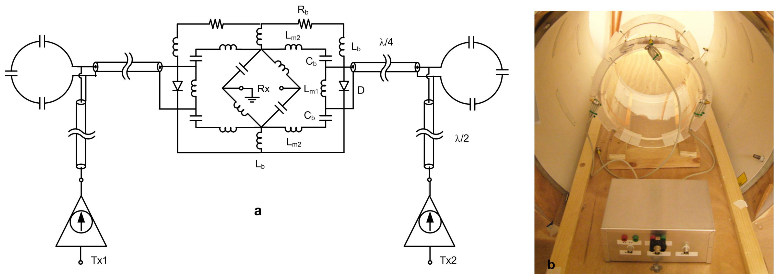

Figure 1. (a)The circuit diagram of the two-channel transmit incorporating RFCSs and single channel receive coil shows the receive network, which is composed of symmetrical matching and switching circuits. (B) Picture of the volume transmit and receive coil setup

Results RF amplitude (A1-5) and phase (P1-5) controlled images in five consecutive control steps are shown in figure 2. At equal drive current amplitude on both transmitting loops, the five consecutive phase controlled images (upper half of fig 2) show the null field region moving along the vertical direction. A simulation of the vector sum of the B_1 field contributions from the two loops predicts the movement of the low intensity region along the vertical. At fixed 180 degree phase shift between the two loops, the amplitude controlled images (lower half of fig 2) show a movement of the low intensity region along the horizontal line. This region is pushed toward the loop that carries less current amplitude. The fixed phase shift between the left and right elements yields in the constructive field addition in the top and bottom region of the images regardless of the amplitude control steps, resulting in the observed trajectory of the low intensity region in horizontal direction. The low intensity region can be placed anywhere within the sample by setting up a proper combination of RF amplitude and phase.

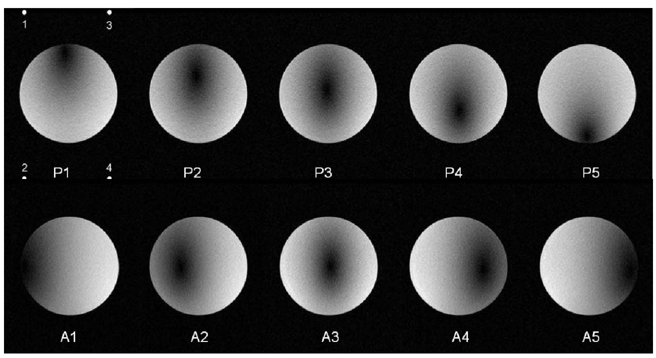

Figure 2. SPGR images with RF amplitude and phase control steps. The white dots on the figure P1 represent longitudinal linear elements of two transmit loops. Dots 1 and 2 are linear elements of the left hand loop, while dots 3 and 4 represent linear elements of the right hand loop. The vertical travel of the B_1 field null in images P1-P5 (top row) is obtained by varying the relative phase of the driven currents on the transmitting loops with equal driven current amplitude. The horizontal travel of the B_1 field null in images A1-A5 (bottom row) is obtained by the varying the driven current amplitudes on the two transmitting loops while maintaining a constant 180 degree phase relationship.

Discussion & Conclusion The predictable B_1 field pattern control demonstrates the use of the RFCS concept in a practical application at 3T. Transmit field control without any other decoupling strategies, was achieved just by the RFCS property that enforces driven currents into transmitting loops, and that simultaneously suppresses induced currents. Compared to passive decoupling networks, the push-pull RFCS technique allows simple and reliable transmit array construction, decouples not only neighboring elements but also distant array elements, and mitigates load dependent drive currents. This technique may be applicable to a large number of transmit array elements, where capacitor ladder networks may be cumbersome, or it may be used with a combination of other decoupling strategies.

Reference [1] Zhu Y., Magn. Reson. Med. 2004;51. pp775-784 [2] Lee W., et al., Proc. Intl. Soc. Mag. Reson. Med. 2008;16. p1091