B1 shimming using passive surface coils in the abdomen

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INTRODUCTION: One of the most significant issues in high field MR is the problem of RF field inhomogeneity. Significant problems from this begin to arise at 3T in the body, where the RF wavelength in tissue begins to be approximately on the order of the size of the imaging object. Several options have been proposed to improve B1 inhomogeneity- some of the more popular being parallel transmit with two or more actively transmitting RF coils, or modifying the polarization of the RF transmit coil from circular to elliptical. The B1 field can also be modified by passive materials- dielectric paddling has been used with some limited success. Passive resonant coils have been proposed as a means to locally modify an inhomogeneous B1 field (1,2). Here, we start with a population study of 3 Tesla B1 maps in the abdomen. Based on these B1 maps we calculated an average size, tuning, and placement of two passive surface coils above, and below the patient on the outside of the receive coil. In all subjects studied, the B1 maps had similar areas of low B1, and the same coil placement significantly improved the B1 homogeneity without any significant artifacts.

THEORY: Here we deal with the case of a passive resonant circular loop coil placed inside a volume coil producing a primary 128 MHz circularly polarized RF field. A simple analytical equation for the B1 field perturbation produced by this surface coil of radius a at distance k-a from the coil center was published by Wang et al (2) and is shown in Eqn. 1. B1o is the original circularly polarized RF field without the modulating passive coil, fL is the Larmor frequency, Δf is the difference between the passive coil tuning frequency and Larmor frequency, and rW is the radius of the wire used in the loop coil.

\[
B_1^c = \left[ 1 + \frac{\pi}{8(1+k^2)^{1/2}} \ln \left( \frac{8a}{r_W} \right) \right] B_{1o}
\]

Eqn. 1

METHODS: All data were acquired with a 3T GE Signa Excite HD scanner with a whole body transmit coil, and an 8 channel torso receive array, subjects oriented feet first in the magnet. Multi-slice spin echo Bloch-Siegert B1 maps were acquired in 6 subjects over an area covering 40x40x18 cm (3). The B1 maps were averaged over the z-direction, as very little variation along this direction was present in the B1 maps. Two loop coils were designed to correct the B1 inhomogeneity- one with 15 cm and one 12 cm diameter, with the plan that they become fixed components located on the outside of a local torso receive coil. The vertical distance from the body surface to the coil was 2 cm, and the optimal average off-center placements over the six subjects was found to be 2.7/2.0 cm right of center for the upper coil, and 0.13/0.36 cm right of center for the lower coil. Eqn. 1 was used to calculate the optimal tuning frequency for these six subjects for the two coils of radius a = 7.5, 6.0 cm, and copper tape with radius rW = 2.5 cm, to correct the B1 field to 0.065 gauss up to a depth of 15 cm. The tuning frequencies for these six people were found to be fL + Δf = 136.5±1.7 MHz for the top, and 140.0±3.2 MHz for the bottom coil.

RESULTS: Figure 2 shows axial Bloch-Siegert B1 maps, 1 cm slice thickness, for two subjects centered on the corrective coils, without (a.) and with (b.) the B1 corrective coil loops. The B1 maps with the corrective coils used a transmit gain that was 0.4 dB lower for both subjects but gave the same average B1 over the slice. c. ratio of B1 map (with coils) / B1 map (without).

DISCUSSION: In the population studied, the B1 distributions in the abdomen were very similar, with high B1 field on the sides, and low B1 field 2.7 cm to the right of magnet center on the anterior, and 0.13 cm right of center on the posterior the abdomen. The high degree of similarity between subjects allows a simple general solution of two corrective passive loop coils to be used to great effect to at least partially homogenize the B1 field. The overall transmit power used to achieve the same average flip angle over the slice was 0.4 dB lower in the two subjects with the corrective loop coils. The corrective coils lower the power needed for a given flip angle, reducing overall SAR.