

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 padding 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. B_{1o}⁺ is the original circularly polarized RF field without the modulating passive coil, *f_L* is the Larmor frequency, Δ*f* is the difference between the passive coil tuning frequency and Larmor frequency, and *r_w* is the radius of the wire used in the loop coil.

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±0.2 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 *r_w* = 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 *f_L* + Δ*f* = 136.5±1.7 MHz for the top, and 141.0±3.2 MHz for the bottom coil.

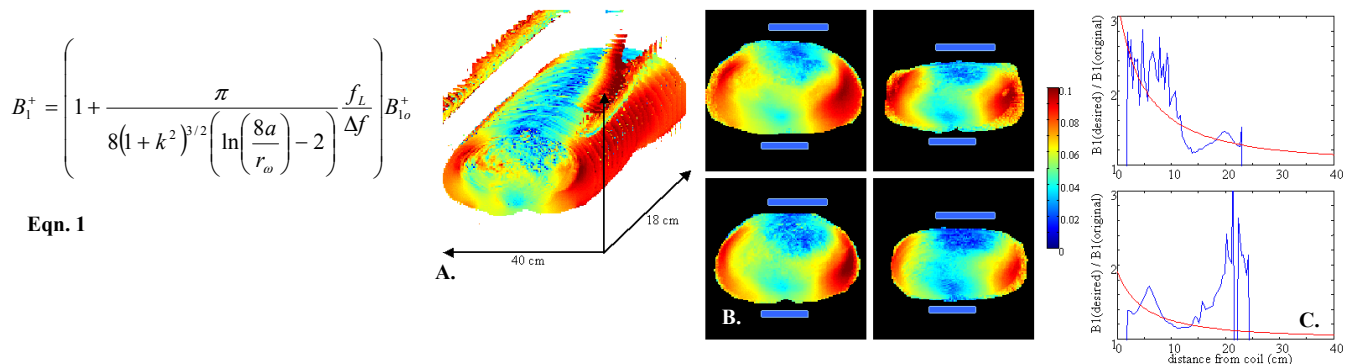


Figure 1: a. 18 slice axial, abdomen B₁ map in one subject. b. mean axial B₁ maps, averaged over the z-direction over 18 cm. in four subjects, with the average placement of the two passive coils shown on the maps. The coils are placed 2.7 cm. right of center on the top, centered on the bottom, 2 cm away from the surface of the patient. c. Target B₁ field: B₁⁺/B_{1o} for the two passive coils in one subject (blue), and expected corrective B₁ field for *f_L* + Δ*f* = 135 MHz (top) and 145 MHz (bottom), (red).

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.

REFERENCES: 1. Schmitt M, Feiweier T, Voellmecke E, Lazar R, Krueger G, Reykowski A. ISMRM 13th Meeting; p.331, 2005. 2. Wang S, Murphy-Boesch J, Merkle H, Koretsky AP, Duyn JH. IEEE Trans Med Imag 2009;28:551-554. 3. Sacolick LI, Wiesinger F, Hancu I, Vogel MW. B₁ mapping by Bloch-Siegert shift. Magn Reson Med 2009; in press.