B1 Shimming Performance Versus Channel/Mode Count

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Introduction.

Clinical 3T MRI systems capable of parallel RF transmission have recently been introduced [1]. With such functionality it has become possible to significantly minimize and even eliminate the RF uniformity issues encountered at these higher field strengths while simultaneously reducing SAR [2]. With the development of any parallel imaging technology the dominant question is "how does performance scale with the number of channels?". The answer is rarely straightforward and often depends on the application, the definition of what is a channel, and the definition of performance. In the case of parallel transmission, the primary application is to improve B1 field uniformity. This is different to parallel reception in which the primary application is generally scan time reduction. For parallel reception, the SNR is often the limiting constraint. For parallel transmission, the maximum available RF power, and its distribution, becomes a dominant constraint. This study reports on abdominal B1 shimming performance, using a multi-element volume body coil, as a function of transmit channel/mode count and available RF power.

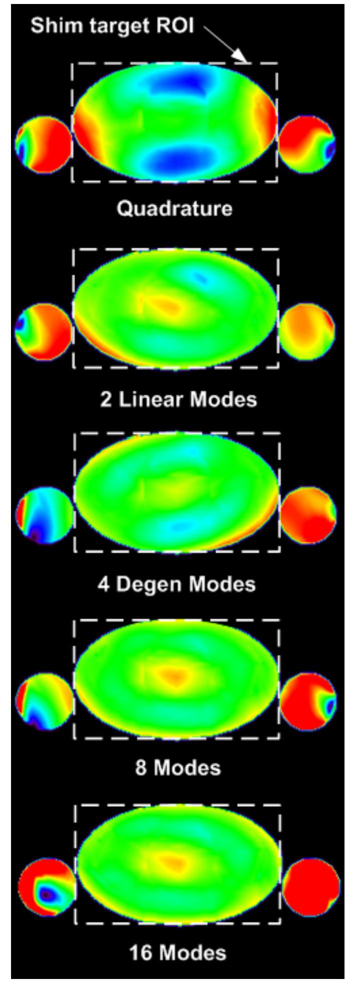

Figure 1: B1 uniformity plots for each driving scheme.

Materials & Methods.

Electro-magnetic (EM) field simulations were performed using HFSS (Ansoft, USA) with focus on shimming the B1 field in the torso/abdominal region. A 16 element TEM coil model was constructed in the simulation environment. The coil could be driven at each of 16 independent wave ports (with active decoupling). The amplitude and phase of the power supplied at each input could be treated as fully independent or grouped to emulate various modes of an equivalent degenerate birdcage coil [3,4]. The coil model was loaded with a stylized body model placed with the upper abdomen at iso-center. The body model had previously been validated to exhibit similar loading and B1 shading properties to those of an average human body of equivalent dimensions. B1 shim simulations were performed for a target ROI covering the whole abdomen. Shim fitting was performed in IDL by importing the complex B1 maps obtained for each element from the HFSS simulation. A number of virtual coils were constructed by combining the individual element fields into basis sets consisting of either radial element modes, linear modes or degenerate modes. The Levenberg-Marquardt method was used to perform amplitude and phase weighted fitting of the basis sets to realize the target B1 field with the minimum coefficient of variance (maximum uniformity) within the target ROI. Unconstrained fitting was used to determine the best possible uniformity improvement that could be obtained with the maximum degrees of freedom using 16 independent elements. This uniformity improvement served as the baseline by which to compare the other driving schemes including various constraints.

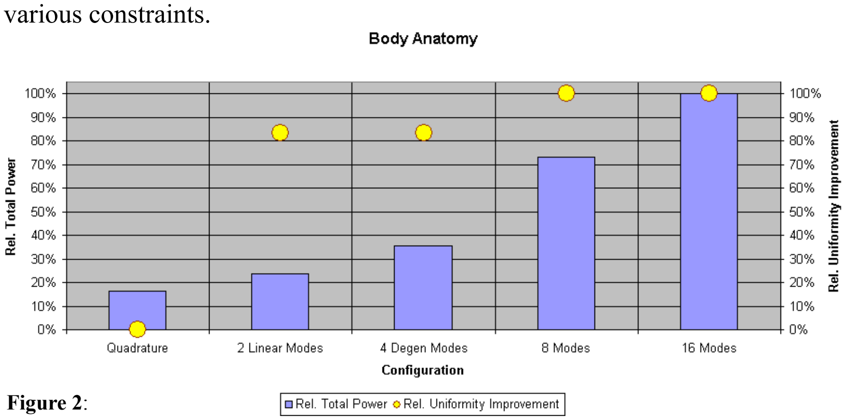

Figure 2:

Results.

Figure 1 shows the quadrature and shimmed B1 maps for each of the driving schemes examined. Figure 2 shows the relative shimming performance as a function of channel/mode count (yellow dots). An important factor in the comparison is the total power required to achieve a gain in shimming performance (blue bars).

Conclusions.

These simulations indicate that, for RF shimming in the torso, increasing the number of transmit channels/modes beyond 2 provides limited improvement in shimming performance with the disadvantage of an increase in power demand. 16 channels/modes provides no notable advantage over 8 channels/modes. 4 channels/modes offers negligible improvement over 2 channels/modes. 2 channels/modes provides as much as 80% of the maximum attainable uniformity improvement in the torso.

References.

[1] Kuhl C.K., et al Proc. ISMRM 2009, 4133, [2] Harvey P.R., et al Proc. ISMRM 2009, 4786, [3] Nistler J., et al, Proc. ISMRM 2006, 2471, [4] King S.B., et al, Proc. ISMRM 2009, 390.