B_1 Shimming using a Volume Coil at High Fields

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INTRODUCTION: Dielectric resonance effect is a major factor to cause B_1 inhomogeneity in the human brain at high fields. This B_1 inhomogeneity ultimately results in nonuniform human head images (1). In this work, we demonstrate that microstrip transmission line (MTL) volume coils can generate different B_1 patterns by changing the microstrip element parameters and investigate the feasibility of using B_1 pre-emphasis method for B_1 shimming to overcome the image inhomogeneity problem due to the dielectric resonance effect, ultimately, achieving uniform human head images at high fields based on MTL volume coils with the adjustable B_1 distribution.

METHODS: Two 16-element MTL volume coils for human head MR imaging (2,3) were examined. The widths *W* of the strip conductors of the MTL resonant elements for both coils were 2.54 cm while the substrate thickness *H* or the distance between the strip conductor and the ground plane were 0.6 cm and 2.1 cm, respectively. The coils had the same diameters of 25.4 cm and comparable lengths of 21 cm and 18 cm. By changing the ratio of *W*/*H*, different B_1 pattern of the MTL volume coil can be expected. To map the intrinsic B_1 (empty coil) distributions of the two coils, a mineral oil phantom (15 cm in diameter) which has a low permittivity and zero conductivity was used to mimic an unloaded case. In practice, it would be costly and time-consuming to build a large number of volume coils with different substrate thickness so that different B_1 patterns can be evaluated. However, it is known that given a coil B_1 distribution, the B_1 distribution in a phantom varies when the ion concentration of the phantom changes. Therefore, to investigate the possibility of B_1 shimming in the human head using the pre-emphasis method at high fields, we are able to use an alternative but easy-to-do method that we fix a pre-emphasized B_1 pattern of a volume coil and examine if it is possible to achieve a uniform B_1 distribution in a phantom (simulating the loaded case) at certain ion concentration. This method is analogous to that of changing the thickness of the substrate of the coil elements. Five phantoms with different NaCl concentrations (50mM, 80mM. 100mM, 115mM and 125mM) were used in this study. Finally we compared human head images acquired using the two volume coils with flat intrinsic B_1 (shielded birdcage coil) and pre-emphasized B_1 (MTL volume coil) at 4T. MR experiments were performed on 4T/90cm and 7T/90cm magnets (Magnex Scientific, UK) interfaced to the Varian INOVA console (Varian Associates, Palo Alto, California).

RESULTS: Small flip angle (~11 degree) and long repetition time (TR, 5 seconds at 4T and 10 seconds at 7T) mineral oil images, as shown in Fig 1, were acquired using the two MTL volume coils. The image intensity obtained with these imaging acquisition parameters can approximately reflect the B_1 distribution and behavior. The left insert in Fig 1 shows a pre-emphasized B_1 pattern (weak in center and strong in periphery) generated from the MTL coil with a relatively large *W*/*H* ratio of 4.2 (2.54cm/0.6cm) at 4T. The right insert in Fig 1 indicates that coil's B_1 penetrates into the center area of the image and a uniform (intrinsic) B_1 distribution is achieved using the MTL volume coil with a relatively small *W*/*H* ratio of 1.2 (2.54cm/2.1cm) at 7T. These results demonstrate that B_1 distribution can be manipulated in some level using MTL volume coils by simply changing the ratio of *W*/*H*. The MTL volume coil with the pre-emphasized B_1 pattern at 4T was used to study the feasibility of B_1 shimming to overcome image inhomogeneity due to dielectric resonance effect at high fields. Fig 2 shows the B_1 behavior changes with the different NaCl concentration of the phantom used. When NaCl concentration reaches 125 mM, a nearly homogeneous image was obtained. Human head images with a long TR were acquired from a health volunteer at 4T using the MTL volume coil (*H* = 0.6 cm) that had a pre-emphasized B_1 and a shielded birdcage coil which had a homogeneous (intrinsic) B_1. Besides the significantly improved MRI sensitivity, a ~42% improvement of image homogeneity in the human brain was obtained from the pre-emphasized MTL coil, comparing with the image collected using the shielded birdcage coil.

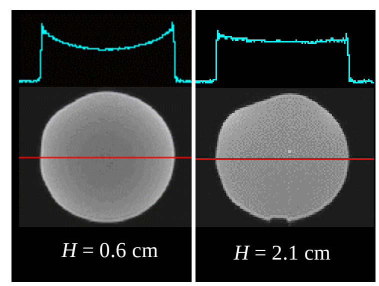

Fig 1 As an example, two different B_1 patterns are generated in a mineral oil phantom (a nearly unloaded case) using the two MTL volume coils with different substrate thicknesses (*H*) of 0.6-cm and 2.1-cm. The top insert of each image shows their 1D profile.

CONCLUSIONS: The MTL volume coil is unique and advantageous in high field MR imaging due to its robustness for adjusting B_1 pattern. With this adjustable B_1 pattern, it is possible to perform B_1 shimming using the pre-emphasis method to overcome the B_1 inhomogeneity problem caused by the dielectric resonance effect, achieving a uniform human head image at high fields.

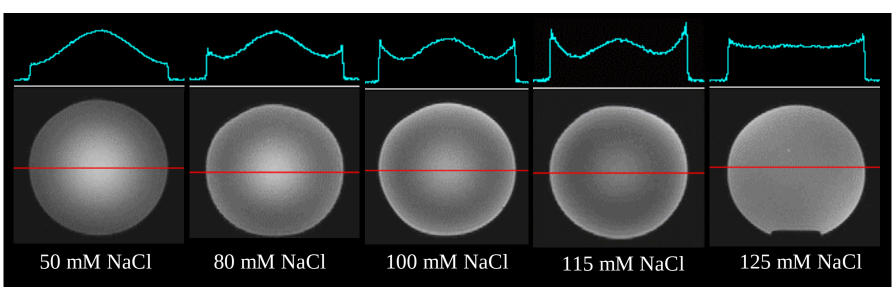

Fig 2 Phantoms images of the NaCl solution with different concentrations acquired using the MTL volume coil with the pre-emphasized B_1 (*H* = 0.6 cm) at 4T. The top insert of each image shows their 1D profile. A relatively flat B_1 is achieved in the phantom with 125-mM NaCl solution.

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