RF Selective Excitation for Localized Imaging at 9.4 Tesla

T. Ibrahim[1]

[1]School of Electrical and Computer ENgineering, The University of Oklahoma, Norman, Oklahoma, United States

Introduction: Human MRI is now reaching magnetic field strengths as high as 7, 8, and 9.4 Tesla. High field operation brings the potential for increases in SNR, chemical shift dispersion, related BOLD contrast, as well as reduced scan time. However with such advantages, significant technical difficulties are associated with designing suitable RF coils and/or designing new RF techniques that render useful clinical and research images. In this work, a new method is utilized to further magnify the sensitivity of ultra high field MRI, namely 9.4 Tesla human head imaging, through the use of localized imaging techniques that is solely based on electromagnetic theory.

Methods: A 9.4 Tesla head coil based on the design of the transverse electromagnetic resonator [1] was numerically considered such that the homogenous mode is tuned to approx. 400 MHz. The computational electromagnetics tool used was an in-house finite difference time domain [2] simulator specifically tailored for the design and evaluation of MRI coils. The uniqueness of such a tool is extenuated in its capability to fully account for the physical dimensions and shapes of any types of animals/humans due to the treatment of the biological structures and the MRI RF system as a single unit. The mathematical model of the coil was tuned while the coil was loaded with the anatomically detailed human head mesh such that the calculations accurately accounts for the electromagnetic interactions between the coil, drive ports, and the sample. The coil struts (in this case 16) were all driven simultaneously to achieve the typically needed volume and the proposed localized overages.

The volume and localized overages were obtained using optimization routines that utilize phased array antennas and superposition theories. The localized coverage considered both the region of interest as well as all the other regions within the same slice. For the localized coverage mechanism, two criteria were implemented, a) maximizing the spin excitation in the region of interest and 2) minimizing the spin excitation everywhere else, both of which are done simultaneously.

Results: Fig. 1 displays axial and sagittal slices of a normalized B_1^+ field (linearly proportional to the flip angle map) for non-optimized (standard progressive phase shifts with uniform magnitudes), and for optimized volume and localized coverage over a predetermined region of interest. For the volume coverage mechanism, the FDTD calculations indicate that an approx. 3 fold improvement in terms of the overall B_1^+ field homogeneity across the slice (calculated utilizing the standard deviation) when compared to the standard progressive phase shifts techniques. For the localized coverage mechanism, this arrangement demonstrate that the average flip angle in a surface area (16 cm^2 in this situation) could be on the order of 6 times higher than any where else in the slice.

Discussion and Conclusions: The main approach taken in the localized focus is to use the non-uniform nature of the fields as an advantage rather than a disadvantage. In other words, relocate the high intensity spots (always exist in 9.4 Tesla imaging due to the non-uniformity of the B_1^+ field) to another region of interest, or simply in electromagnetics terms produce a strong and uniform B_1^+ field in this region. Now, interestingly enough this approach requires significant inhomogeneity in the fields; as the load becomes electrically large and as the frequency of operation increases, the inhomogeneities should increase. Therefore, this capability deteriorates with decreasing the field strength and/or the load size (not shown). The calculations show that a focal excitation could be achieved in the majority of the regions that are enclosed within the resonator structure. Fig. 1 demonstrates how the sweet spot could be moved around from the surface of the head (axial slice) to more deep structures (sagittal slice).

The proposed localized approach would allow a reduction of the number of spatial encoding steps to increase spatial resolution while maintaining a reasonable scanning time. With such localized approach, significant increase in the signal can be achieved for in-vivo studies for large animal and human head/body applications at 9.4 Tesla which will have a significant impact on applications such as fMRI, and microscopy.

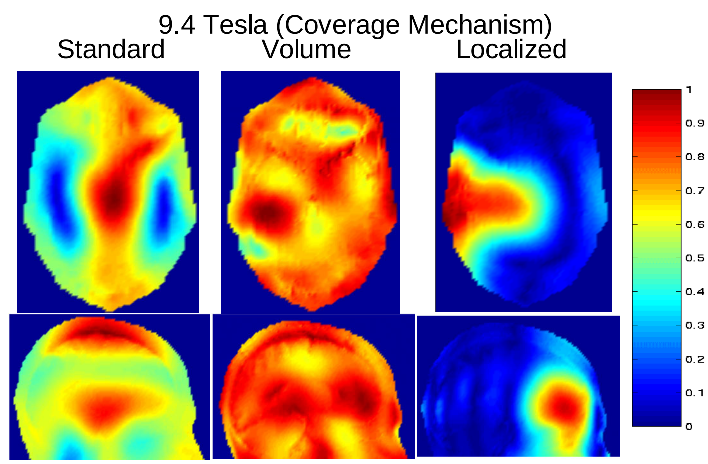

Fig.1: Standard (uniform magnitude and progressive phase shifts), volume, and localized coverage at 9.4 Tesla for a TEM based coil loaded with an anatomically detailed human model. The coil was driven in all possible ports and was optimized for both volume as well as localized ultra high field imaging.

References:

[1] J. T. Vaughan, et al *MRM*, 32:206-218.

[2] K. S. Yee, *IEEE Trans. Ant Prop*, vol. AP-14, no. 4, pp. 302-307, 1966.