Experiments and Analysis of Virtual Observation Points at 7T

Yujuan Zhao[1], Tiejun Zhao[2], and Tamer Ibrahim[1]

[1]*University of Pittsburgh, Pittsburgh, Pennsylvania, United States,* [2]*Siemens Medical Solutions USA, Pittsburgh, Pennsylvania, United States*

Target Audience: Ultra high field MRI users interested in online monitoring the real-time peak/average SAR

Purpose: In this study, the system global power and the local SAR from Virtual Observation Points (VOP) model in conjunction with rigorous RF modeling that incorporates coupling are demonstrated and verified in-vivo by experiments acquired using the Parallel RF transmission system. The input simulated SAR model is also verified quantitatively using B_1^+ maps as well as local VOP SAR monitoring.

Introduction: Parallel RF transmission (PTX) is useful to improve 3T/7T MRI B_1^+ inhomogeneity by slice-selective RF pulses [1] or B_1^+ shimming methods [2, 3], while PTX excitation may create distinct hot spots inside the human body by constructive interference of electric fields, generated by the respective coil elements driven with individual amplitudes and phases. Monitoring global and local peak SAR is a challenging task. Pre-calculated 3D SAR modeling is widely used to estimate the SAR of the worst case scenario. But calculations without the consideration of different waveforms at different instances of time limit their usefulness in clinical applications. The Virtual Observation Points (VOP) [4, 5] implemented on a PTX 7T MRI system is promising to online monitoring the real-time peak local SAR by evaluating only a limited upper bounded set of matrices for real-time arbitrary RF waveforms.

Methods:

Experiments: All experiments are done in 7T Siemens MRI scanner (Erlangen, Germany) equipped with 8 channel parallel transition (PTX Step 2.2 system). The 8 direction couplers (DICO), shown in Fig.1, pick up the real-time amplitudes and phases of the transmitted RF pulses. The pulse information will be used to calculate global power transmitted inside the coil as well as an input to the VOP model to calculate real-time local SAR. A modular 20-channel transmit/receive array [6] with the TR switch box is used to excite different transmission patterns by driven different phases and amplitudes.

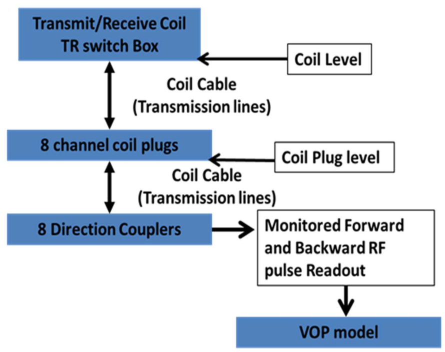

Fig. 1 Global and Local SAR monitoring pathway

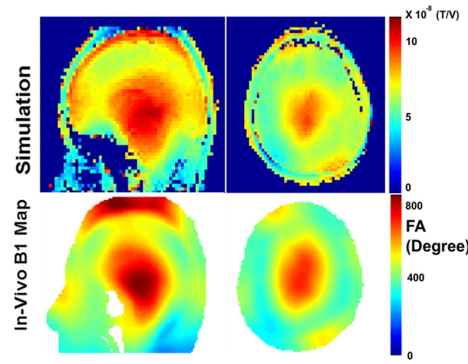

Fig2 . Simulation and experiments comparison

Simulations: The field information of the human head model is calculated by the in-house FDTD simulation package. The amplitudes and phases are processed by the SAR calculation packages to calculate the local SAR per 10g tissue mass and absorbed power per input power. The SAR model is compressed by the VOP concepts.

Theory: From the conservation law, within the region of interest, the supplied power P_s is equal to the power P_e exiting the region plus the power P_d dissipated inside the region (absorbed by the human body) plus the energies stored within that region (magnetic and electric energies $\overline{W_m}$ and $\overline{W_e}$). $P_s = P_e + P_d + j2\omega(\overline{W_m} - \overline{W_e})$.

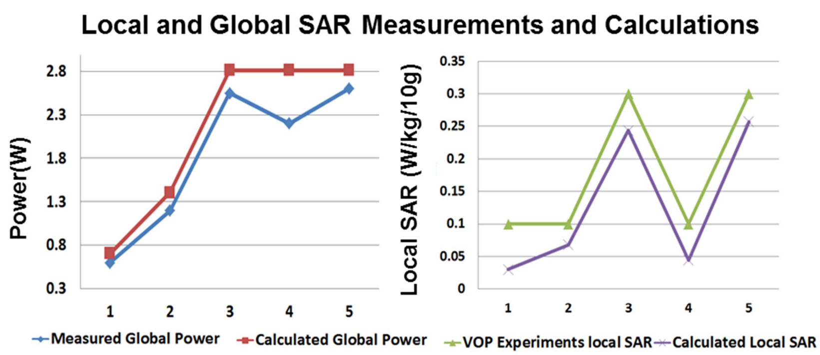

Fig.3 Global power and local SAR verifications with the VOP supervision

Results and Discussion: **Quantitative Simulation Verifications:** The field (distribution and intensity) is verified by the in-vivo B_1^+ maps and simulated fields (see Fig.2). For one of the tested coil RF shimmed modes, the average of the flip angle inside the brain is about 600º per 1000 V (Fig.2) 1ms square pulse. Considering the loss between the DICO and the coil level, array coupling and $\theta = \gamma B_1 T$, the average B_1^+ intensity $\approx$**58μT**. In the simulations, for the same region of the interest $B_1^+ \approx$ **60 μT** .

Online Global power and Local SAR Verifications: An FID sequence is applied and the input voltage is 50 V per channel (at the coil plug level), the applied RF pulse is a 2ms rectangular pulse, TR=200ms, therefore the input power per channel is 0.5W. Five different combination cases (Fig.3) are tested by driving different phases and amplitudes on the 20-channel coil. The results in Fig.3 show the excellent agreement between the calculated global power and the measured global power (forward-backward). The local SAR calculations also match the VOP measured results.

Taking one particular mode as an example (combination 3 in Fig.3), the real input forward power is measured to be 3.12W at the DICO level (Fig.1) when counting the cable loss, etc. The backward (from reflected and coupling) power is 0.31W at the DICO level. As a result, the calculated total global power is **2.8W** (3.12W-0.31W) at the DICO level. The measured global power was **2.6 W** at the DICO level from the PTX system.

To calculate the local SAR, it is noticed that the measured global power includes the power absorbed by the head and the power radiated out of the coil. For the combination 3, the absorbed ratio is about 28 % of the total supplied real power. Taking the model mass and measured global power into the considerations, the peak local SAR = **0.25W/kg/10g** which still closely matches the overestimated (because of the VOP theory) VOP local SAR measurement (**0.3W/kg/10g).** For the safety concern, the measured peak local SAR is normally 10% more than real/simulated peak local SAR, which also shown in the Fig.3. **Conclusion:** The VOP approach could be used to online monitoring the real-time local peak SAR. **Acknowledgements:** This work was partially supported by NIH and Siemens Medical Solutions. We also acknowledge Rene Gumbrecht (Siemens).

References: [1].Setsompop, K., et al., MRM, 2008.[2].Collins, C.M., et al., MRM, 2005.[3].Tang,L.,et al.Concepts Magn Reson 2011.[4].Eichfelder, G. MRM, 2011.[5]. Bitz, A.K., et al. in *ISMRM 2013*. [6] Zhao Y., el., MRM 2014. In Press (10.1002/mrm.25424).