Parallel Transmit Pulse Design with Implant-Friendly Modes

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Target Audience Neuro-MRI researchers conducting imaging studies with patients who carry active implantable devices in their body

Purpose We extend an approach that was previously proposed for implant SAR reduction with birdcage coils to pulse design with parallel transmit arrays. In a previous work it was shown that a dual-drive birdcage coil can be used to reduce the SAR around the implant by using a linearly polarized excitation [1]. Field uniformity obtained by linear excitation may not always be sufficient for sequences which are sensitive to flip angle distribution. Furthermore, linear excitation causes 2 times more global SAR and 4 times more peak local SAR compared to the conventional quadrature excitation. In this work we utilize implant- friendly modes of an 8 channel transmit array to reduce the SAR around an implant and to design a spoke pulse to obtain uniform flip angle distribution. We also demonstrate that local and global SAR can be kept within safety limits.

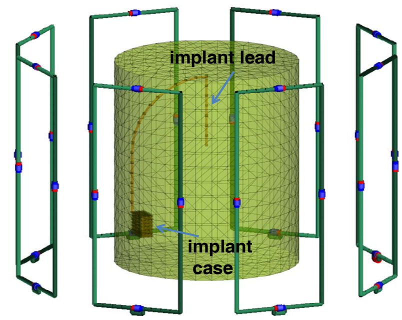

Figure 1 A generic implant model inside a uniform phantom is excited by an 8-channel transmit array

Methods First we simulated the electromagnetic field inside a phantom with a generic implant (Figure 1) due to unit current excitation of each loop coil. We used the FEKO EM solver (EMSS-SA) for all simulations. The values of the conductivity and the relative permittivity of the phantom was chosen as σ=0.7 S/m and ε_r=60. The implant is modeled as an insulated copper wire electrically connected to a copper implant case. The wire diameter and the insulation thickness are chosen as 500μm and 40μm respectively. Then we generated implant-friendly modes by exciting the loop array with the given excitation pattern $\alpha_i = A_m \cdot \cos[m \cdot (2\pi(i-1)/N - \phi)]$ where i is the channel index, N is the number of channels, ϕ is the steering angle for the field pattern, and m is the implant friendly mode index. A_m's are the complex coefficients for each mode that needs to be optimized for pulse design. SAR matrices due to each mode are compressed to a smaller set of VOP (Virtual Observation Points)[2] to enable fast evaluation of peak 10 g local SAR during pulse optimization. Using the implant friendly modes, the optimum least square 3-spokes pulse design solution is calculated using an optimization approach which explicitly constrains both global and local SAR[3].

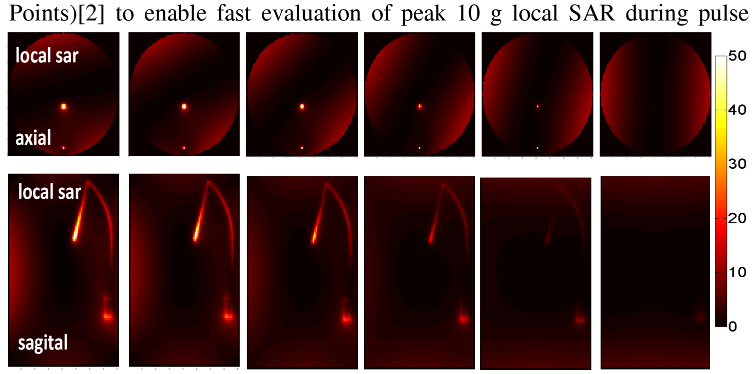

Figure2 SAR around the implant is reduced by steering the implant friendly pattern (mode 1 shown above) in angular direction.

Results Figure 2 shows the SAR distribution in the phantom and around the lead in axial and sagittal planes. Axial plane shows the maximum SAR around the tip of the implant. SAR around the implant can be reduced by steering a single mode of the transmit array(mode 1 shown in Figure 2) by changing ϕ Similarly SAR reduction can be achieved by using higher-order, implant-friendly modes as well. Figure 3 shows the SAR distribution in the phantom due to optimum implant friendly SAR pattern calculated by 3-spokes pulse design. The uniform 20^o flip angle profile due to the same solution is also shown. Peak 10 g average SAR and global SAR due to pulse design is calculated as 7.2 W/kg and 1.95 W/kg respectively.

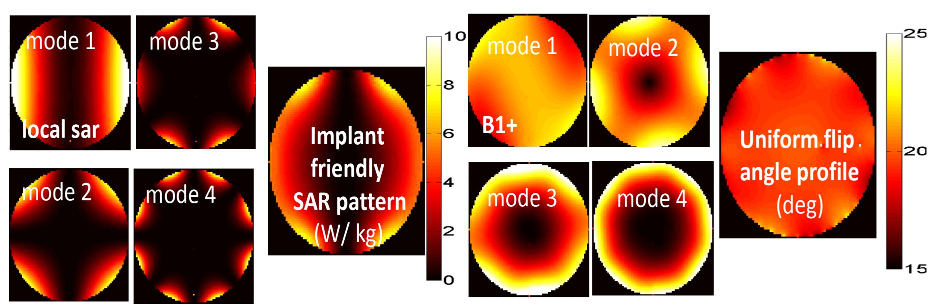

Figure3 3 spokes pulse design is made to generate an "implant friendly SAR pattern" and a uniform flip angle profile by using the 4 implant friendly modes of the 8 channel transmit array

Discussion The pulse design is made for a uniform phantom at 3T. For clinical significance, similar approach should be demonstrated in a more realistic head model with tissue inhomogeneities. In a previous work [1], the SAR at the tip of a deep brain stimulator implanted in a swine (ex-vivo) was minimized by using a linear dual-drive birdcage excitation. That solution corresponds to the first order implant friendly mode of the transmit array simulated in this work. By utilizing higher order modes and the pulse design, SAR reduction may also be realized in more realistic detailed head models.

Conclusion The local SAR around a generic implant in a uniform phantom is reduced below SAR limits by designing a 3-spoke pulse with implant friendly modes of a transmit array. A uniform axial flip angle distribution is obtained.

Reference [1]Eryaman,Y. (2012) MRM doi: 10.1002/mrm.24316 [2]Gebhardt, M. (2011). MRM **66**(5): 1468-1476 [3]Guerin B (2012)Proc.Intl.Soc.Mag.Reson.Med 20 #2215 Acknowledgements: R01EB006847,R01EB007942 .This project is also supported by the Comunidad de Madrid and the Madrid MIT M+Vision Consortium