Evaluating the SNR performance of using dielectric pads with multiple channel RF coils at 7T

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Target Audience: Designers of RF coils for MRI, and high field MRI users with an interest in using dielectric pads to optimize the RF field

Introduction: Due to the intrinsic RF field inhomogeneity when performing MRI at ultra high magnetic field strengths, dielectric pads with high permittivity have been proposed to achieve a local increase in the RF transmit field [1]. The use of dielectric pads to increase the transmit field in a B_1^+ starved area for the commonly used single channel transmit 32-channel (32-ch) receive head coil (Nova Medical, Wilmington, MA) at 7T has also been reported [2]. Furthermore, prior work on the use of dielectric pads with this coil has shown that, although the SAR distribution changes, the change in maximum SAR is minimal when the pads are employed [3].This can be attributed to the large size of transmit birdcage in the 32-ch 7T Nova head coil. However, the 32-ch receive array of the coil is designed to be very close to the subject in order to maximize signal-to-noise ratio (SNR) without explicit optimization or evaluation of the effects of adding dielectric pads. In this work, we compare the SNRs of 7T 32-ch head coil with and without the use of dielectric pads.

Methods: To perform a preliminary experiment of coil sensitivity to dielectric pads, a12cm x 12cm square loop was built. The loop was loaded with a cylindrical phantom with a diameter of 18cm, a relative permittivity of 80, and a conductivity of 0.5S/m. The reflection coefficient (S11) of the loop with and without four dielectric pads sandwiched between the loop and phantom were tested. The size of each dielectric bag was 11cm x11cm, and the pad (a suspension of calcium titanate and water with mass-mass ratio of 3:1) had a relatively permittivity of 137.4. The same setup was simulated using the finite difference time domain method in Microwave Studio (CST, Framingham, MA), as shown in Figure 1a. Second, a 16cm spherical oil phantom was loaded into the 32-ch head coil with and without the four dielectric pads between the phantom and coil. For the case with the dielectric pads inserted, the pads were placed on the posterior part of the coil, right against the phantom. A 3mm thick foam pad was placed between the dielectric pads and the coil frame. The flip angle (B_1^+) maps of the two setups were acquired using double angle B1 mapping method [4, 5] and the SNR maps were calculated with two identical GRE acquisitions (TR/TE=200/4.1ms, BW=260 Hz/pixel, FOV=250x250mm, Matrix=256x256, slice thickness=5mm) at 7T (Siemens whole body 7T scanner) with RF excitation turned on and off. The B_1^+ maps were used to normalize the SNR to the value that would result if there was a 90°excitation uniformly obtained in the sample.

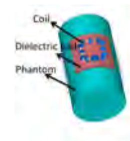

Figure 1a

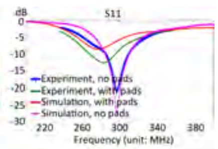

Figure 1b

Results: We found shifts in the resonant frequency due to the presence of the dielectric pads. The resonant frequency of the square loop, originally matched and tuned at 297.2MHz, was shifted to 273.5MHz when dielectric pads were inserted. Additionally, with the dielectric pads, the S11 at 297.2MHz was degraded by -9.8dB. Single loop simulations show similar results for the two cases. The signal behavior with respect to frequency is plotted in Figure 1b. In the 32-ch head coil experiment, the flip angle maps in Figure 2demonstrate that 30% higher transmit field was achieved in the vicinity of the dielectric pads, compared to without the dielectric pads. However, the noise coefficient matrices in Figure 3 show that the maximum off-diagonal value was increased from 0.32 (no dielectric pads) to 0.67 when using the dielectric pads. Furthermore, the sum-of-squares(SOS) SNR normalized for excitation (Figure 4) decreased from 97.87 to 68.62in the center of the phantom when dielectric pads were used. However, the optimal SNR [6] normalized for excitation (Figure 5) at the center was actually higher for the case with dielectric pads (114.2) when compared to no pads (110.2).

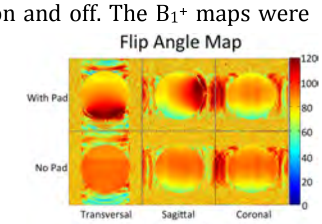

Figure 2

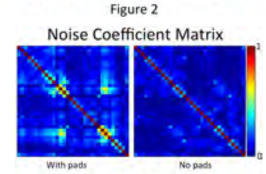

Figure 3

Discussion: The S11 of the single loop in both the experiment and simulation show that the resonant frequency of the loop was shifted more than 10MHz when using calcium titanate dielectric pads. For a coil array with a large number of elements, this frequency shift can change the coupling between the elements, preamp noise matching, and preamp decoupling. This is demonstrated in the noise coefficient matrices shown in Figure 3 of the Nova 32-ch coil loaded with an oil phantom in the case of with and without dielectric pads. The calculated noise coefficient matrices show that the decoupling between the coil elements degraded dramatically when using the dielectric pads resulting in a 30% reduction in the SOS SNR. However, the optimal SNR in the case with the dielectric pads actually was a little higher than in the case without the dielectric pads, indicating that if the coupling between the coil elements is deliberately adjusted to be at a minimum with the existence of the dielectric pads, higher SNR in addition to more uniform B_1^+ may be achieved using dielectric pads.

Conclusion: Insertion of dielectric pads may reduce SNR performance of coils with multiple receive elements. In order to optimally use dielectric pads in RF coils, the dielectric pads should be integrated in the coil design and fabrication.

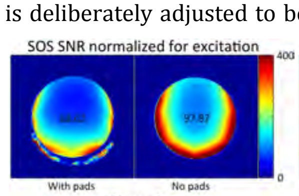

Figure 4

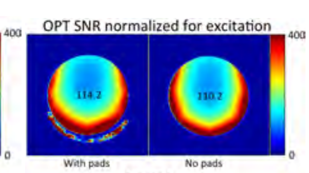

Figure 5

References: 1. Yang QX, et al., J MagnReson Imaging. 2006; 24(1):197-202; 2. O'Brien K, et al., Proc 21st ISMRM, #3009; 3. Bitz AK, et al., Proc 22nd ISMRM, #4892; 4.Stollberger R, et al., Magn Reson Med 1996; 35(2):246-251; 5. Insko EK, et al., J Magn Reson Series A 1993; 103:82-85; 6. Roemer PB, et al., Magn Reson Med 1990; 16(2):192-225