Considerations for the design of Transmit SENSE coil arrays

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INTRODUCTION:

The ideas of parallel imaging can be translated to the transmit case by using multiple, spatially independent transmit coils and independent waveforms applied to the individual coils [1]. In standard receive SENSE, the shortening of acquisition time leads to the well-known noise amplification in the resulting images [2]. This noise amplification depends on the geometry of the used coil array and on the resulting ill-conditioning of the sensitivity matrix. It has recently been shown [3], that noise amplification due to matrix ill-conditioning is negligible for Transmit SENSE, and thus, is not a criterion for coil array design. Instead, the current study investigates the RF-power requirements as a possible criterion for Transmit SENSE coil array design, which may become relevant for SAR-related questions.

METHODS AND RESULTS:

The basic equation of Transmit SENSE is

$$B_{des}(x) = \sum_{r \le R} S_r(x) B_r(x) \ , \qquad (1)$$

with $B_{des}(x)$ the desired spatial excitation pattern, $S_r(x)$ the sensitivities, and $B_r(x)$ the excitation patterns of the R individual coils. From Eq. (1), the individual RF-waveforms $b_r(t)$ exciting the individual patterns $B_r(x)$ are deduced [1]. These $b_r(t)$ belong to a reduced *k*-space trajectory and pulse duration leading to subsampling artifacts in the $B_r(x)$, cancelled by the superposition of Eq. (1). The RF-power P required for Transmit SENSE is estimated by (T the pulse duration)

$$P \sim \sum_{r \le R} \int_{t \le T} b_r^2(t) dt \ , \qquad (2)$$

neglecting interactions between the coil array elements, but reflecting variations of the sensitivities $S_r(x)$, possibly leading to an ill-conditioned matrix inversion solving Eq. (1) for $b_r(t)$. Thus, P might serve for benchmarking different coil arrays.

A circle on a 32x32 matrix was defined as $B_{des}(x)$ to be excited by a 2D RF-pulse at B_o = 1.5 T. Two coils, a twofold reduction, and dipolar shaped coil sensitivities were assumed in the simulations. The required RF-power was calculated according to Eqs. (1, 2) for different angular coil positions. First, the angle between the coils was fixed to 180°, and both coils rotated around the FOX (field of excitation). Second, one coil was fixed, and only the other coil rotated around the FOX, reducing the angle between the coils. A Cartesian and a spiral *k*-space trajectory were used. The results are shown in the figure.

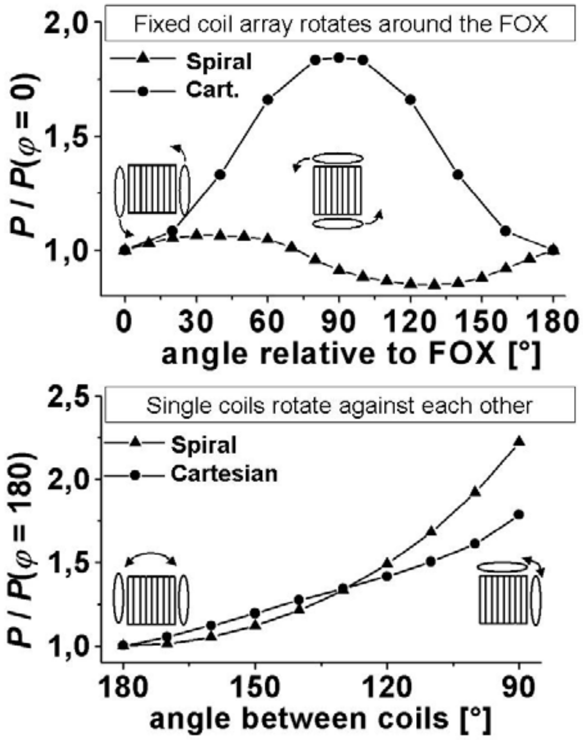

Figure 1: Normalized RF-power requirements for a Transmit SENSE coil array and a twofold reduction for Cartesian and spiral *k*-space trajectories. Above: The rotation of a fixed coil array with respect to the FOX changes the required RF-power roughly by a factor of 2 for Cartesian and ± 10% for spiral trajectories. Below: Reducing the angle between the two transmit coils from 180° to 135°, the required RF-power increases roughly by a factor of 1.3 for both *k*-space trajectories.

DISCUSSION:

The study shows only a moderate dependence of the required RF-power on the coil array geometry. The angular positions of the array elements can be varied up to ±20-30° without increasing the required RF-power by more than 20-30%. It is expected, that this behavior can be found not only for the investigated scenario, but also for other cases like three-dimensional pulses, higher reduction factors, or higher field strengths. Thus, the RF-power does not seem to be a critical factor for the design of Transmit SENSE coil arrays.

REFERENCES:

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