# Analysis of coil configurations for transmit SENSE

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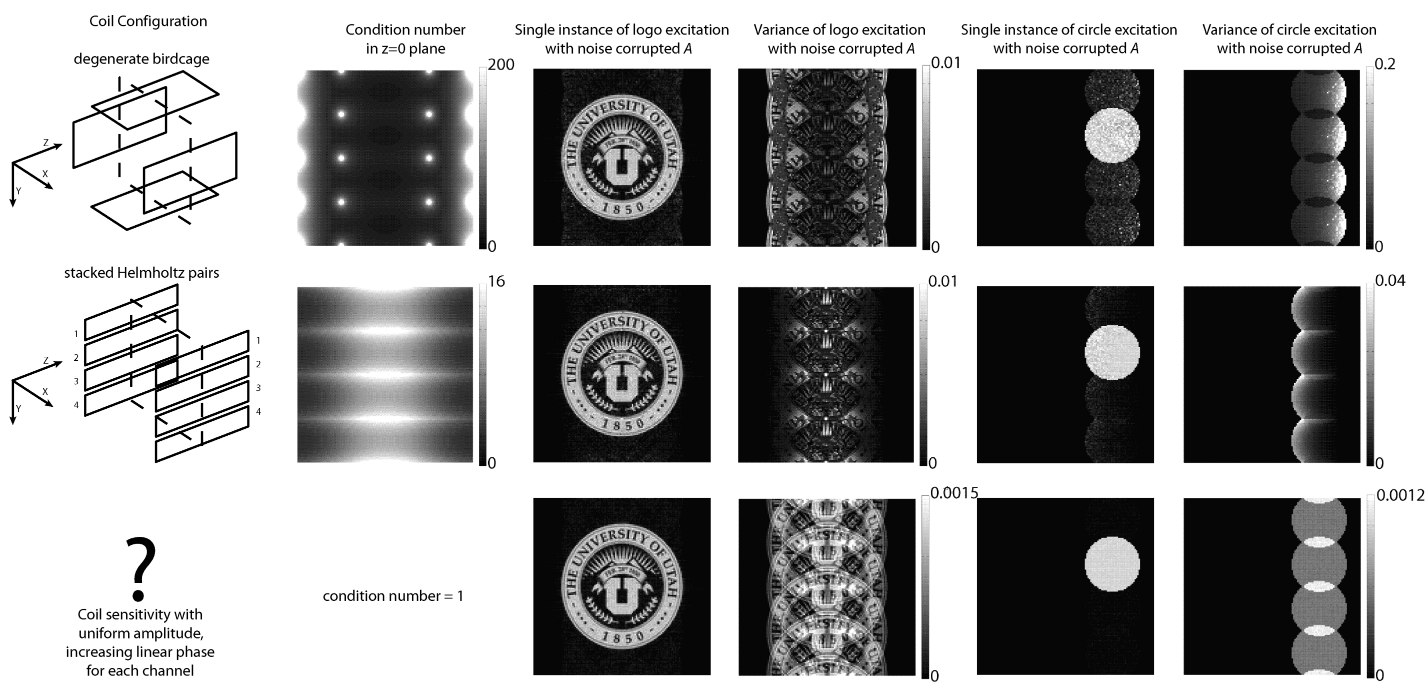
**Introduction:** Transmit SENSE (1-3) requires the measurement of coil sensitivity profiles to design RF waveforms to achieve a desired excitation profile. Errors in coil sensitivity measurement cause error in the achieved excitation. We present a means of analyzing the performance of a transmit sense coil configuration in the presence of coil sensitivity measurement noise.

**Methods:** If the transmit SENSE problem is formulated for subsampled Cartesian excitation k-space (1), the waveform design process involves the inversion of an $n_c$ x $n_c$ coil sensitivity matrix $A$ for each point in the field of view over which the desired excitation is defined, where $n_c$ is the number of coils. If each coil sensitivity measurement is corrupted by noise, each matrix $A$ is replaced by a noise corrupted matrix $A + E$, where the elements of $E$ are Gaussian white noise samples. The desired excitation P(**r**) then becomes an erroneous excitation $\tilde{P}(\mathbf{r})$, and the relative error of excitation $\left\|\tilde{P}(\mathbf{r}) - P(\mathbf{r})\right\| / \left\|P(\mathbf{r})\right\|$ is bounded by $\left\|\tilde{P}(\mathbf{r}) - P(\mathbf{r})\right\| / \left\|P(\mathbf{r})\right\| \leq \mathrm{cond}(A)\left\|A^{-1}E\right\| \Big/ \left(1 - \left\|A^{-1}E\right\|\right)$ where cond($A$) is the condition number of the matrix $A$. Since cond($A$) depends only on the coil sensitivity profile, cond($A$) is a property of a given coil configuration and can be evaluated point-by-point over the imaging volume, giving insight into the performance of a transmit sense coil configuration.

Three candidate coil configurations were evaluated for a hypothetical four-channel system. For the first two configurations, sensitivity profiles were derived from quasi-static analysis via the Biot-Savart law. The third configuration, designated the "linear phase" coil set, is defined by coil sensitivity profiles which are constant in magnitude over the imaging volume, with the first coil having constant phase, the second having linear phase varying by 2π radians over the imaging volume, the third coil varying by 4π, and so on. No physical coil configuration is illustrated for this case.

Two different two-dimensional excitation patterns were implemented. Monte Carlo simulation of excitation fidelity was performed by designing RF waveforms for 1000 different instances of the noise matrix $E$ and then calculating the variance of the achieved excitation (determined by Bloch equation simulation) across the ensemble of 1000 excitations.




**Results and Conclusion:** Error in excitation caused by noisy coil sensitivity estimates reflects the shape of the desired excitation pattern but is also shaped by cond($A$), showing that cond($A$) can serve as a criteria for evaluation of the performance of a transmit SENSE coil configuration. Lower cond($A$) leads to better fidelity of excitation. In particular, the hypothetical linear phase coil configuration gives cond($A$) = 1 over the entire imaging volume and gives optimal excitation fidelity.

**References:** **1)** Zhu Y, Magn Reson Med 2004;51(4):775-784. **2)** Katscher U *et al.*, Magn Reson Med 2003;49(1):144-150. **3)** Grissom *et al.,* Magn Reson Med 2006;56(3):620-629.