

## MR Physics for Physicists / $B_1$ Shimming and Parallel Transmission Ulrich Katscher (ulrich.katscher@philips.com)

### Highlights

- Inhomogeneities of  $B_1$  at high main field strengths can be mitigated by parallel transmission.
- (Accelerated) multidimensional RF pulses allow further improvement of  $B_1$  homogeneity.
- $B_1$  shimming and parallel transmission open new possibilities for SAR management.

### Target audience:

(Ultra-)high field MRI and RF physicists / engineers and users interested in parallel RF excitation and pulse design for research and clinical applications.

### OUTCOME/Objectives:

Learners will understand the principles of parallel transmission as an important prerequisite for a correct, efficient, and safe application of  $B_1$  shimming for (ultra-)high field MR imaging.

### PURPOSE:

In high field MR, wave propagation effects are able to build up local flip angle maxima and minima, leading to significant signal and contrast inhomogeneities in the obtained images. Without removing or sufficiently reducing these  $B_1$  inhomogeneities, the diagnostic value of the images may be compromised.

### METHODS:

Currently, among other means, modifications of the applied RF pulses are investigated to cope with the mentioned  $B_1$  inhomogeneities. First, using a coil array for RF transmission, standard slice selective pulses can be transmitted with different weights in the different array elements (see, e.g., [1]). These weights, i.e., amplitude and phase of each element, are designed to yield a flip angle variation as small as possible ("basic"  $B_1$  shimming). On the other hand, a two- or three-dimensional RF pulse can be applied, whose target pattern is the reciprocal of the  $B_1$  inhomogeneity to be compensated. Thus, the resulting flip angle is constant across the field of excitation ("tailored"  $B_1$  shimming). Using not a single RF transmit coil, but again a coil array, the required multi-dimensional RF pulses can be based on short trajectories, which are "sparse" in the excitation k-space. The resulting gaps in the excitation k-space can be filled by utilizing the different sensitivity profiles of the elements of the transmit array used ("Transmit SENSE", see, e.g., [2]).

A much debated topic for  $B_1$  shimming and parallel transmission is the specific energy absorption rate (SAR) in the framework of RF patient safety (see, e.g., [3]). On one hand, the new degrees of freedom introduced by parallel transmission remove the proportionality of RF power and SAR as found for single channel systems, and RF safety concepts have to be adapted accordingly. On the other hand, parallel transmission also offers the possibility to reduce SAR, and thus, to fully exploit the capabilities of the MR system used.

### RESULTS:

Numerous *in vivo* studies have investigated and utilized  $B_1$  shimming and parallel transmission. Transmit arrays used range from two elements in commercial systems up to 64 elements in research.  $B_1$  shimming and parallel transmission have been reported for main field strengths of 3T, where the technique is applied, e.g., for abdominal, cardiac, and breast imaging, as well as for 7T and above.

### DISCUSSION / CONCLUSION:

$B_1$  shimming and parallel transmission is a key element to enable high field and ultra-high field MRI at maximum image quality and RF patient safety.

### REFERENCES:

[1] Ibrahim TS, Lee R, Baertlein BA, Kangarlu A, Robitaille P. Application of finite difference time domain method for the design of birdcage RF head coils using multi-port excitations. *Magn Reson Imag.* 2000; 18: 733-742. [2] Katscher U, Börnert P, Leussler C, van den Brink J. Transmit SENSE. *Magn Reson Med.* 2003; 49: 144-150. [3] Seifert F, Wübbeler G, Junge S, Ittermann B, Rinneberg H. Patient safety concept for multichannel transmit coils. *J Magn Reson Imag.* 2007; 26: 1315-1321.