It goes to 11: A scalable home-built transmit array beyond eight channels

Andre Kuehne[1,2], Patrick Waxmann[3], Werner Hoffmann[3], Harald Pfeiffer[3], Reiner Seemann[3], Frank Seifert[3], Oliver Speck[4], and Bernd Ittermann[3]
[1]Center for Medical Physics and Biomedical Engineering, Medical University of Vienna, Vienna, Austria, [2]MR Centre of Excellence, Medical University of Vienna, Vienna, Austria, [3]Physikalisch-Technische Bundesanstalt (PTB), Braunschweig und Berlin, Berlin, Germany, [4]Otto-von-Guericke-University, Magdeburg, Germany

Target Audience: Researchers interested in the development of parallel transmission signal chains

Purpose: Parallel transmission (pTx) techniques are promising candidates for tackling RF inhomogeneity issues in high- and ultrahigh field MR. Transmit SENSE [1] is the most versatile pTx method, allowing to excite arbitrarily shaped regions of interest, and directly benefitting from a high number of excitation channels for increased acceleration factors [2]. In order to go beyond the channel limit currently offered by MR vendors, it is desirable to develop an extended multichannel transmit signal chain that can interface with the existing vendor-supplied hardware while providing a higher degree of flexibility at low cost. In this work we extended a previously demonstrated setup [3,4] by substituting the complete Tx chain of a Verio 3T MR scanner (Siemens, Erlangen, Germany) by a home built 12-channel Tx array.

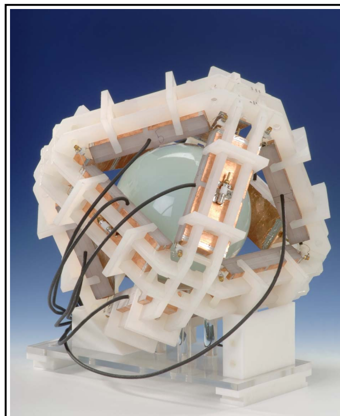

Fig. 1: The 12-channel octahedral coil used in the experiments.

Methods: The signal generation process [3,4] is displayed together with the scanner/amplifier interface in Fig. 2. The signal is digitally generated using synchronized 16-Bit digital pattern generator PCI-Express cards in a control PC (M2i.7020/7021, Spectrum GmbH, Germany), which are fed into digital/analog converters (DAC 5687, Texas Intruments, USA). Setup and control of the DAC is achieved by using an Arduino microcontroller to connect to the DAC SPI interface. The input signal is digitally upconverted to the scanner frequency by the DACs; unwanted Nyquist images are removed by bandpass filters. The twelve analog signals are subsequently fed into eight 8 kW (AN8135S8, Analogic Corp, Peabody, USA) and four 4 kW (LPPA 13040W, Dressler, Stolberg, Germany) RF power amplifiers and used to drive a 12-channel octahedral coil [5]. The gain of the analog outputs was individually adjusted to yield identical high-power output for the same nominal input. The setup thus completely replaces and extends the small-signal transmit chain of the existing scanner. Synchronization to the MR scanner is achieved via its internal 10 MHz clock, and triggering the pulse output was achieved by tapping into the RFPA unblank signals from the scanner. These trigger pulses show the same very high degree of stability w.r.t the RF pulse phase as triggering pulses generated inside an MR sequence, but utilizing the unblank signal allows to re-use existing MR sequences without modifying their source code to provide appropriate triggers. The selective pulses were calculated according to Grissom's approach [6] and implemented in MATLAB (Mathworks, Natick, USA), which was also used to program the digital cards and replicate the RF part of the desired MR sequences. Due to a hardware failure of one coil channels the setup was used for 11-channel transmit SENSE experiments in multiple slice orientations. All required prerequisite images (B_0, B_1 maps) were also acquired with the presented setup.

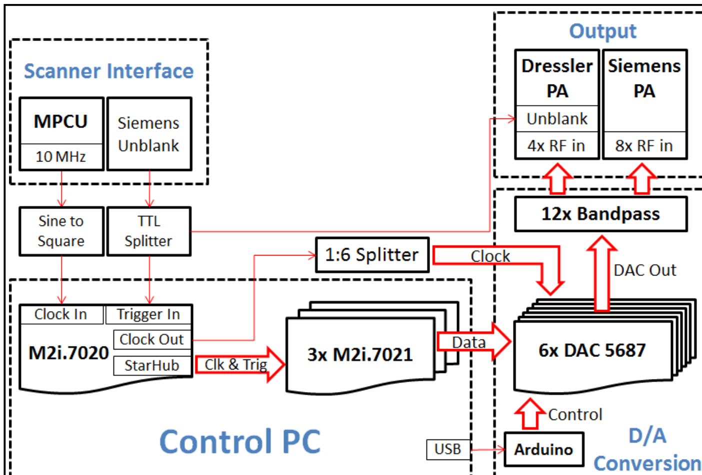

Fig. 2: Complete setup of the pulse generator and its interface with the MR scanner and the additional amplifiers.

Results: Imaging results from an agarose phantom are shown in Fig. 3. The generated excitation patterns show a close agreement to the desired shapes, apart from a very small rotation indicating a slight residual delay between RF pulse and gradient waveform, which can be corrected by measuring and adjusting the trigger delay of the setup.

Conclusion: The results show that our setup can easily be integrated with a heterogeneous amplifier infrastructure in order to utilize all available hardware options to extend the MR system's number of transmit channels beyond eight. It is flexible and features a comparatively low footprint and cost (~$1500/channel). For further extensions, 20 channels can be in principle supported by one PC, with the option of interlinking multiple of these setups by larger hubs.

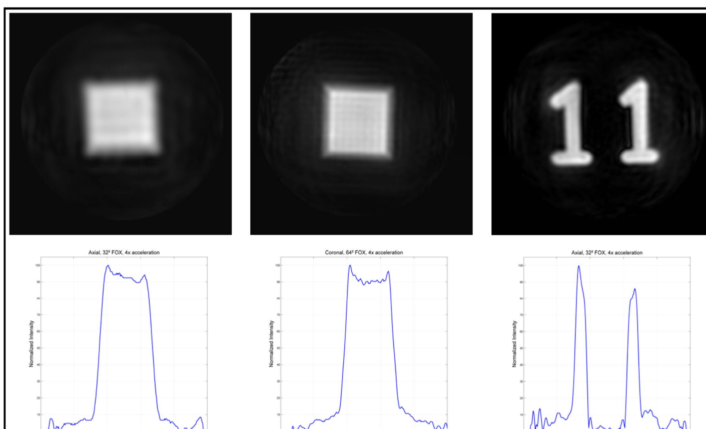

Fig. 2: Spatially selective excitation in an agarose phantom (top) and intensity profiles through the center of the images (bottom). The left and right images are in an axial plane, the center dataset is a coronal slice, demonstrating that selective excitation is possible in multiple slice orientations. TR/TE=100/5 ms, FOX: 32² (left) or 64² (center and right), 4-fold acceleration

References:

[1] Katscher, U. et al., (2003). *MRM* 49(1), 144–50.
[2] P. Ullmann, et al., *MRM* 54 (2005) 994-1001
[3] Kuehne, A. et al., *Proc. ISMRM 2009*, #3017
[4] Kuehne, A. et al., *Proc. ISMRM 2012*, #4404
[5] Kirilina, EP et al., *Proc. ISMRM 2007*, #1035
[6] Grissom, W. et al.,(2006), *MRM*,56:620-629