A Wide Band Frequency Transverter for High Field MRI

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Introduction:
The improved image resolution involved with higher magnet field strengths in clinical MRI allows many new applications in particular in the field of functional MRI and neurological diagnostics, e.g. Alzheimers disease. Recently a project with a whole body magnet of 11.7 T planned field strength was launched in Europe [1]. In addition many MR animal scanners are equipped with >7 T magnets. Therefore it is reasonable to extend the 12.5 – 300 MHz frequency range of the existing Siemens RF-hardware [2] to even higher frequencies. Using the wide band transverter presented below an additional frequency range of 340 to 570 MHz can now be covered. Thus, almost any field strength between 0.3 and 13.4 T is possible for proton imaging.

Block diagram and principle of operation:

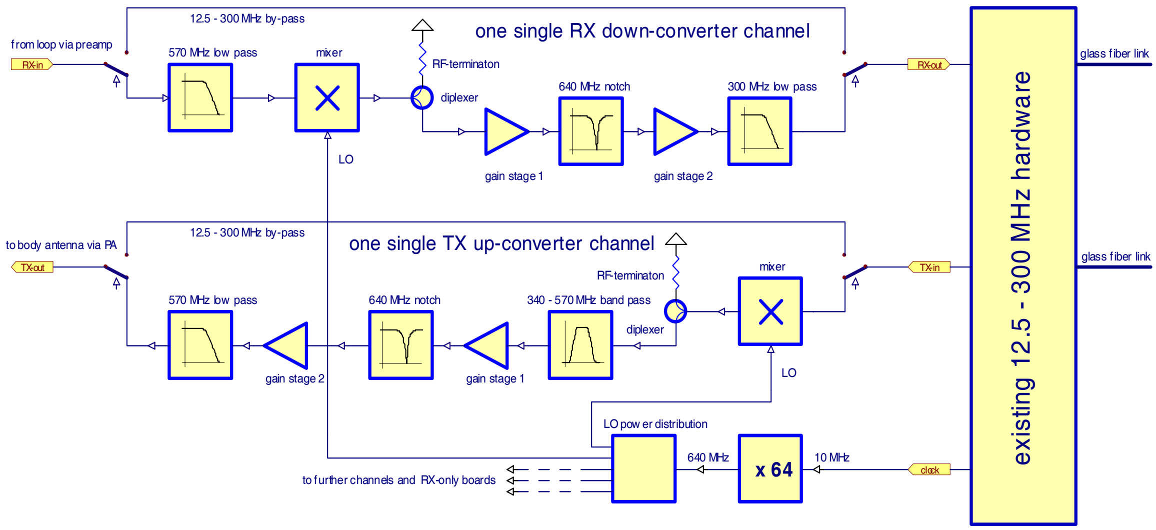

Fig. 1: Block diagram of the 340 – 570 MHz MRI transverter

Fig. 1 shows the block diagram of an up- and down-converter channel and the LO-signal (**l**ocal **o**scillator) conditioning. Because the existing 12.5 – 300 MHz hardware is used as a wide band IF-section (**i**ntermediate **f**requency) the LO frequency f_{LO} can be set to a fixed value. This significantly alleviates the design of the high fidelity LO-conditioning circuit. To a very high extend the LO must be free of spurious signals and side band noise [3]. Otherwise the MR-signal quality would suffer from the mixing process. Spurious in the signal paths can be reduced in choosing f_{LO} higher than the highest transverted frequency. With f_{LO} /MHz = 640 = $2^6 \cdot 10$ synchronisation to the 10 MHz crystal oven system clock is easily possible without noisy phase locked loops. Using 70 instead of 12.5 MHz as lowest IF tremendously reduces the requirements for the image frequency filter. While the transverted frequency range is still 230 MHz wide (f_{LO} - f_{IF} = 340…570 MHz) the closest image frequency gap calculates to 2·70 = 140 MHz instead of only 2·12.5 = 25 MHz. Thus, with a moderate expense the 570 MHz low pass filters of fig. 1 obtain at least 30 dB image band suppression. Both, the RX- and the TX-channels are designed for a 0 dB overall gain with a switchable by-pass, e.g. for imaging isotopes other than protons.

Technical realization and results:
The board shown in fig 2 accommodates the LO signal conditioning, three transmit channels, and five receive channels two of them used for power monitoring. An additional board (not shown) contains eight receive channels available for multi channel receive coil arrays. The frequency flatness of the TX- and RX-converter stays in the range of ±1 dB over the whole 340 – 570 MHz bandwidth. Linearity at 400 MHz (9.4 T) is better than 50 dB IM3 for a +4 dBm PEP two tone input signal, again for RX and TX. The noise figure of the RX-down converter is about 10 dB. Because of the preceding LNA with 30 dB gain virtually no overall system noise performance degradation can be observed.

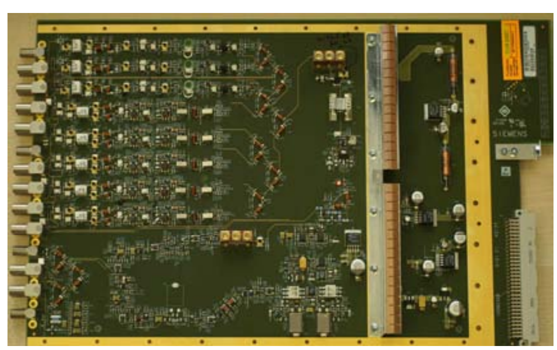

Fig. 2: Photo of a transverter board consisting of three transmit and five receive channels

References:
[1] Siemens and CEA press release: http://www-dsv.cea.fr/content/cea_eng/esp_info/pour_tous/presse/cp05_siemens.htm, 07/20/2005
[2] Bollenbeck J. et al.: *A high performance multi-channel RF Receiver for Magnetic Res. Imaging Systems,* poster #860, ISMRM 2005
[3] Bollenbeck J. et al.: *An RF Small Signal Unit Optimized for a 7T Multinuclear MR System,* poster #2028, ISMRM 2006