Converting digital MRI receivers built for 1.5T into 7T receivers using Surface Acoustic Wave filters

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Introduction: 7T MRI can improve SNR and spatiotemporal resolution compared to 3T and 1.5T.Therefore the dynamic range in acquired signals increases (more SNR), as well as the need for more receiver channels (to increase SENSE acceleration). In order to achieve high channel counting at 7T, we made use of Philips digital receivers developed at 1.5T (Philips, Best, The Netherlands) and we have investigated the use of under-sampling and Surface Acoustic Wave (SAW) filters to adapt existing 1.5T to 7T digital receivers.

Methods: The sampling frequency of the ADC is 38MHz, enabling detection of the 298MHz after 8-fold aliasing. The filters inside the digital receivers have been adapted to pass the 298MHz signal. To preserve the noise figure, the filters are required to suppress the side bands of which the closest will be at 310MHz and 272M. SAW filters (RF Monolithics, Inc) were installed at the output of the preamplifier (WanTcom, Inc) (Fig 1). Noise figure was measured by comparing the noise obtained by the MRI system using a 50 ohm terminator either connected directly to the input of the preamplifier, or via another calibrated preamplifier with known noise figure and gain. Scaling and gain corrections were obtained by using signals from an external RF synthesiser connected at the input of the preamplifier. A total of 16 receivers were modified to enable MRI acquisition with a 16 channel head coil (NOVA).

Figure 1. Photograph of external preamplifiers with SAW filters at 298MHz (7T) connected to the adapted digital 1.5T receivers.

Results: The adapted filter inside the digital receiver could be tuned to 298MHz, obtaining attenuation at 310 MHz and 272MHz of only 5.1dB and 5.3dB respectively. This resulted in an increased noise figure of 2.0 dB without the SAW filter (Fig 2) (the noise figure of the preamplifier is 0.7dB).The inclusion of the SAW filter attenuated the side bands by 56dB and 59dB respectively (Fig 2). After merging the software of the 7T console with the 1.5T software, 7T MRI could be obtained with the adapted digital receivers (Fig 4).

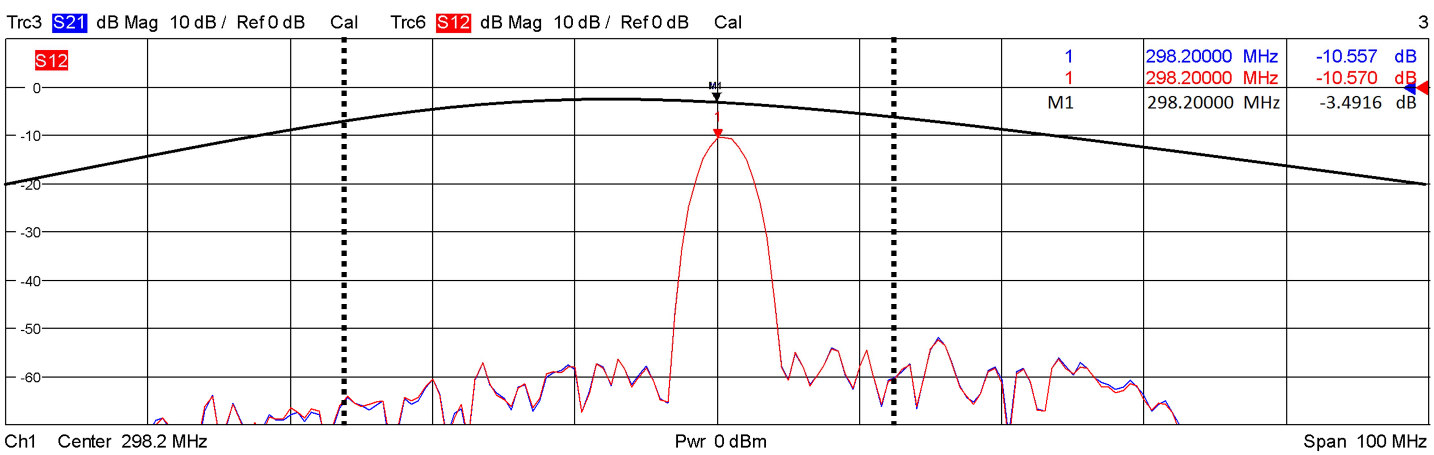

Figure 2. Frequency response (S12) of the adapted filter inside the digital receiver (Black, M1) and the SAW filter (red, 1). Based on the sample frequency of 38MHz of the digital receiver and the proton frequency of 298MHz at 7T, the sidebands of the 7th and 8th harmonic are indicated by the dashed lines. Note that the SAW filter attenuates the side bands of the aliased noise bands by more than 50dB.

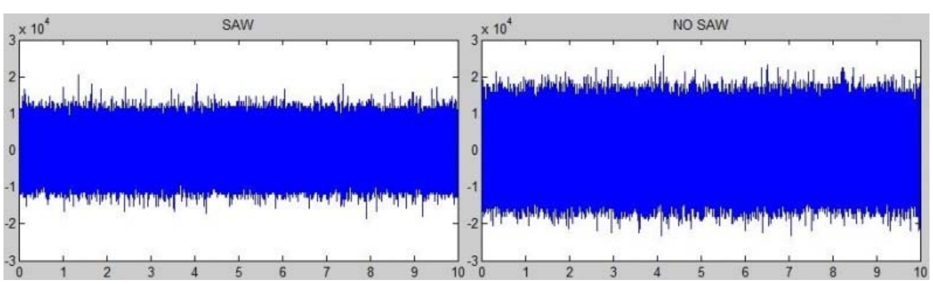

Figure 3. 27dB amplified 50 ohm noise detected with (left) and without (right) the SAW filter, scaled to obtain identical signal level.

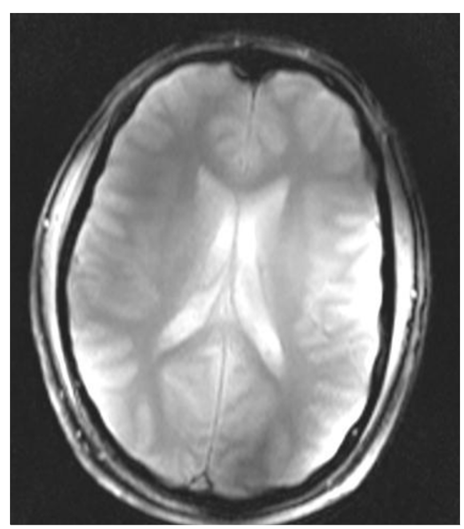

Figure 4. MRI obtained at 7T with 16 modified digital 1.5T receivers.

Discussion/conclusion: We have shown that digital 1.5T receivers can be used to acquire MRI signals at 7T with a low noise figure by including a SAW filter after the RF coil preamplifier. The high gain of the preamplifier could overcome the substantial loss in the pass band of the SAW filter. Having shown proof of operation with digital 7T MRI, the limits in high coil density receiver arrays at 7T can now be explored.