

Analog Optical Transmission of 4 MRI Receive Channels with high Dynamic Range over one Single Optical Fiber

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Introduction

Analog optical transmission of MRI signals between local coil (LC) and receiver (RX) has been investigated by various authors in the past [1,2]. The advantage of an optical transmission concept is the fact that large bundles of copper cables including cable traps for shield wave suppression can become redundant. Metallic cables can be replaced with optical fibers carrying both, the MRI signal from the LC to the RX and the power for driving the preamplifiers and the electro-optic conversion. As the number of antenna elements is steadily increasing (32 channels), analog optical transmission of more than one receive channel over one optical fiber is considered as a key experiment to reduce the number and the costs of fiber optic connections.

Method and Experimental Setup

Fig. 1 shows the principal block diagram of the setup used for transmission of 4 RX channels by means of one fiber. The signal received from one loop antenna is amplified and downconverted to an IF-frequency. An analog sampling circuit is used to multiplex 4 channels in the time domain as described by Bollenbeck et al. [3]. The signal-amplitude is compressed to reduce the dynamic range by an active compressor circuit and by the laser diode used for the electro-optical conversion. Due to the time division multiplex operation and the nonlinear signal conditioning the energy of the band-limited input signal is spread over a broad frequency range. As a result the extremely demanding dynamic range requirement for the link-components is transferred into a bandwidth requirement. This is advantageous especially for optical links, because today's fast optical devices (laser and photodiodes as well as fibers) can easily cover bandwidths much greater than 100MHz. After transmission over an optical fiber, the signal is converted back to the electrical domain by a photodiode and sampled by an ADC. In order to compensate for the nonlinearities of the compressor and the laser diode, the link was characterized to generate a decompression look-up table, which is used to restore the original signal sample by sample in the digital processing chain. A demonstrator for the above described experiment is implemented into the receiver board of a Siemens Avanto scanner at 63.6MHz as shown in Fig. 1 and 2. Although the link components shown here are implemented on the RX-board for the sake of this first experiment, the devices could also be integrated into a LC. As electro-optical converters we used a vertical cavity surface emitting laser diodes (VCSEL) which are significantly less expensive and exhibit less heat dissipation than high-end telecom DFB-lasers [2].

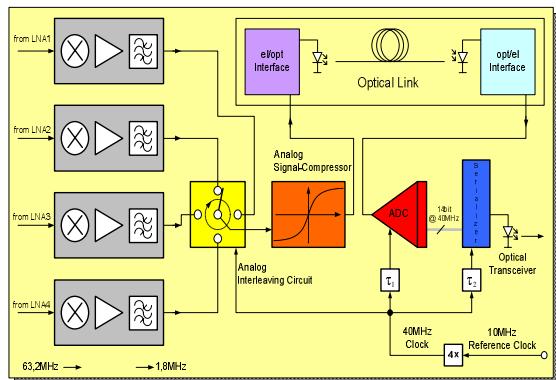


Figure 1: block diagram of optical link

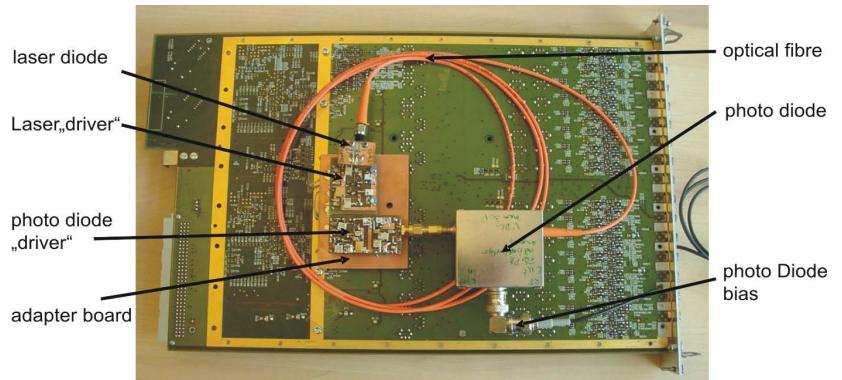


Figure 2: Photo of experimental link integrated on RX board

Results and Discussion

Since the non-linear characteristic of the complete link is equalized by postprocessing in the digital domain, the laser diode can be driven into moderate compression without degrading the link performance. In contrast to previously published concepts, the dynamic range of the link input signal is reduced rather than expanded as this would be the case using linearization based on predistortion techniques. The dynamic range of each of the four simultaneously processed receiver chains was measured to be about 152dBc/Hz. This is only 12dB less than the dynamic range of the Avanto receiver without optical link. This difference results from accessory noise which is added by the link components. Therefore, the optical link realized here allows simultaneous transmission of 4 RX channels over one fiber with outstanding performance. Fig. 3 shows a scan of a human brain using a 12 channel head coil. By only using the 4 CP mode channels from a commercial Siemens 12 channel head coil, images from a human brain could be acquired with the optical link and the conventional RX for reference. No difference in image quality available from the optical link and the conventional RX respectively could be discovered (sequence used: TSE with $T_R=4000\text{ms}$ and $T_E=93\text{ms}$).

Conclusions

The experiments shown here demonstrate for the first time the transmission of multiple MRI RX channels over one fiber. The presented approach furthermore allows the use of low cost components (e.g. VCSELs) without compromising the noise figure and with only minor degradation of the overall dynamic range of the receiver.

Reference

- [1] J. Yuan et al, A 4-channel optical link transmission for RF coil array at 1.5T, ISMRM 2007
- [2] G. P. Koste et al, Optical MR Receive Coil Array Interconnect, ISMRM 2005
- [3] J. Bollenbeck et al, A High Performance Multi-Channel RF Receiver for Magnet Resonance Imaging Systems, ISMRM 2005

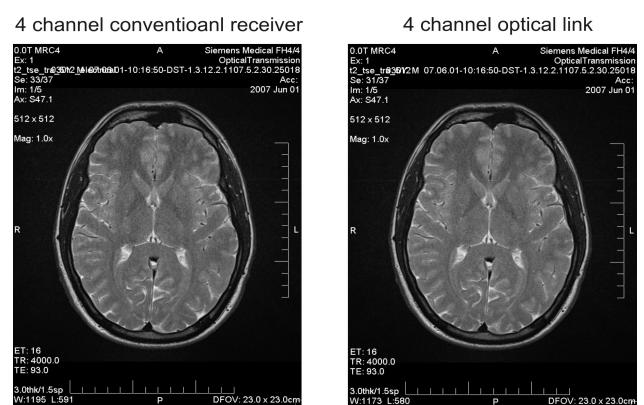


Figure 3: Comparison of images with conventional and optical transmission