Parallel transmission approach for 7T based on optically controlled on-coil CMCD amplifiers

Natalia Gudino[1], Qi Duan[1], Joe Murphy-Boesch[1], Jacco A de Zwart[1], Hellmut Merkle[1], Peter Van Gelderen[1], and Jeff H Duyn[1]
[1]*Advanced MRI section, LFMI, NINDS, National Institutes of Health, Bethesda, MD, United States*

Audience: Those interested in RF technology and parallel transmission.

Purpose: High field (> 7T) MRI of the brain has yielded increased contrast, sensitivity, and resolution [1]. Unfortunately, wavelength effects typical of high field compromise B_1 homogeneity, and can degrade image quality. Several "B_1 shimming" [2] methods have been presented to mitigate this problem, often through multi-channel transmitters. It has been shown that on-coil switch-mode current source amplification presents several advantages for the implementation of a multi-channel transmitter [3,4]. Following this approach, we obtained preliminary data with two surface loops driven by optimized 300 MHz on-coil amplifiers [5], which are controlled by a customized multi-channel optical interface..

Methods: A 64 MHz CMCD prototype built from eGan FETs [6] (EPC Corporation) has demonstrated the benefits of reduced amplifier size and increased RF efficiency.. These FETs require a relatively low gate voltage to switch, but as switching frequency is increased more peak current is required from the driver to charge the port capacitances. To switch the FETs (EPC2012) at 300 MHz, more driver power was required, so the output of the optical receiver (Fiberfin) was connected to a preamplifier stage that provided 15 dB of voltage gain and up to 1 A continuous output current. A schematic of the amplifier (without envelope modulation) [3] and its main components are shown in Fig.1. The amplifier prototype was built on a multi-layer board with dimensions of 9 cm by 10 cm. The board included additional space for another CMCD amplification stage (using eGaN FETs EPC2014) when higher power was required. The amplifier was optically controlled by a customized broadband multi-channel interface described elsewhere. Two 6 cm diameter surface loops were tuned at 300 MHz on a 4.5 L Sucrose-NaCl gel phantom that mimics the dielectric properties of brain tissue [7]. The 2-channel setup (Fig. 2) was tested on a Siemens 7T whole-body MRI system. First, baseline images were acquired with a custom-built 7T head volume coil [8] operating in TX/RX mode. The volume coil was then set in receive-only mode, and the two coils connected to on-coil amplifier were placed in the scanner. The on-coil amplifiers were then connected via 10-m long fiber cables to the optical interface, located in the scanner equipment room. The low-power RF signal (RF_{IN}) was connected as input to the interface while the RF unblank signal was used to enable the optical transmitter only during RF transmission. A multi-echo 3D GRE sequence was run for subsequent frequency maps calculation after which a 2D GRE sequence was used for imaging with different phase settings that were dynamically controlled through the interface.

Results: Using a calibrated probe on the benchtop, we measured ~13 μT at ~1 cm distance from the coil at ~ 10 W output power (confirmed by B1 maps, data not shown). No force was perceived when moving the amplifiers in the region of strong magnetic field. Figure 3a shows the images obtained when transmitting with the volume coil (left) and with one of the on-coil transmitters (right). Figure 3b shows the corresponding frequency maps as well as the frequency difference map (right) obtained from the multi-echo data. No phase artifacts are apparent, even with the amplifiers located at the edge of the phantom, suggesting minimal magnetic interactions. Images obtained with single channel transmission (with input to the other coil blanked) and with a simultaneous 180^0-out-of-phase excitation are shown in Fig. 4, note the coil placement is different than in Fig. 2.

Discussion and Conclusion: We have shown here preliminary data with a 7 T 2-channel on-coil transmitter setup. In this first prototype we used eGan FETs no dedicated for RF applications with port capacitances too large for switching at these high frequencies. Nevertheless, we were able to push its operation to 300 MHz by designing the appropriate driving circuitry. Just recently, the manufacturer has released RF eGan FETs with operation frequencies up to GHz that should further extend the capability of the transmitter. The absence of phase artifact confirms that the amplifier and setup are suitable for susceptibility-weighted imaging and other phase sensitive applications.

References:

1. Duyn J. Neuroimage. 2012 Aug 15;62(2):1241-8.
2. Mao W, Smith MB and Collins CM. Magn Reson Med. 2006 Oct;56(4):918-22.
3. Gudino N, Heilman, JA, Riffe MJ et al. Magn Reson Med. 2013 Jul;70(1):276-89.
4. Gudino N and Griswold MA. Magn Reson Med. 2013 Apr;69(4):1180-5.
5. Gudino N, Heilman, JA, Riffe MJ et al. Proc. ISMRM 2009 (Abstract 398).
6. Twieg M, Riffe MJ, Gudino N et al. Proc. ISMRM 2013 (Abstract 725).
7. http://www.amri.ninds.nih.gov/phantomrecipe.html
8. Murphy-Boesch, J. Proc. ISMRM 2010 (Abstract 3817).

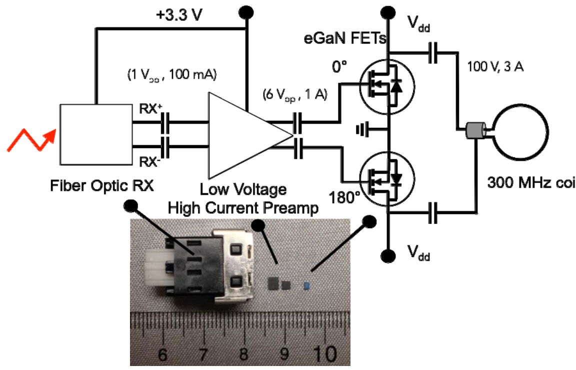

Figure 1: Simplified diagram of the 7T amplifier and photo of the main components in the board.

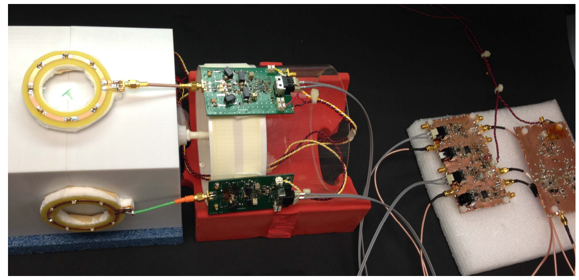

Figure 2: Preliminary test with two amplifiers driven by the optical interface.

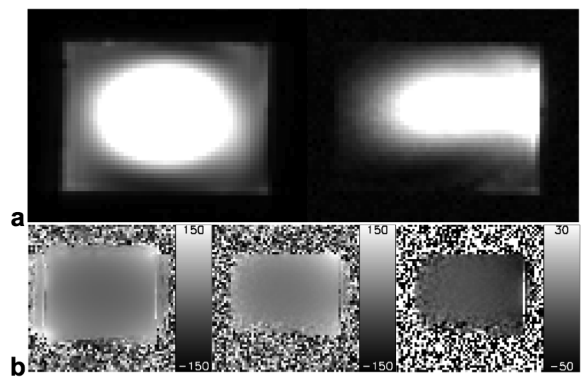

Figure 3: Image obtained with volume coil (left) and with a single on-coil amp (a). From left to right, frequency maps of head volume TX/RX coil, surface TX coil and frequency difference map of both setups.

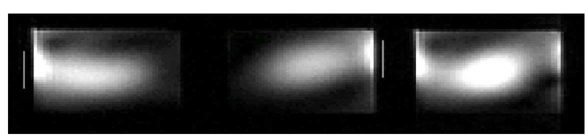

Figure 4: Single channel transmission (left & center) and simultaneous 180^0 out-of-phase transmission (right).