

1.5T On-Coil Current-Mode Class-D (CMCD) Amplifier with Amplitude Modulation Feedback and Voltage-Mode Class-D (VMCD) Preamplifier

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Introduction: On-coil current-mode (CM) switching amplifiers are a promising solution for the implementation of transmit arrays with large number of elements [1-3]. Here we present a Current-Mode Class-D (CMCD) amplifier with Amplitude Modulation (AM) feedback and class-D preamplification that avoids the characteristic DC losses of linear preamplification as presented previously [4-5].

Material and Methods: The amplifier diagram is shown in Fig. 1. A digital encoded RF pulse is amplified and split into two out-of-phase digital signals through a high speed Emitter Coupled Logic (ECL) comparator. This is demodulated through a band-pass filter and further amplified through a cascade of high-speed differential amplifiers. Two stages of Voltage-Mode Class-D (VMCD) amplifiers boost the voltage amplitude of the out-of-phase signal to a high enough level to efficiently switch the MOSFET of the CMCD output stage. The amplitude of the RF signal is modulated by connecting the power stage to the output of a customized Buck regulator controlled by PWM [6]. The digitally encoded target RF envelope is sent to the system, demodulated and compared with the sensed RF envelope [7]. The actual transmitted RF amplitude is obtained by a wire loop coupled to the coil [8] followed by a low-pass filter with a cutoff frequency below the coil resonant frequency (63.6 MHz). A trigger signal is sent to the saw oscillator of the PWM control to avoid any false switching when there is no RF pulse. In order to measure output power with a 50Ω standard technique a 1: 25 impedance transformer was connected to the output stage. Decoupling between two on-coil transmitters was evaluated in a 1.5T clinical MRI scanner (Espree, Siemens) using the body coil as the receiver. A data timing generator (Tektronix DTG7058 750Mb/s) synchronized with the scanner was used to synthesize the digital encoded RF pulse and RF envelope for each of the channels. A FLASH sequence with 1ms Gauss RF pulse excitation (16ms TR, 7.8ms TE, 10mm slice thickness and 30x30cm² FOV) was used to image a cylindrical phantom.

Results: Fig. 2A shows the filtered output of the VMCD preamplifier that connects to the gate of the output MOSFETs. A maximum 55Vpp amplitude was obtained and the signals are 180 degree out of phase as is optimal for push-pull operation. Fig. 2B shows the modulated RF pulse on the coil when a Gauss pulse is set as the target envelope. We can see that the system generates a clean wave shape indicating good performance of the envelope feedback. A maximum output power near 2kW was measured with duty cycle set to 0.5 % to protect the measuring devices. Fig.3 shows a picture of the two CMCD amplifiers with AM feedback and Figure 4A and 4B the signal intensity profiles when transmitting with each amplifier individually.

Discussion: This work demonstrates an optimized CMCD amplifier with switching preamplification stage that minimize DC losses characteristic to linear preamplification. We have also shown a good wave profile of the AM feedback system that modulates the RF pulse. Preliminary images prove successful operation of the system in the scanner.

References: [1] H. Kobayashi et al IEEE Transaction on Microwave Theory and Techniques Vol. 49, No. 12, Dec 2001 [2] Kurpad K.N., et. al., Proc. ISMRM 2005:00016 [3] Heilman J.A., et al Proc. ISMRM 2007:00171. [4] Heilman J.A., et al Proc. ISMRM 2009:03027. [5] Gudino N, et al Proc. ISMRM 2009:00397[6] Gudino N, et al Proc. ISMRM 2009:04769 [7] Feipeng Wang, et al IEEE Trans on Microwave Theory and Techniques VOL. 53, No. 4, April 2005 pp 1244-1255 [8]Scott G.C. ISMRM 2008:00146

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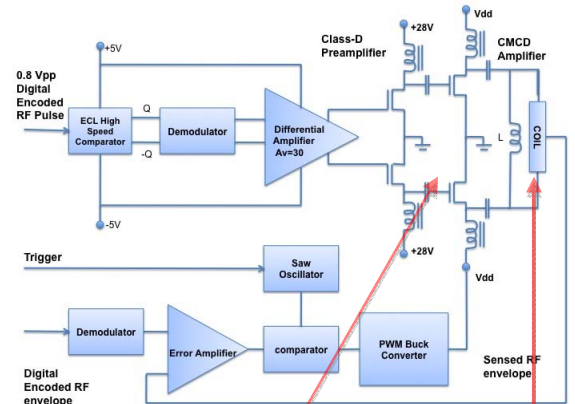


Fig.1 Amplifier Schematic Diagram

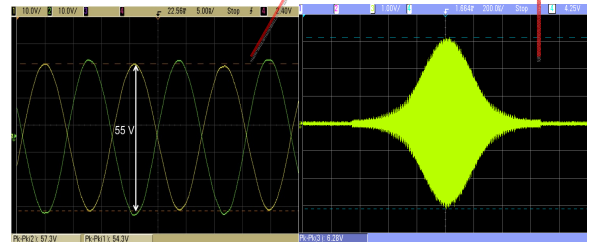


Fig.2 (A) VMCD Preamplifier Output (B) Modulate

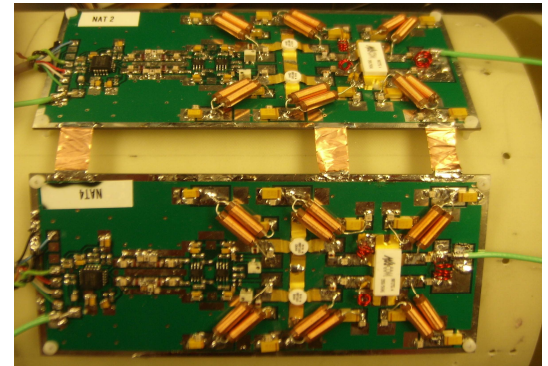


Fig.3 CMCD amplifier with AM feedback

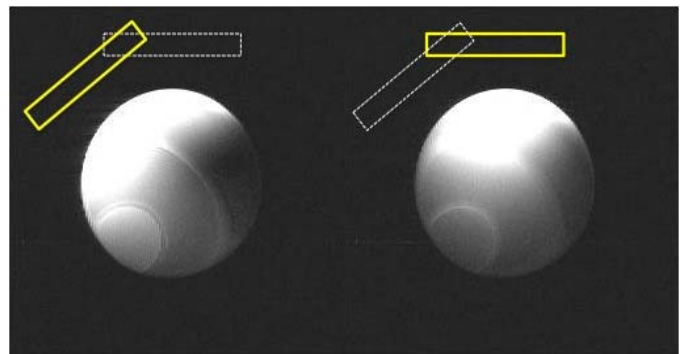


Fig.4 Axial images of cylindrical phantom, 1ms Gauss RF excitation (A) Amplifier 1 transmitting (B) Amplifier 2 transmitting. Note that apparent substructures are a result of broad Gaussian excitation.