

## A Fast MOSFET Switch for RF Pulse Management and Shaping in Low-Field NMR and MRI

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Transmit Array Spatial Encoding (TRASE) is a MRI method that achieves spatial encoding through repeated pulses of radiofrequency (RF) B1 fields from different phase-gradient transmit coils. It does not require the application of B0 gradients and is a distinct alternative to the standard MRI approach.<sup>1</sup> An evaluation of the benefits and limitations of TRASE MRI at low field (a few mT) is under way using hyperpolarised gas samples.<sup>2,3</sup> Fast switching between two or more transmit coils with negligible wait time between pulses is required to reduce the total RF encoding time. PIN diodes are often used for coil switching in MRI but bias control with RF isolation involves response times (several RF periods) which are too slow for the targeted low-frequency application. We have designed bidirectional MOSFET switches with floating and optically isolated gate control.<sup>4</sup> A similar device was recently reported to be suitable as Q-switch in low-field NMR.<sup>5</sup> Our tests have been performed with different RF power amplifiers and different loads at various frequencies (in the DC – 200 kHz range). An Apollo Tecmag console was used to manage RF pulses and TTL signals controlling the switches. RF currents were recorded using a digital oscilloscope by monitoring the voltage drop across a 1- $\Omega$  resistor inserted on the ground line at the output of the RF amplifier.

Our MOSFET switch (with components rated for 500V and 32 A or for 1.7kV and 9A) has switching times below 1  $\mu$ s. It has a low ON impedance ( $R \sim 1 \Omega$ ) and a frequency-dependent OFF impedance ( $\sim 500$  pF capacitance), yielding efficient RF current switching in resistive loads and in transmit coils (various situations will be reported). Additionally, current switching at null current and maximum voltage can be used to abruptly stop or start pulses in series-tuned RF coils, therefore avoiding the rise and fall times associated with the Q-factors (Fig. 1). RF energy can be efficiently stored in tuning capacitors for times as long as hundreds of milliseconds. Besides TRASE MRI, this energy storage approach may find applications in fast repeated spin-echo experiments.

[1] Q Deng et al., Magn Reson Imaging 31:891 (2013)

[2] PJ Nacher et al., Proc ESMRMB15, Magn. Reson. Mater. Phys. 28 Suppl. 1 (2015) S64

[3] S Kumaragamage et al., Proc ESMRMB16, Magn. Reson. Mater. Phys. 29 Suppl. 1 (2015) S34

[4] PJ Nacher et al., Proc ISMRM 2018, abstract 2874

[5] JZ Zhen et al., J Magn Reson 287 (2018) 33

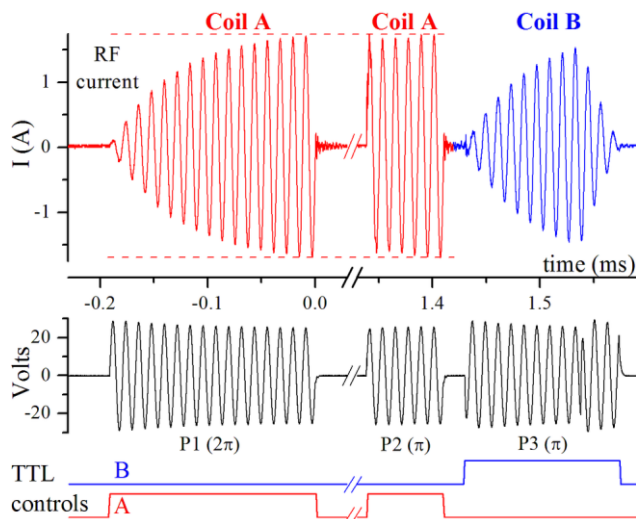


Fig. 1: RF currents (top) driven by RF voltages (middle trace) at 83.682 kHz in two (series-tuned) transmit coils A and B ( $L=2.4$  mH,  $C=9.5$  nF,  $Q=15$ ). Currents are fed to the coils from a single RF amplifier through switches (TTL-controls: bottom). The first pulse (P1) builds up RF energy in coil A while performing a  $2\pi$  rotation in 18 RF periods. When P1 is interrupted the capacitor C is fully charged and excitation with full RF amplitude is resumed, allowing for a rectangular  $\pi$  pulse in 6 periods (P2) at the end of which energy remains stored. Without energy storage in coil B, a  $\pi$  pulse lasts 12 periods (P3), with fast current decay thanks to the RF sign change after 9 periods.