RF Current Source Development for Parallel Transmit Arrays Using a High Power MOSFET

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Introduction In high field MRI, conventional multi-mode volume coil excitation is hampered by the load dependent B_1 field inhomogeneity caused by the sample electrical properties and increased coil-sample interaction [1]. Parallel excitation algorithms that may be used to optimize B_1 field homogeneity at high static fields or to implement volume selective excitation, require independently controllable RF transmitters. One class of such transmitters consists of active devices that are integrated with the transmitting elements as independent voltage controlled RF current sources ("active rung") [2]. A disadvantage of this early design is the dependency of induced current suppression on the output capacitance of the current source, which is generally dependent on the power handling capacity of the active device. In this abstract, we briefly describe the design and development of a RF current source technology using a high power MOSFET in a gated class AB push-pull configuration. Experimental results demonstrate improved driven current efficiency and reliability against load variations, and improved induced current suppression.

Method As shown in figure 1, a RF power MOSFET (ARF475FL; CW 300 Watt push-pull) was configured as a gated class AB push pull pair for efficiency and linearity. The balanced drain terminals of ARF475FL were connected to a symmetrical conducting loop (driven loop) that was series tuned at 127.7 MHz. An input matching network was implemented to transfer maximum driving power, stabilize the balanced gate terminals, and also to protect the preliminary drive stages. The shunt inductor, $L_{d,sh}$, connected across the drain terminals shunted out the output capacitance of the MOSFET for the given DC bias, creating a large impedance block (~420 ohm) to the current induced in the transmitting element. The amplitude of the driven current was measured in pulsed condition (10% duty cycle, 3ms period) using a shielded probe to study current efficiency in relation to the maximum current rating of the device and load dependent driven current changes. The induced current suppression, $I_{ind,supp}$, was quantified by the suppression of current induced along the resting driven loop (DC biased but no RF), I_{cs}, relative to the current induced along the reference loop, I_{ref}, by the 50 ohm matched excitation loop, in dB scale ($I_{nd,supp} = I_{cs}/I_{ref}$ [dB]) as schematically shown in figure 2. In addition, the detuning of the 50 ohm coil neighboring with the driven and reference loops was measured to observe mutual coupling changes.

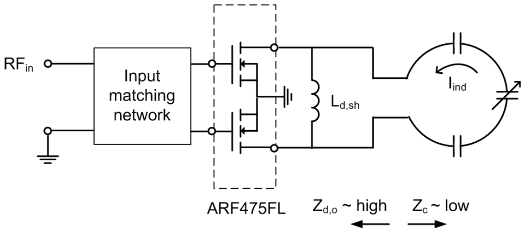

Figure 1 Block diagram of the RF current source.

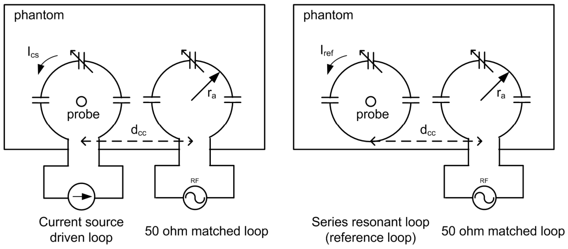

Figure 2 Decoupling measurement setup

Results The measured peak driven currents were plotted with various loaded and unloaded coil impedances, Z_c, as a function of control voltage, $V_{amp,c}$, at the driving amplifier in figure 3. They were compared to the peak current amplitude evaluated from the 50 ohm pulsed power measurements (star symbol). The use of driven current through the driven loop was more efficient compared to current through the 50 ohm load line resistance as the premature current saturation was observed in the star symbol trace. The deviation of the driven current was 0.2 A (2.6 %) from its mean 7.6 A at the maximum driving power with coil impedances ranging from 0.4 ohms to 10.3 ohms, implying current mode operation. The induced current suppression at the closest loop to loop distance was measured about -17 dB just achieved by the output impedance of the current source. The detuning of the 50 ohm loop neighboring with the driven and reference loops is shown in the figure 4. The black trace shows the resonance of the stand alone 50 ohm loop only. The blue dotted line shows bifurcated resonance peaks due to the significant mutual coupling between the excitation and reference loops. While, the red dashed line shows slight resonance shift because of the minimized mutual coupling between the excitation and resting driven loops.

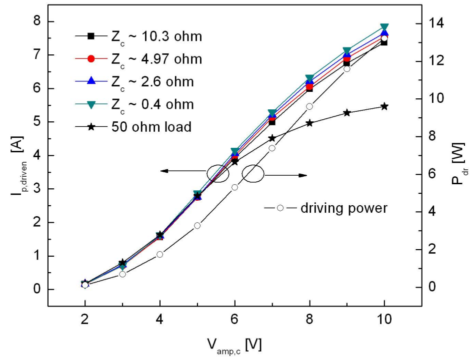

Figure 3 Driven current amplitudes vs. control voltage, $V_{amp,c}$.

Discussion & Conclusion A controlled RF current source using a high power MOSFET was developed for independent driven current control in the application of parallel transmit arrays. The chosen power device has a high drain breakdown voltage and relatively small output capacitance compared to other compatible power devices. The high breakdown voltage allows more tolerable driven and induced voltage swings at the drain, resulting in reliable driven current flowing into the driven loop in presence of strong mutual coupling. The relatively small output capacitance at the drain and the push pull configuration enable the formation of a high output impedance block by connecting a shunt inductor across the balanced drain terminals, hence suppressing the current induced by neighboring elements. The non-reciprocal properties of the device aids in parallel transmit design as it enhances driven current amplitude and simultaneously suppresses undesired currents induced by other transmitters. This property is manifested as different drain terminal impedances depending on the direction of RF energy flow. The developed RF current source should find its application in parallel transmit arrays.

Reference [1] Yang X, et al., Magn. Reson. Med. 2002;25. [2] Kurpad K, et al., Proc. Intl. Soc. Mag. Reson. Med. 2004;11.

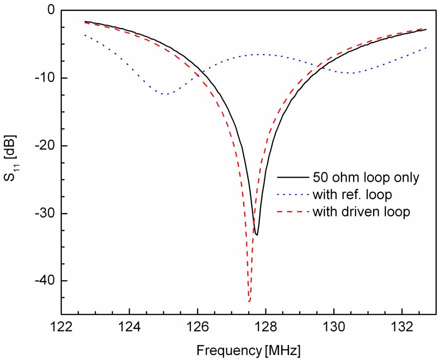

Figure 4 Detuning of the 50 ohm excitation loop neighboring with the reference and current source driven loops.