Implementation of coil integrated RF Power MOSFET as Voltage Controlled Current Source in a Transmit Phased Array coil

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Introduction

Currently, transmit coils for MRI are designed as parallel resonant circuits, excited by a voltage source. The voltage source is generally a power amplifier with very high power rating, designed for linear operation in pulsed mode. The output stage of the power amplifier is matched to a 50Ω transmission line which, in turn, is matched to the coil impedance at the coil interface, thereby ensuring maximum power transfer between the power amplifier and RF coil. This is a forced voltage excitation scheme, where the coil current distribution is determined by the local coil impedances. When loaded with a lossy, asymmetrically placed sample at high frequencies (128 MHz and above), significant and asymmetric load-coil interaction perturbs the ideal sinusoidal current distribution, causing B_1 field inhomogeneity. Another cause of inhomogeneity is the dielectric property of the load which results in the formation of interference patterns within it. A simple way to optimize B_1 field homogeneity would be to adjust the amplitudes and phases of the currents on each rung independently [1]. One way of achieving this would be to use a forced current excitation scheme where a dedicated, controllable RF current source is used to drive current through each rung.

In this work, we present a RF current source design that would enable forced current excitation of each rung. We show that the amplitude of the output current is linearly related to the amplitude of the control voltage and that the output current bears a constant phase relationship with the control voltage.

Method

Figure 1 shows the circuit diagram of the RF current source. The RF power MOSFET used was the BLF245 (Philips Semiconductors). The BLF245 is rated for a maximum output power of 30W at a gain of 17dB. A drain bias voltage of 28V was applied to the drain terminal of the MOSFET. This set the MOSFET in the saturation region of its DC characteristic, where it behaves as a current source [2]. The gate bias voltage was set to 3.6V, making this a class AB amplifier. The output impedance of the MOSFET was measured to be 9Ω. In order to route maximum RF current through the rung, the rung impedance would have to be set to a minimum possible value. The series trimmer on the rung was adjusted such that the rung was tuned to series resonance at 128MHz, effectively creating a very low resistance path to ground as seen from the drain terminal of the MOSFET. Single-ended class AB amplifiers are inherently non-linear since the conduction angle of the MOSFET is less than 360^o. However, the flywheel effect of the series resonant rung completed the output waveform, thus making the amplifier linear. The input matching network was tuned to match the input impedance of the MOSFET to a 50Ω cable coming from the driver amplifier. The control voltage was then ramped and the output current was measured for each setting of the control voltage. Finally, control voltage phase was varied over the range of the phase shifter and the phase of the output current was observed.

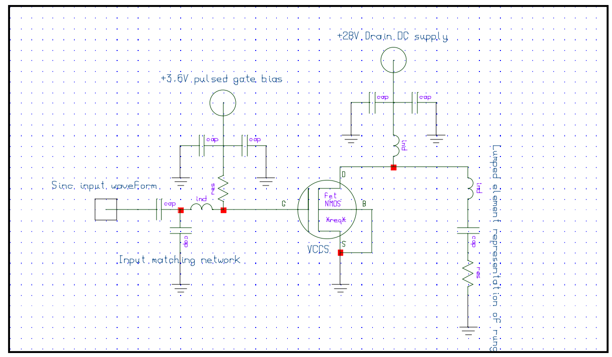

Figure 1 **Circuit diagram of the RF current source. A RF power MOSFET is used as a voltage controlled current source to drive current through the rung. The rung is represented by a series LCR network that is grounded at one end and connected to the MOSFET drain terminal at the other.**

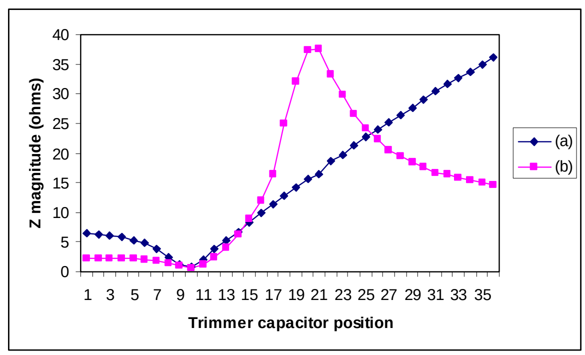

Figure 2 **The range of rung impedances over which the MOSFET acts as a true RF current source is limited by the output impedance of the MOSFET. Measured rung impedance (a) with MOSFET removed from circuit and measured impedance at same location with MOSFET reintroduced into circuit (b). Increasing trimmer position represents increasing value of capacitance**

Results and discussion

Figure 2 shows the range of rung impedance values over which maximum current can be routed through the rung. Beyond series resonance, the rung becomes inductive, with increasing value of the trimmer and forms a parallel resonant loop with the output capacitance of the MOSFET. So the MOSFET begins to act as a voltage source beyond series resonance. Figure 3 illustrates the linear relationship between rung current and control voltage amplitudes. The rung current was found to bear a constant phase relationship with the control voltage.

Conclusions

We have designed a linear, class AB RF current source that can be integrated with a rung of a transmit coil. We have shown that the current amplitude and phase can be controlled reliably by the input control voltage. This feature is central to the design of the transmit phased array coil with independent control of rung current phase and amplitude

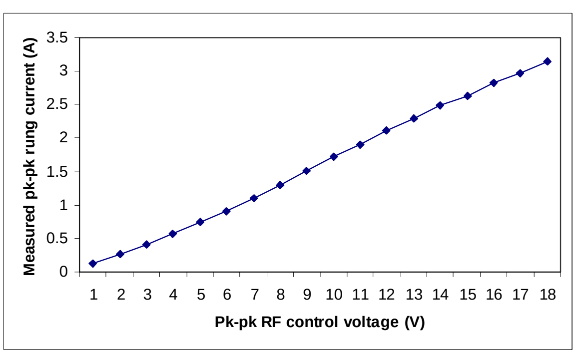

Figure 3 **Linear relationship between output current amplitude and amplitude of the control voltage**

Reference

[1] **K.N.Kurpad *et al.* ISMRM 2004 (Submitted for publication)**

[2] **H.L.Krauss *et al.* "Solid State Radio Engineering", Wiley, 1980**