A Novel Power MOSFET Decoupling Technique for Parallel Transmit Arrays

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Introduction The use of transmit SENSE techniques to accomplish B_1 field shimming at high fields and selective volume excitation necessitates the development of a technique that accomplishes individual and independent current control on each array element [1]. One way to achieve such control is using a nonreciprocal active device integrated with a current element, through which neighbor induced RF power is attenuated in a reverse power flow. In previous work, Kurpad et al. [2,3] introduced the active rung design enabling independent current control using a power MOSFET. Nam et al presented a transmit SENSE image using a 4-channel dual MOSFET current source in a surface coil array [4]. However, the critical issues in this technology are the lack of the driven current magnitude and low power efficiency due to the power mismatch at the drain terminal of the MOSFET. In this work, we present a novel power MOSFET decoupling network in two interacting transmit elements. Experimental bench results show significant improvement in driven current magnitude compared to previous RF current source designs. Simultaneously, the decoupling network suppressed neighbor induced current regardless of the output reactance of the MOSFET.

Method Two parallel copper strips were implemented as a transmit array, each 10.5 inches long, 1 inch wide, 1 inch high connected through a variable capacitor to the ground plane (TEM element or rung). A single ended RF power MOSFET (SP201, RF Polyfet Devices) with rated maximum power of 4 Watts and 1.2A drain current, was used to drive the current elements. The device was set to Class AB operation and compensated for stability by placing a 62 Ohm chip resistor across the gate and source terminal. Based on the measured S parameters of the MOSFET, the L section input matching network was built so that it provided high unloaded Q factor at the drain. By shunting the output capacitance of the MOSFET the output impedance at the drain was 1.1 kOhms allowing simultaneous output matching. The output matching network provided two cases of impedance transformation at the drain, the load line resistance, $R_{L,opt}$, and half of $R_{L,opt}$ from the terminal impedance of the series resonant element, $R_{TEM,res}$ (~0.6 Ohm for empty rung). Simultaneously, the output matching network formed an output impedance block seen by the induced voltage at the array terminal and the magnitude of the output impedance depends on the impedance transformation ratio of the output matching network. Using a shielded probe, the magnetic field distributions normalized by the maximum driven field due to the single excitation at rung A with three different terminations at rung B were measured and plotted to estimate the amount of induced current suppression. Three terminations at rung B referred to the open circuited, the non-driven decoupling network terminated which produced $R_{L,opt}$ and its half at the drain. Similarly, driven current magnitudes were obtained as a function of input power for three load impedances at the drain, $R_{L,opt}$, $R_{L,opt}$ / 2, and $R_{TEM,res}$.

Results The magnetic field picked up by the probe showed a constructive and destructive pattern along the measurement line in Figure 1, implying that the fields were predominantly a linear response of the driven current on rung A and its counter direction image current on the ground plane. The asymmetry of the pattern may be introduced by the finite size of the ground plane and biased placement of rung A. Although there were noticeable field variations by the induced current on rung B when using the output matching network (triangle and circle traces), it was not sufficiently significant in magnitude to affect the driven fields above rung A. The output impedances looking into the matching network at the rung terminal were approximately 260 Ohms and 120 Ohms for $R_{L,opt}$ / 2 (circle trace) and $R_{L,opt}$ (triangle trace) matching at the drain, respectively. The corresponding induced current suppressions from the maximum driven field magnitude were -29 dB and -24 dB. Driven current magnitudes during use of the output matching network were significantly improved as in the circle and triangle traces in Figure 2. With $R_{L,opt}$ / 2 and $R_{L,opt}$ matching at the drain the linear gain and 1dB gain compression point, P_{1dB}, improved by a factor of 6.2 dB (circle trace) and 9.5 dB (triangle trace), corresponding to double and triple times higher in peak current magnitude compared to those in the absence of the matching network (square trace).

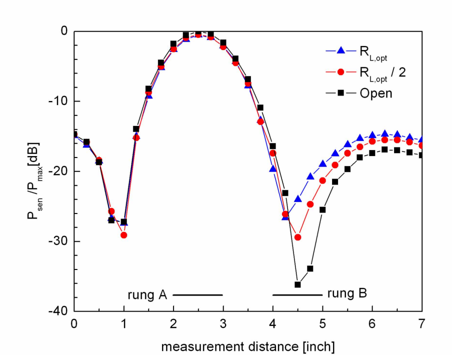

Figure 1. Normalized transverse magnetic field distribution along the measurement line for the single excitation on rung A with open (square trace) and decoupling network terminations at rung B (circle and triangle traces)

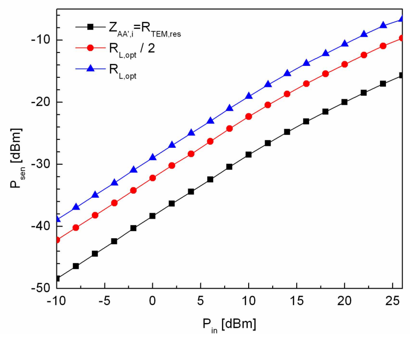

Figure 2. Driven current magnitudes vs. input power in terms of sensed probe power for three load resistances at the drain, $R_{TEM,res}$ (square trace), $R_{l,opt}$ / 2 , and $R_{L,opt}$ (circle and triangle traces).

Discussion & Conclusion Simultaneous output matching networks integrated with the power MOSFET resulted in improved linear gain and P_{1dB} compared to the previously published active rung designs, and suppression of the neighbor induced current regardless of the output reactance of the MOSFET. This was accomplished by forming a high drain impedance under control of the input matching network and shunting the output capacitance of the MOSFET and the output matching network provided the preferential load line impedance at the drain terminal. The concept of the decoupling network is that the driven and the induced sources see different terminal impedances. The amount of induced current suppression depends on the output terminal impedance of the matching network. As the impedance transformation ratio of the output matching network increases the output terminal impedance decreases, degrading induced current suppression.

Reference [1] Katscher U, et al., Magn. Reson. Med. 2003;49. [2] Kurpad K, et al., Proc. Intl. Soc. Mag. Reson. Med. 2004;11. [3] Kurpad K, et al., Proc. Intl. Soc. Mag. Reson. Med. 2005;13. [4] Nam H, et al., Proc. Intl. Soc. Mag. Reson. Med. 2006;14