Developments in Active Rung Design for Parallel Transmit Coils

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Introduction

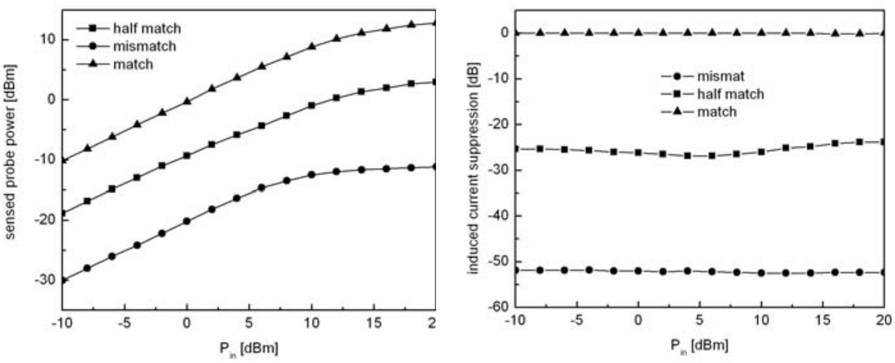
With the development of the Transmit SENSE [1] technique for selective excitation, there is considerable interest in the development of parallel transmit arrays with independent control of the RF current amplitude and phase in each transmit element. In previous work, Kurpad et al. [2,3] introduced the active rung design and demonstrated independent control of current in adjacently placed active rungs due to the induced current suppression. However, a drawback of this design is the reduced amplitude of driven current. In this work, we present the effect of a variation of the output impedance of the MOSFET on the driven current amplitude and induced current suppression.

Method

A series resonant rung tuned at 127.7 MHz was applied as a very low impedance (about one ohm) load of the MOSFET. A RF power MOSFET with low output power rating (Polyfet SP201 maximum ratings 1.2A drain current, 20W total device dissipation power) was used to drive the current elements. The low power rating aided understanding MOSFET behavior for our application while operating within the power handling capabilities of our instrumentation. The device was set to Class AB operation and the small signal S parameter of the device was extracted using VNA. Based on S parameters, three different matching networks were implemented in order to compare the driven current amplitude and corresponding induced current suppression in two adjacent active rungs. First, a matching network was implemented to produce the maximum driven current on the single rung by setting up the highest transducer power-gain in the stable region. Second, a matching network was designed for extreme mismatch of the series resonant rung, i.e., matching to the high impedance load. Third, only the input matching network was designed without output matching (direct rung connection to the drain). For the induced current suppression experiment, two identical MOSFET circuits along with the series resonant rungs were built. Induced currents were measured by positioning the magnetic field probe on the second rung which did not supply driven currents in the presence of the driven current on the first rung. Then the induced currents were normalized by the induced current due to a short circuited rung. To demonstrate the control over the driven current amplitude, the driven currents were measured versus input power with the presence of the maximum induced current produced by the second rung.

Results

Matching to the rung impedance produced the highest driven current on the rung as shown in triangle trace (figure 1a). However, it also resulted in 0 dB induced current suppression in figure 1b. This showed complete loss of the current control in the presence of neighboring current elements over entire input power range in figure 2. A deliberate extreme mismatching to the rung provided the best induced current suppression of 52 dB but the lowest driven current of 20 dB below the matching case. Half matching to the rung showed intermediate performance in the driven current amplitude which was 10 dB smaller than the matching case and the induced current suppression of 25 dB.



(a) (b)

Figure 1. Driven current magnitude (a) and induced current suppression (b) versus input power for three different matching networks.

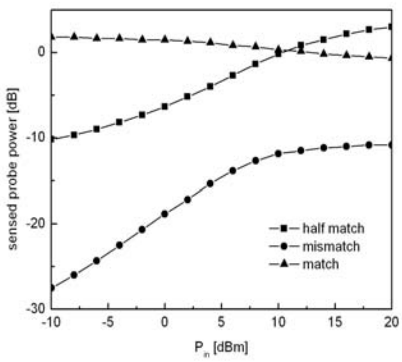


Figure 2. Sensed probe power in the presence of the maximum induced current versus input power for three different matching networks

Discussion & Conclusion

Impedance matching of the MOSFET for the given bias condition to the series resonant rung may provide the best driven current, but it also allows the maximum induced current by the adjacent rung. This accounts for the formation of the very low impedance loop formed by the output matching network and the series resonant rung so that both the driven and induced current currents are maximized. On the other hand, the deliberate mismatch to the rung illustrates very high impedance loop formation for both driven and induced currents, by the consequences, leads to the best control but the lowest power efficiency. The experimental results show a trade off between the driven current amplitude and induced current suppression with variation in the matching network. Using a single ended MOSFET, being in control of both the driven current amplitude and the induced current suppression may be limited. In order to boost the driven current without loss of the induced current suppression, other types of MOSFET configurations, such as push-pull or parallel scheme, are under consideration. The suppression of induced current is also under consideration by adapting decoupling techniques exploited in PSA structures [4,5] without the loss of the driven current.

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] Lee Ray, et al., Magn. Reson. Med. 2001;45. [5] Boscamp E, et al., Proc. Intl. Soc. Mag. Reson. Med. 2002;10.