A high-power RF switch for arterial spin labelling with a separate tagging coil

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Introduction: Continuous arterial spin labelling typically uses two RF coils; one for spin tagging and one for imaging [1]. As the coils are not used simultaneously, a high-power RF switch can be used to enables a single RF power amplifier to drive both coils (fig. 1). A common design for a high-power, single-pole double-throw (SPDT) RF switch uses a pair of series-connected PIN diodes (fig. 2). When reverse biased, PIN diodes exhibit significant capacitance. The isolation of the switch in the OFF state can be considerably increased by adding an inductor in parallel with the diode, creating a parallel resonant circuit [2].

In this abstract, a circuit capable of switching a 600MHz signal at 1kW peak power is shown, which is suitable for use with an animal imaging system. The circuit is used to demonstrate the improvement in isolation achievable when using a resonant circuit. The switch is designed to have high isolation in the OFF state and reasonably low insertion loss in the ON state. Unlike a transmit-receive switch, this switch is not part of the receive pathway; losses in the switch in the ON state reduce the system transmit efficiency, but do not affect system SNR.

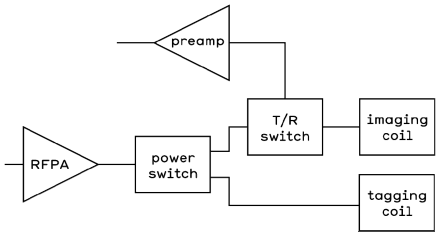

Figure 1: Block diagram showing the high power switch inserted before the T/R switch in the transmit pathway.

Methods: A switch was designed and built to operate at 600MHz, based around MMP7080-127-1 PIN diodes (Aeroflex, NH) (figure 2). The capacitance of the reverse-biased PIN diode is approximately 0.62pF [3]. The inductance required to resonate the diode at 600MHz was calculated ($L = 1/(\omega^2 C) = 113$ nH). A pair of air-cored inductors were hand-wound (3mm diameter, 10 turns of 0.6mm copper wire) and soldered into place. Large capacitors (620pF) were added in series with L_1 and L_2 to prevent the inductors from bypassing the DC bias across the diodes, without significantly changing the RF pathway. The resonance frequency was then fine-tuned by bending the inductors while monitoring the switch isolation using a network analyser (Agilent E5071C). Switch performance was measured with and without inductors L_1 and L_2, to demonstrate the improvement gained by resonating the diodes.

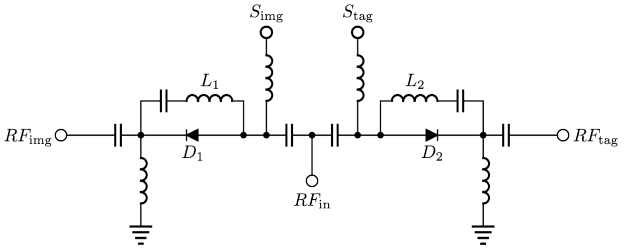

Figure 2: Circuit schematic. D_1 and D_2 are the PIN diodes, L_1 and L_2 resonate D_1 and D_2 in the off state. All remaining inductors are RF chokes (1µH), all capacitors are DC blocks (620pF). S_{img} and S_{tag} are the control signals.

Results: The switch was driven at 100mA (ON) and -30V (OFF) using a suitable PIN diode driver (e.g. [4]). Performance of each channel at 600MHz is shown in table 1. Plots from the network analyzer are shown in figure 3.

	Non-resonant	Resonant
Insertion loss /dB	1.08, 1.13	1.08, 1.11
Isolation /dB	20.7, 20.9	65.5, 62.3

Table 1: Measured switch performance at 600MHz.

Discussion: The original ASL experimental setup required two separate RF power amplifiers to drive the tagging and imaging coils. The switch presented here simplifies the experimental setup by enabling a single amplifier to be switched between the two coils. Resonating the PIN diodes improved the switch isolation by more than 40dB, without changing the insertion loss. While the use of resonant circuits makes the switch narrow-band, NMR experiments are already inherently very narrow-band, so this is not restrictive in practice. This technique is applicable to any RF switch using a series PIN diode (e.g. T/R switches), and can easily be extended to a higher power rating by using a larger PIN diode. The authors are willing to share the parts list and Gerber files for the PCB layout.

References: [1] H. Lei et al, IEEE Eng. Med. Biol. Soc., Boston, 2011; [2] W.E. Doherty and R.D.Joos, 'The PIN diode designers handbook', Microsemi Corp., 1998; [3] MMP7080-127-1 datasheet, Aeroflex; [4] B. Beck et al, abstract no. 1829, ISMRM, Montreal, 2011.

Acknowledgements: This study was supported by Centre d'Imagerie BioMédicale (CIBM) of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations.

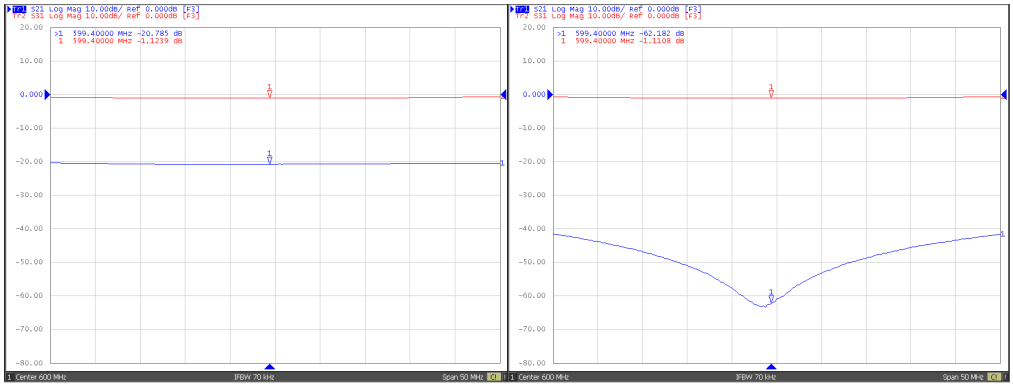

Figure 3: Isolation (blue) and insertion loss (red) for the untuned (left) and tuned (right) switch (center=600MHz, span=50MHz, 10dB/div).