A 0.13-μm CMOS RF Tx/Rx Switch for Wideband Applications

Jeong-Yeon Kim · Chang-Wan Kim

Abstract

This paper describes a 0.13-μm CMOS RF switch for 3~5 GHz UWB band(mode 1). It can improve isolation characteristics between ports by using deep n-well RF devices while their source and body terminals are separated. From the measurement results, the proposed T/R switch is comparative to the on-wafer probing measurement results of the series-shunt T/R switches. When the proposed T/R switch operates as Tx mode, measured insertion loss from Tx to output port is less than 1.5 dB and isolation between Tx and Rx is more than 27 dB for 3~5 GHz. Return loss for the Tx port is more than −10 dB and input P1dB is +10 dBm.

Key words : CMOS, Switch, SPDT, Ultra-Wideband, UWB.

I. Introduction

The ultra-wideband(UWB) system has emerged as a major technology for high data rate services in short range wireless communication systems, which include such wireless systems as the wireless universal serial bus(USB), the wireless IEEE 1394, and the wireless link between HDTVs and laptop computers. The unlicensed UWB band between 3.1 and 10.6 GHz has been reserved and its transmitted spectrum shape of modulated output power and maximum power level are limited as 41.3 dBm/MHz by the FCC[1]. The RF switch, which covers UWB band from 3.1 to 10.6 GHz is an important circuit block in the RF transceiver. Today, most RF switches are implemented using GaAs technology as off-chip modules. The implementation of RF switches using CMOS technology can reduce the cost and size of the RF transceivers. Recently, many advanced CMOS RF switches are introduced in [1]~[4].

This paper describes a 0.13 μm CMOS RF switch for 3.1~5 GHz UWB band(mode 1). It can improves isolation characteristics between ports by using deep n-well RF devices while their source and body terminals are separated.

II. Switch Implementation

From previously reported RF transmit/receiver(T/R) switches[1]~[4], the series-shunt T/R switch configurations show improved isolation characteristics with their shunt transistors than that of the series configurations. However, the measurement results in those previous works are based on on-wafer tests and do not include parasitic bonding wire inductances. In the practical cases in which parasitic inductances from ground bonding wires cannot be ignored, parasitic inductances can series-resonant with the parasitic capacitance of the shunt transistors. If peaking caused by this series resonance occurs in the interested UWB band, major characteristics of the series-shunt T/R switches can be considerably degraded. In this work, the proposed T/R switch, as shown in Fig. 1, is implemented as the series configuration to avoid the possibility of the above series resonant problems by shunt transistors. The device sizes of M_1 and M_2 are carefully chosen as W/L=(75 μm/0.13 μm) considering the trade-off between insertion loss and isolation[2]. In Fig. 1, switch transistors M_1 and M_2 are deep n-well MOS transistors, which can provide better substrate isolation between other RF building blocks. As shown in

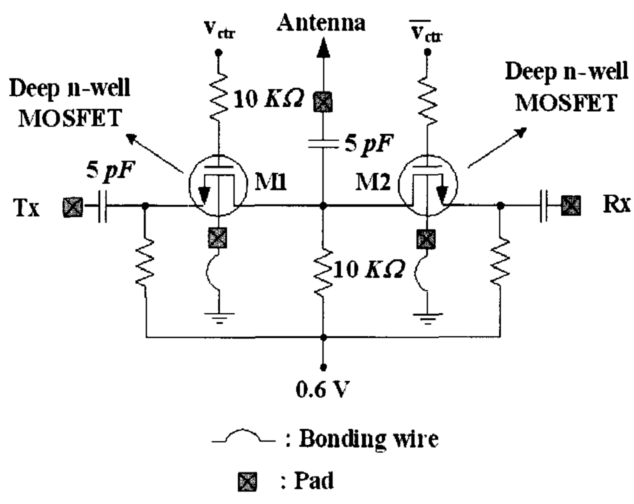

Fig. 1. Proposed RF switch configuration.

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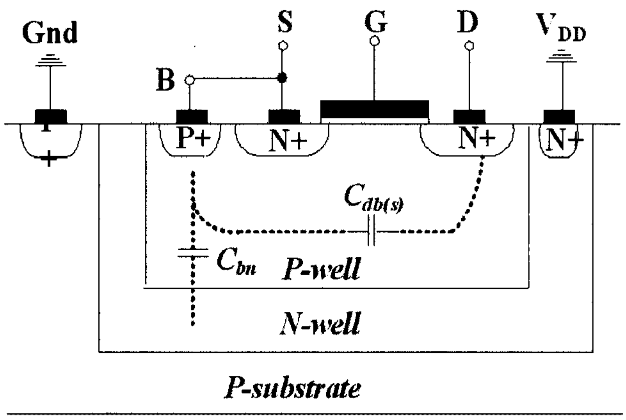
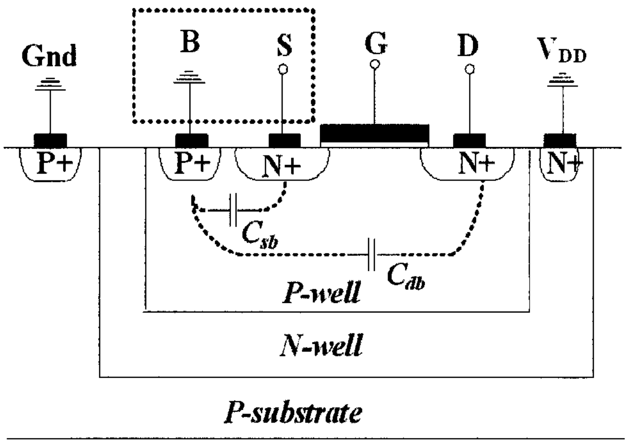
Fig. 1, however, each local body terminal(B) of M_1 and M_2 is independently connected to the ground for better isolation between the Tx and Rx port. Fig. 2(a) shows the conventional deep n-well NMOSFET cross structure and major parasitic capacitances; other parasitic capacitances are omitted for simplicity. The deep n-well NMOSFET inherently produces additional parasitic capacitance $C_{db(s)}$ between the drain(D) to the source(S) because its local body(B) is generally connected with the source (S). This parasitic capacitance $C_{db(s)}$ produces an unwanted signal path from the drain(D) to source(S) when the transistor turns off. Therefore, it considerably increases unwanted signal coupling between the drain to the source. To overcome this problem, the structure of deep n-well NMOSFET is modified in this work, as shown in Fig. 2(b). In Fig. 2(b), the local body(B) is disconnected from the source(S) but attached to the ground node. This modification can avoid parasitic capacitance



(a)



(b)

Fig. 2. (a) Conventional deep n-well NMOSET cross structure; the local body connected to the source, and (b) Local body attached to the ground node, instead of the source in the deep n-well structure to remove parasitic capacitance between the drain to the source.

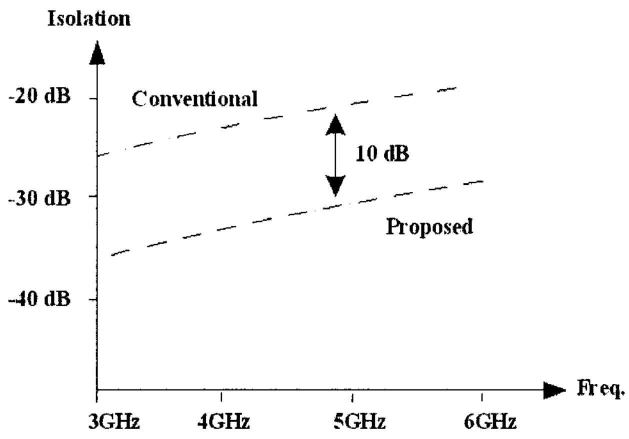


Fig. 3. Simulated isolation characteristic.

$C_{db(s)}$ in the deep n-well MOSFET. When other parasitic capacitances(C_{gd}, C_{gs}, and so on) are ignored, only drain/source to substrate junction capacitors(C_{db} and C_{sb}) affect the switch isolation.

Fig. 3 shows the simulated isolation characteristics between a T/R switch using the device in Fig. 2(a) and the proposed T/R switch using the device of Fig. 2(b), when they all operate as Tx mode(M_1 is on and M_2 off). In Fig. 3, isolation of the proposed configuration using the device of Fig. 2(b) is better than 10 dB compared to that of the T/R switch using deep n-well devices in Fig. 2(a). In Fig. 1, all drain and source nodes are dc biased to 0.6 V for less parasitic junction capacitances from the drain and source to p+ silicon substrate and power handling capability.

Ⅲ. Measurement Results

The proposed 0.13 μm CMOS RF T/R switch in Fig. 1 is measured after mounting it on the FR4 PCB to evaluate its characteristics. All bonding wire inductances effects are included in this test. The photograph of the fabricated T/R switch is shown in Fig. 4. The size of the chip including pad is 0.7×0.8 mm.

Fig. 5 and Fig. 6 show the 50 ohm matching characteristics of each port. Tx, Rx, and antenna ports are well matched to 50 ohm impedance over 3~5 GHz. As shown in Fig. 7, when the T/R switch operates as Tx mode, measured insertion loss from Tx to output port is less than 1.5 dB and isolation between Tx and Rx more than 27 dB for 3~5 GHz. Return loss for the Tx port is more than −10 dB. As shown in Table 1, performance of the proposed T/R switch is comparative to the on-wafer probing measurement results of the series-shunt T/R switches[1]~[4]. Table 2 also compares the simulated results with the measured results of the proposed T/R switch when Tx mode operates.

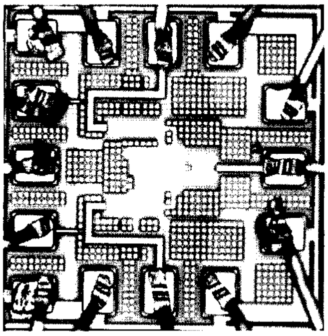


Fig. 4. Chip photo (0.7×0.8 μm).

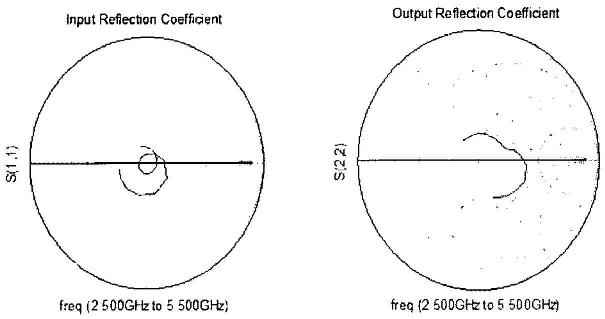


Fig. 5. 50 ohm matching: S_{11}(Tx node) and S_{22}(antenna node) over 2.5 to 5 GHz.

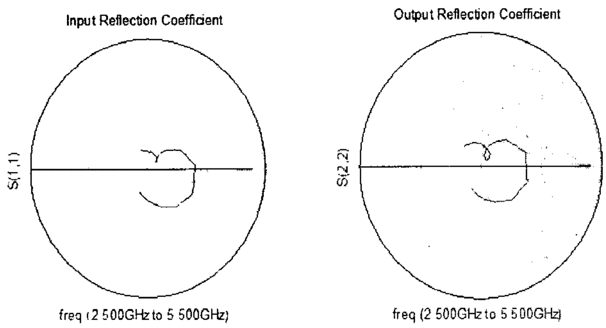


Fig. 6. 50 ohm matching: S_{11}(Rx node) and S_{22}(antenna node) over 2.5 to 5 GHz.

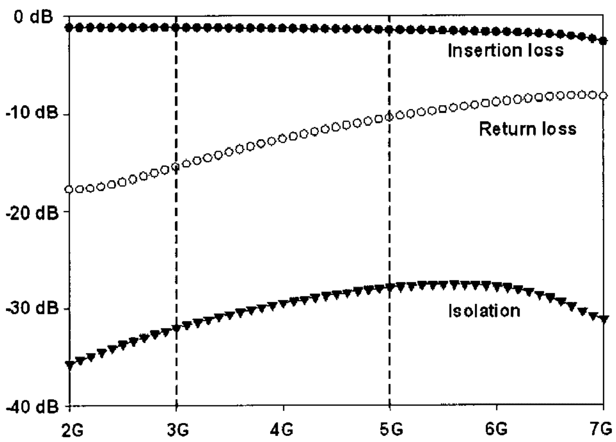


Fig. 7. Measured T/R switch performances(When Tx mode operates).

Table 1. Performances comparison.

	This work	[1]	[2]	[3]	[4]
Frequency range(GHz)	3~5	3.1~10.6	5.8	2.4~20	3~10
Insertion loss (dB)	1.5*	2.2*	0.8	1.5**	2.5*
Isolation(dB)	27*	34*	29	34**	30*
Input P1 dB (dBm)	10	n/a	17	30	20
CMOS technology	0.13 μm	0.13 μm	0.18 μm	0.13 μm	0.18 μm

*Measured results at 5 GHz,
**Measured results at 5.8 GHz

Table 2. Comparison between simulated and measured results.

	Simulation			Measurement		
	3 GHz	4 GHz	5 GHz	3 GHz	4 GHz	5 GHz
Insertion loss(dB)	0.7	0.7	1.2	1	1.3	1.5
Isolation(dB)	36.6	34.5	33.6	33	30	27
Return loss(dB)	−14.3	−14.2	−11.4	−17	−13	−11
Input P1 dB(dBm)	+9			+10		

Ⅳ. Conclusion

A 0.13 μm CMOS RF T/R switch are implemented, which coves the mode 1 UWB frequency band 3~5 GHz. It can improves high isolation characteristics between ports by using deep n-well RF devices while their source and body terminals are separated. From the measurement results, the proposed T/R switch is comparative to the on-wafer probing measurement results of the series-shunt T/R switches. Finally, the proposed T/R switch is suitable for UWB applications.

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References

[1] Yalin Jin, Cam Nguyen, "A 0.25-m CMOS T/R switch for UWB wireless communications", *IEEE Microw. Compon. Lett.*, vol. 15, no. 8, pp. 502-504, Aug. 2005.
[2] Zhenbiao Li *et al.*, "5.8 GHz CMOS T/R switches with high and low substrate resistances in a 0.18 μm

CMOS process", *IEEE Microw. Compon. Lett.*, vol. 13, no. 1, pp. 1-3, Jan. 2003.

[3] Qiang Li *et al.*, "CMOS T/R switch design: towards ultra-wideband and higher frequency", *IEEE J. Solid-State Circuits*, vol. 42, no. 3, pp. 563-570, Mar. 2007.

[4] K-H Pao *et al.*, "A 3-10 GHz broadband CMOS T/R switch for UWB applications", *Proceedings of the 1st European Microwave Integrated Circuits Conference*, pp. 452-455, Sep. 2006.

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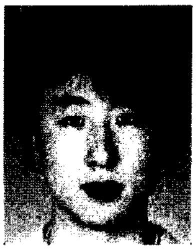

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