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Low-Power RF Circuits in SOI

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1. Introduction

SOI technologies are ideal for low-power RF circuit applications. There excellent RF performance at low voltages, 0.2-μm nMOSFET/SOI has an f_{MAX} of 26 GHz at 0.5-V supply [1], is due to the small parasitic capacitance at the drain region; SOI devices have small junction areas that are isolated by rather thick buried oxide. In addition, fully-depleted SOI technology allows us to reduce the threshold voltage easily. Low-threshold-voltage devices have high gains at low supply voltages. Moreover, we can make undoped-channel MOSFETs (depletion-mode MOSFETs) without using masks or adding process steps. This paper describes how to design RF circuits using SOI technology; in particular, it describes the design and fabrication of RF switches, voltage controlled oscillators (VCO), and a mixer are designed and fabricated.

2. Circuit Implementation

RF Switches

RF switches must have high isolation and low loss. A single-pole double-throw (SPDT) switch was made by A. Kanda et al. [2] using 0.5-μm CMOS/SOI technology (Fig. 1). They showed that the performance at a 3-V supply was similar to that of GaAs FET technology and that the SOI switch has a clear advantage over bulk-CMOS technologies. Because of the small parasitic capacitance of SOI devices, we can widen the channel width of the switch transistor to decrease the transmission loss without sacrificing isolation characteristics. We have verified that the measured performance of the SPDT switch made from 0.35-μm CMOS/SOI technology has a ON/OFF ratio that is similar to that in Fig. 1 even at a 1-V supply.

Voltage Controlled Oscillators (VCO)

The small drain capacitance of SOI devices allows us to use the tuning-range switching technique to obtain a wide tuning range for the oscillation frequency of the VCO [3]. Figures 2 and 3 show a schematic diagram of the VCO and the measured output frequency of the VCO as a function of control voltage, respectively. The tuning-range switches can switch capacitances connected at oscillating nodes, which can shift the oscillation frequency. This switching technique enables a wide frequency range and appropriate tuning sensitivity. At a supply voltage of 2 V, the oscillation range is between 5.72 and over 6.2 GHz. The VCO can operate at supply voltages as low as 1.1 V, while its current dissipation is 7.5 mA. To reduce the power consumption even further, the VCO must be able to operate at lower voltages. We developed a 2-GHz VCO using undoped-channel MOSFETs [1]. It can operate at supply voltages as low as 0.5 V, while the power dissipation is 3 mW (Fig. 4). The availability of undoped-channel MOSFETs is an advantage when designing such a low-voltage VCO.

Mixer

A Gilbert cell, which is most commonly used for the mixer, normally has a stack of three transistors. In order to lower supply voltage, this stacking must be avoided. The number of transistors in the stack is decreased by folding a circuit, and then, the node at which the circuit is folded is connected to a current source. Stacking of transistors in the folded circuit, however, cannot be avoided because the current source is usually made of a transistor. The dc drop in this transistor greatly reduces the operation range at supply voltages below 1 V. We propose using an LC tank instead of the current source, which can make the dc drop zero [1]. The LC tank acts as a current source near its resonant frequency because the impedance is high enough. As a result, the stacking of MOSFETs can be avoided. Figure 5 shows a schematic diagram of the proposed folded mixer. Using LC tanks having a resonant frequency of about 2 GHz, the RF input pair is folded. This technique makes 0.5-V operation possible. Output buffer circuits made of undoped-channel MOSFETs keep the drivability at high enough level at low voltages.

3. Conclusion

SOI technologies are very useful in RF circuits. The SOI is suitable for low-voltage operation, which will greatly reduce power consumption of wireless terminals. A MOSFET/SOI itself makes a good RF switch. This allows us to make RF circuits that conventional technologies can not make.

Acknowledgments

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References

[1] M. Harada, T. Tsukahara, and J. Yamada, *Proc. of ISSCC 2000*, pp. 378-379, 2000.

[2] A. Kanda and M. Muraguchi, *2000 Asia-Pacific Workshop on Fundamental and Application of Advanced Semiconductor Devices (AWAD2000)*, #10.3, 2000.

[3] A. Yamagishi, T. Tsukahara, M. Harada, and J. Kodate, *in Proc. of MTT-S International Microwave Symposium (IMS2000)*, WE2A-4, 2000.

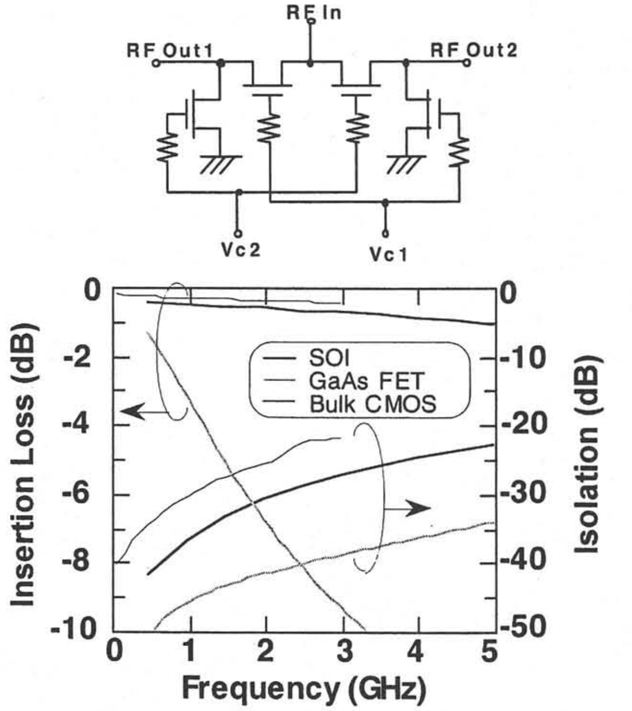

Fig. 1. Schematic of the SPDT switch and measured performance [2].

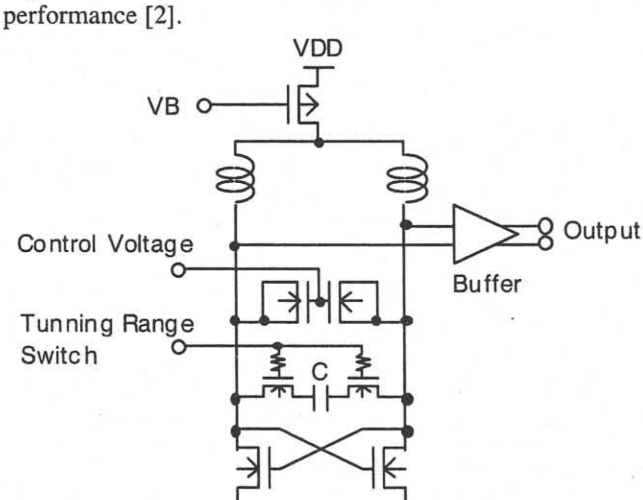

Fig. 2. Schematic of a VCO using the tuning-range switching technique.

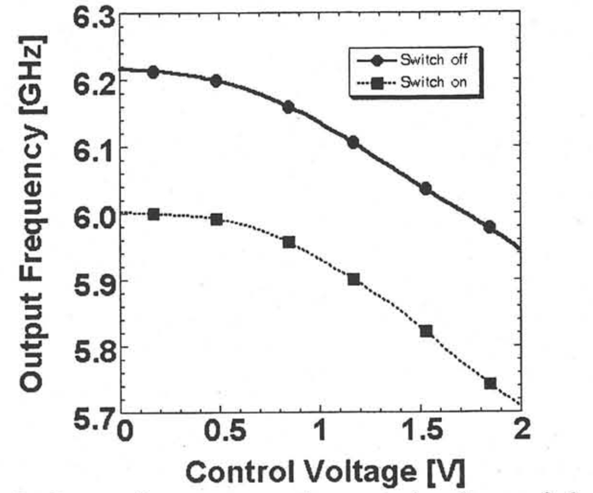

Fig. 3. Output frequency vs. the control voltage of the VCO using the tuning-range switching technique at supply voltage of 2 V.

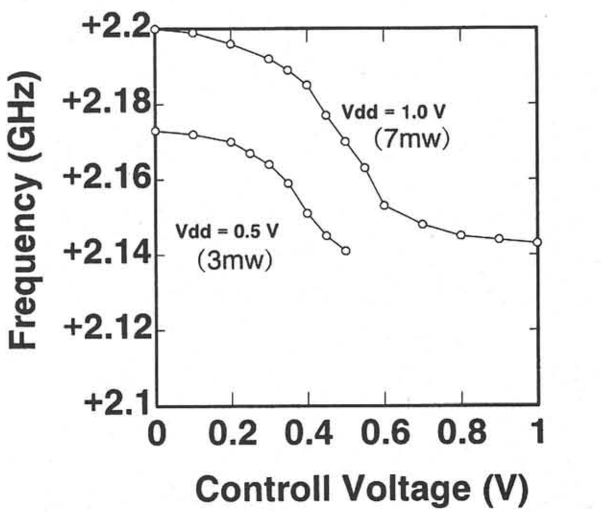

Fig. 4. Output frequency vs. the control voltage of the low-voltage VCO.

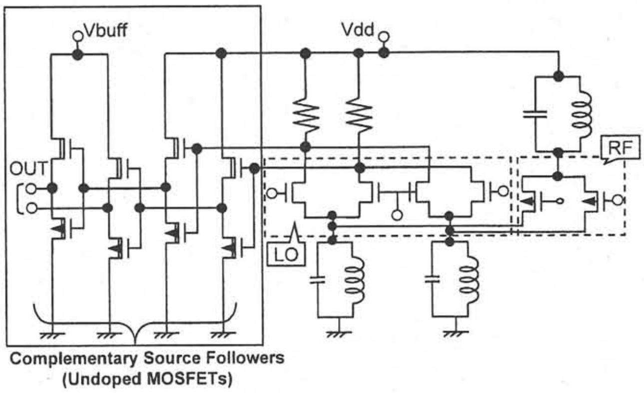

Fig. 5. Schematic of the LC-tuned folded mixer.