A High Isolation CMFB Downconversion Micromixer Using 0.18-μm Deep N-well CMOS Technology

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Abstract **— CMOS deep N-well technology can eliminate body effects of NMOS transistors and improve LO-IF and LO-RF isolation in a Gilbert micromixer. A 37 dB LO-IF and 38 dB LO-RF isolation downconversion micromixer with 19 dB conversion gain, IP_{1dB}=-19.5 dBm and IIP_3=-12.5 dBm when RF=2.4 GHz and LO=2.25 GHz is demonstrated in this paper by using 0.18 μm deep N-well CMOS technology. The input return loss and output return loss are better than 15 dB for frequencies up to 6 GHz. On the other hand, a downconversion micromixer without deep n-well has almost identical power performance but achieves only 20 dB LO-IF isolation and 21 dB LO-RF isolation even if two kinds of mixers are fabricated in adjacent areas of the same wafer. The downconversion micromixer used here has intrinsically single-to-differential input stage and active differential PMOS loads to increase IF differential gain while CMFB is used to stabilize bias points. An IF differential amplifier converts differential output into a single-ended output. Finally, an off-chip rat-race coupler provides balanced LO signals to facilitate isolation measurement.**

I. INTRODUCTION

Micromixer proposed by Gilbert [1]-[3] is the ideal circuit for an RF high frequency mixer. A CMFB (Common Mode Feedback) downconversion micromixer using 0.18 μm deep N-well CMOS Technology is illustrated in figure 1. The common-gate-biased M_3 and common-source-biased M_2 should provide equal but out of phase transconductance gain when M_1 and M_2 are connected as a current mirror. However, the common-gate-biased M_3 suffers from body effect in a standard N-well CMOS process and thus the unequal transconductance causes LO-IF isolation degradation. A deep N-well CMOS technology provides well contacts for N-MOS transistors and is used in this paper to eliminate body effects of NMOS transistors and improve LO-IF isolation.

Circuit topology with a broad band single-ended input and a broad band single-ended output can distinguish the isolation improvement effect from the deep N-well CMOS technology and facilitate on-wafer rf measurement. A micromixer has intrinsically single-to-differential input stage and an IF differential amplifier converts differential output of a mixer into a single-ended output. Active differential PMOS loads can increase IF differential gain but CMFB is needed to guarantee PMOS active loads in the active region. Finally, an off-chip rat-race coupler provides balanced LO signals to facilitate isolation measurement.

A 37 dB LO-IF and 38 dB LO-RF isolation downconversion micromixer with 19 dB conversion gain, IP_{1dB}=-19.5 dBm and IIP_3=-12.5 dBm when RF=2.4 GHz and LO=2.25 GHz at -5 dBm is demonstrated in this paper by using 0.18 μm deep N-well CMOS technology. The supply voltage is 2.4 V. However, a downconversion micromixer without deep N-well has almost identical power performance but achieves only 20 dB LO-IF isolation and 21 dB LO-RF isolation even if two kinds of mixers are fabricated in adjacent areas of the same wafer.

II. CIRCUIT DESIGN

The single-to-differential stage of a Gilbert micromixer renders high speed response and eliminates the need for common mode rejection. The common-gate-configured M_3 possesses good frequency response while the speed of common-source-configured M_2 is improved drastically by adding a low impedance diode-connected M_1 at the input of common-source-configured M_2. The single-to-differential input stage is not only used to turn an unbalanced signal into balanced signals but also facilitates wideband impedance matching. The two resistors in the single-to-differential input stage can improve linearity at the cost of gain reduction and noise figure degradation. The resistance seeing into input port in figure 1 is equal to the parallel combination of the resistance seen into the up branch and the resistance seen into the down branch. For the up branch, the resistance is equal to r_1 resistance, the resistance series connected with the source of M_3, plus the inverse of G_{m3}, the transconductance of M_3. For the down branch, the resistance is equal to r_2 resistance, the resistance series connected with the drain of M_1, plus the inverse of G_{m1}, the transconductance of M_1. We can make the resistance seen into input port be 50 Ω by properly biasing the M_1, M_2 and M_3.

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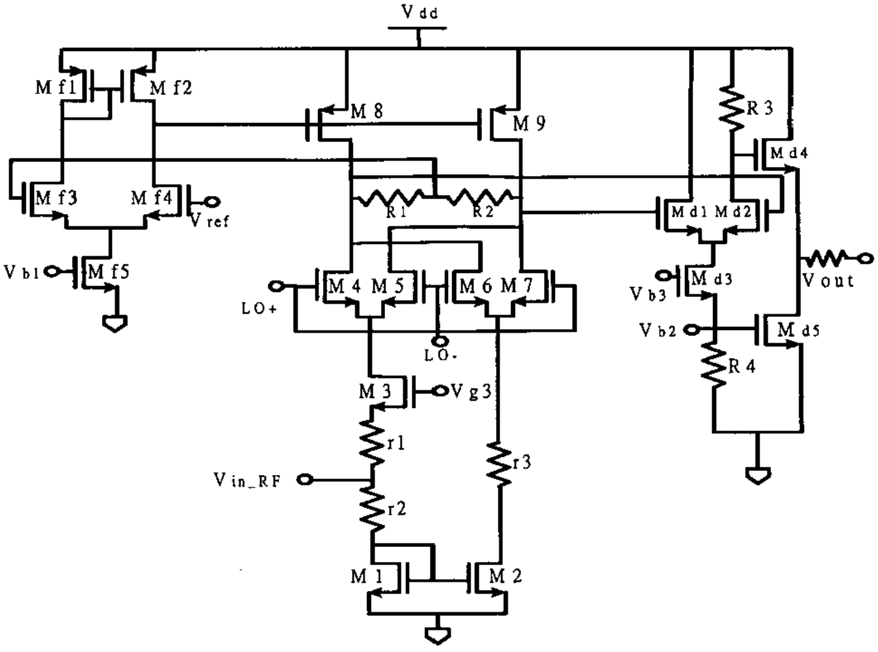

Fig. 1 Schematic of a CMFB CMOS downconversion micromixer

A deep submicron CMOS circuit has low operating voltage and thus differential active PMOS loads instead of resistive loads are used here to increase the conversion gain without sacrificing the voltage swing headroom. However, the high gain offered by differential active loads has a severe bias stability drawback in practical situation because there always exist some mismatches between PMOS and NMOS current sources. Thus, a resistive sensing CMFB as illustrated in figure 1 is used to adjust PMOS current source loads. In other words, M_{f1}-M_{f5} form a comparison amplifier and V_{ref} is set to force the drain voltages of M_8 and M_9 to be V_{ref} by adjusting the PMOS active current loads, M_8 and M_9, to guarantee both NMOS and PMOS current sources in active region. The common mode sensing resistors, R_1 and R_2, lower the differential mode gain because the joint point of R_1 and R_2 is virtually grounded but does not affect the voltage swing headroom. Thus, high IF gain can be achieved by choosing high values of resistors at the cost of reduction IF bandwidth. A differential amplifier formed by M_{d1}~M_{d3} serves as a differential-to-single active balun at the output and a common drain stage, M_{d4}, converts the output to the low impedance level as required by the VSWR consideration.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Source of a NMOS transistor and P-well contacts in a deep N-well CMOS process can be connected together to avoid body effect. Furthermore, deep N-well isolation can reduce substrate noise and coupling to reach NMOS channel. Two identical circuits except M_1~M_3 in deep N-well or M_1~M_3 without deep N-well are fabricated in adjacent areas of the same wafer for comparison purpose.

Figure 2 illustrates the photo of the CMFB 0.18 μm CMOS micromixer. On-wafer rf measurements are performed because the fabricated circuit in figure 2 has a broad band GSG single-ended RF input, a broad band GSG single-ended IF output and a balanced GSGSG LO input. A rat-race coupler can generate balanced LO signals and is used to feed GSGSG LO port in the on-wafer measurement.

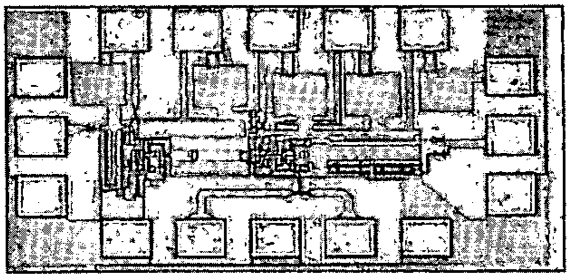

Fig. 2 Photo of a CMFB CMOS micromixer

Figure 3 illustrates that the maximum conversion gain of 19 dB occurs at -5 dBm LO power when LO=2.25 GHz and RF=2.4 GHz. LO-IF isolation and LO-RF isolation measurement results when LO= -5 dBm are illustrated in figure 4 and figure 5, respectively. Deep N-well has great influence on LO-IF and LO-RF isolation as expected. 37 dB LO-IF isolation and 38 dB LO-RF isolation are achieved in downconversion micromixer with deep N-well while 20 dB LO-IF isolation and 21 dB LO-RF isolation are achieved in downconversion micromixer without deep N-well. RF-IF isolation measurement results when LO=2.25 GHz and -5dBm is also illustrated in figure 6 and both circuits have about 21 dB RF-IF isolation because balanced LO signals are provided by the rat-race coupler for both circuits.

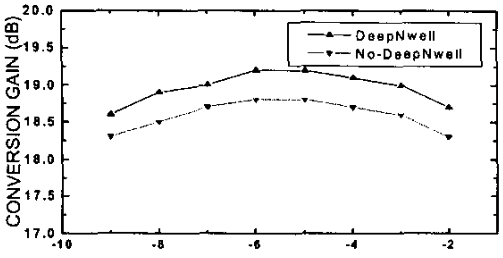

Fig. 3 Measured conversion gain of the CMFB CMOS downconversion micromixer

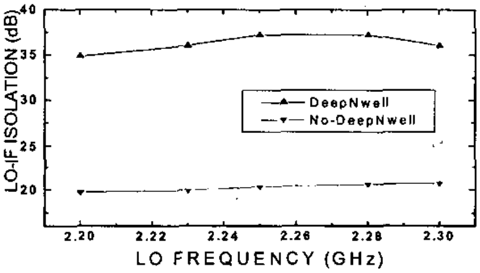

Fig. 4 Measured LO-IF isolation of the CMFB CMOS downconversion micromixer

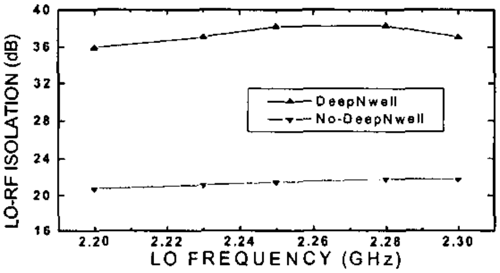

Fig. 5 Measured LO-RF isolation of the CMFB CMOS downconversion micromixer

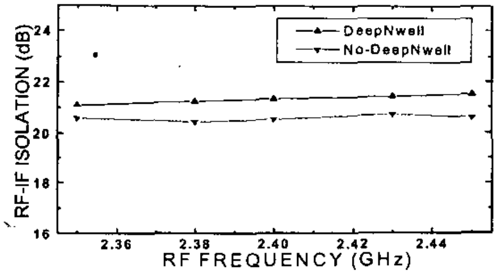

Fig. 6 Measured RF-IF isolation of the CMFB CMOS downconversion micromixer

One tone and two tone intermodulation power measurements are performed and both circuits have almost identical results. Figure 7 illustrates the one tone power measurements and both circuits have 19 dB conversion gain and IP_{1dB}=-19.5 dBm. Two tone intermodulation power measurement results of the mixer with deep n-well is illustrated in figure 8 and IIP_3 equals to -12.5 dBm. All the power measurements are performed when RF=2.4 GHz, LO=2.25 GHz and -5 dBm.

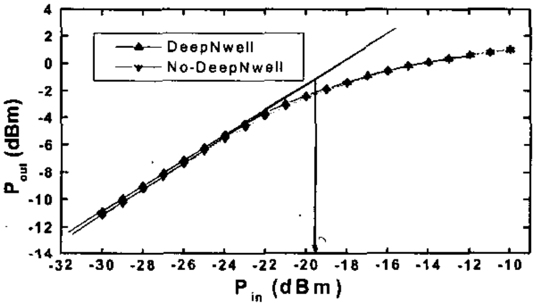

Fig. 7 One tone power measurements of the CMFB CMOS downconversion mixer

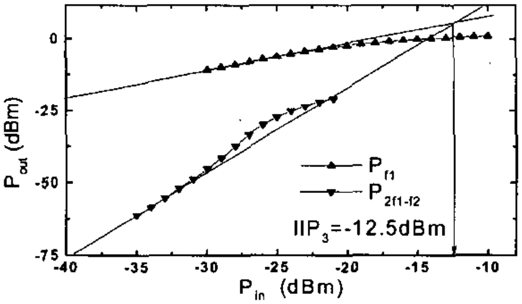

Fig. 8 Two tone power measurement of the CMFB CMOS downconversion micromixer with Deep N-well

The input return loss and output return loss of both circuits are better than 15 dB for frequencies up to 6 GHz as illustrated in figure 9 and 10, respectively. Figure 11 illustrates the conversion gain as a function of rf frequency when LO=2.25 GHz and –5 dBm. The conversion gain is 19 dB when IF=150 MHz and increases up to 24 dB when IF=50 MHz. A DC blocking capacitor is used here to protect the spectrum analyzer and prevents the IF measurement below 10 MHz. The results implies that the CMFB CMOS micromixer has IF bandwidth less than 50 MHz. Certainly there exist trade-offs between IF gain and IF bandwidth by selecting different values of sensing resistors.

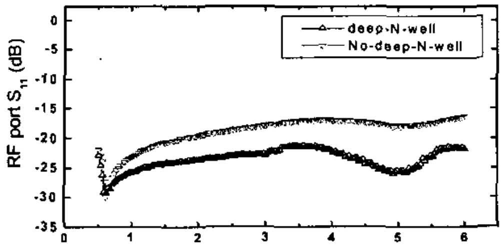

Fig. 9 Measured input return loss in RF port of the CMFB CMOS downconversion micromixer

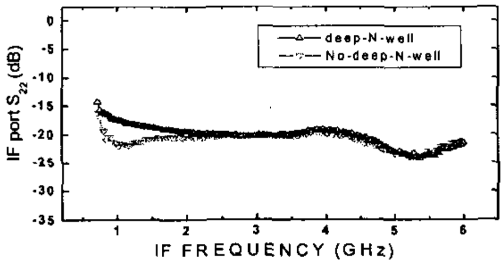

Fig. 10 Measured output return loss in IF port of the CMFB CMOS downconversion micromixer

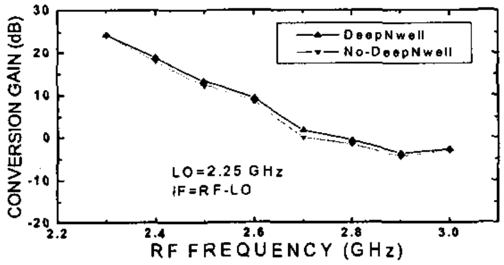

Fig. 11 Measured gain response of the CMFB CMOS downconversion micromixer when LO=2.25 GHz and -5dbm

IV. CONCLUSION

A high isolation CMFB downconversion micromixer using 0.18-μm deep N-well CMOS technology is demonstrated in this paper. Deep N-well has great influence on LO-IF and LO-RF isolation. A Gilbert micromixer has a small die size and is very versatile for many applications. A 37 dB LO-IF and 38 dB LO-RF isolation downconversion micromixer with 19 dB conversion gain, IP_{1dB}=-19.5 dBm and IIP_3=-12.5 dBm when RF=2.4 GHz and LO=2.25 GHz at -5 dBm is demonstrated in this paper by using 0.18 μm deep N-well CMOS technology. The input return loss and output return loss are better than 15 dB for frequencies up to 6 GHz. On the other hand, a downconversion micromixer without deep N-well has almost identical power performance but achieves only 20 dB LO-IF isolation and 21 dB LO-RF isolation even if two kinds of mixers are fabricated in adjacent areas of the same wafer.

ACKNOWLEDGEMENT

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