60 GHz CMOS Down-Conversion Mixer with 15.46 dB Gain and 64.7 dB LO-RF Isolation

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In transceiver design, down-conversion mixer (or demodulator) is a critical block that receives signals from LNA over the whole band of interest, and then amplifies and down-converts (or demodulates) the signals with a good signal-to-noise ratio (SNR) property. The basic requirements of a down-conversion mixer include good input impedance matching and port-to-port isolation, low noise figure (NF), and high conversion gain (CG) over the whole band of interest, and low power consumption. To date, several excellent 60 GHz CMOS down-conversion mixers have been reported [1]-[3]. However, the overall performances of these down-conversion mixers are not satisfactory. To demonstrate that low NF, low power, high CG, and excellent port-to-port isolation can be achieved simultaneously for a 60 GHz CMOS down-conversion mixer, in this work, we report a low-power 60 GHz down-conversion mixer with excellent NF, CG and port-to-port isolation properties using standard 90 nm CMOS technology.

The proposed down-conversion mixer comprises a double-balanced Gilbert cell with a current-reused RF single-to-differential (STD) converter for CG enhancement, a Marchand balun for converting the single LO input signal to differential signal, and an IF amplifier. The chip area of the down-conversion mixer is only 0.591×0.741 mm^2 excluding the test pads. The simulated CG versus RF frequency (i.e., LO frequency plus 0.1 GHz) characteristics at various RF-STD-converter conditions have been studied. RF_{in} is −35 dBm, and LO_{in} is −3 dBm. Over RF frequencies of 57~66 GHz, the mixer with the proposed current-reused STD converter achieves flat and high CG of 13.58±1.54 dB, higher than that (7.79+1.96 dB) of the mixer with a cascode STD converter, and that (6.75±0.92 dB) of the mixer with a common-source (CS) STD converter.

On-wafer measurements were performed by an Agilent's 67 GHz RFIC measurement system. The down-conversion mixer was biased at the condition of V_{IF} = 1.2 V, V_{DD} = 1.35 V, V_{DD1} = 1.8 V, V_g = 0.63 V, I_{IF} = 6.74 mA, I_{DD} = 6.6 mA and I_{DD1} = 16 μA. That is, the mixer consumes only 17 mW power. CG versus RF frequency characteristics of the down-conversion mixer at RF_{in} of −35 dBm have been measured. At LO_{in} of −5 dBm, the mixer achieves maximum CG of 15.46 dB at RF of 62 GHz, and CG of 14.7 dB at RF of 60 GHz, the best CG results ever reported for a 60 GHz CMOS down-conversion mixer. The corresponding ω_{3dB} is 5.4 GHz, from 58.7 GHz to 64.1 GHz. At LO_{in} of −3 dBm, the mixer achieves maximum CG of 14.98 dB at RF of 61 GHz, close to the simulated one (15.11 dB). In addition, for frequencies 59~65 GHz, the mixer achieves flat and high CG of 13.87±1.59 dB for LO_{in} = −5 dBm, close to that (13.19±1.79 dB) for LO_{in} = −3 dBm and that (13.81±1.68 dB) for LO_{in} = −7 dBm.

LO-IF, LO-RF and RF-IF isolations versus RF frequency characteristics of the down-conversion mixer have also been measured. RF frequency is equal to LO frequency plus 0.1 GHz. At RF of 60 GHz, the mixer achieves LO-RF isolation of 64.7 dB, LO-IF isolation of 51.5 dB, and RF-IF isolation of 59.5 dB. In addition, over the 55~67 GHz band, the mixer achieves LO-IF isolation better than 48 dB, LO-RF isolation better than 49.6 dB, and RF-IF isolation better than 47.5 dB, one of the best port-to-port isolation results ever reported for a 60 GHz CMOS down-conversion mixer. A summary of the implemented CMOS down-conversion mixer, and recently reported state-of-the-art 60-GHz-band CMOS down-conversion mixers have also done. The result shows the proposed down-conversion mixer achieves low power consumption, low NF, and the best port-to-port isolations and CG. These results indicate that the proposed down-conversion mixer with current-reused RF STD converter and LO Marchand balun is suitable for 60 GHz transceiver systems.

References

1. Nouri, N., Nezhad-Ahamdi, M.R., Mirabbasi, S., Safavi-Naeini, S., "A Double-Balanced CMOS Mixer with On-Chip Balun for 60-GHz Receivers," *2010 IEEE International NEWCAS Conferenc*, 321-324.
2. Tsai, J.H., and Huang, T.W., "35–65-GHz CMOS broadband modulator and demodulator with sub-harmonic pumping for MMW wireless gigabit applications," *IEEE Trans. Microwave Theory and Technique*, vol. 55, no. 10, pp. 2075-2085, Oct. 2007.
3. Kraemer, M., Ercoli, M., Dragomirescu, D., Plana, R., "A Wideband Single-Balanced Down-Mixer for the 60 GHz Band in 65 nm CMOS," *2010 Asia-Pacific Microwave Conference*, 1849-1852.