Study of Passive CMOS Mixers Effects on Image Rejection Ratio

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Abstract

In this brief, modeling and simulation of quadrature passive mixers are analyzed, focusing on the impact they have on the image rejection ratio (IRR). For this purpose, a 65-nm CMOS technology is used.

Introduction

This work is contextualized in the development of an integrated circuit for radio-over-fiber applications, where an intermediate frequency (IF) of 100 MHz must be transferred to 5 GHz radio frequency (RF) band and vice versa, attaining ease of processing and transmission at IF and RF respectively. Since application uses the 802.11n standard, 5 GHz as radio frequency is a must [1].

A figure of merit (FoM) commonly used in this kind of transceivers is the image rejection ratio (IRR), this ratio gives information about how much the image band is present in relation to the desired band, given by the expression:

$$\mathrm{IRR} = \frac{S_{\mathrm{Desired}}}{S_{\mathrm{Image}}} \qquad (1)$$

where S_{Desired} and S_{Image} denote the power of the desired band and the image band, respectively. High values of IRR are necessary when single sideband (SSB) modulations are required, or to eliminate interference due to an adjacent channel without the need of RF filtering.

The impact on the IRR due to the process-voltage-temperature (PVT) variations and mismatch in polyphase filters (PPF) is analyzed with detail in [2], and a more detailed analysis of passive CMOS mixers is presented in [3].

IRR Analysis in Up Conversion

To evaluate the behavior of the mixer it is used an up conversion scheme shown in Fig. 1(b); the input is an intermediate frequency signal at 100 MHz in quadrature.

Normally, the input signal to the mixer is obtained from a polyphase filter, which produces the quadrature, but in these simulations, it is supposed to be ideal with a perfect balance in phase and amplitude. The IRR can be simply calculated in this case by means of (1). PVT variations are not examined, because it does not affect the IRR. Any variation applied to all the transistors will not decrease the image rejection ratio.

The first issue to be analyzed is the dependence of the IRR with the dimensions of the transistors. For this purpose, Montecarlo analysis is used with different transistor sizes. From Table 1, we conclude that an increase in W/L ratio maintaining a large W and L will produce a better behavior against the mismatch effects. This behavior is explained since what worsens the IRR are variations in W/L ratio, therefore, large dimensions will have small variations in relation to this.

It is necessary to obtain an IRR above 40 dB because the application uses the 802.11n standard, which forces the non-adjacent channels to be 40 dB down [1].

The mix is produced from two mixers, one using the local oscillator in phase and the other in quadrature, implying that there may be differences between these two mixers, which will greatly affect the IRR. Fig. 2 illustrates that to maintain the IRR above 40 dB the difference between the transistors of the two mixers cannot have a mismatch between W/L ratios of more than 1.4 %.

IRR Analysis in Down Conversion

The scheme used is shown in Fig. 1(a) and the PPF is supposed to be ideal, which implies that all signals rotating clockwise will be removed. It is possible to decompose a quadrature signal in the sum of signals rotating in opposite senses, if we introduce the image frequency at the mixer input, at the output it should be a signal which only rotates

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clockwise. A non-ideal mixer will produce an output with amplitude and phase imbalances, and part of the signal will rotate anticlockwise which can pass through the PPF. All simulations from part of the signal will rotate anticlockwise which can pass through the PPF. All simulations from Table 2 have exceeded the objective of 40 dB with a yield of 100 %. In down conversion schemes the mixer will not add any important restriction to the IRR. The mismatch effects have an insignificant impact and are much less relevant than in an up conversion process. As shown in Fig. 3 a mismatch of 6.2 % between mixers is needed to degrade IRR to 40 dB, superior to the 1.4 % from the up conversion process.

Conclusion

In this brief, a study of the IQ mixers in integrated transceivers and their impact on the image reject ratio is presented using a TSMC 65-nm technology. Despite being a characterization of a particular scenario, the results are totally exportable because the technology is forced to the limit using very high frequencies.

The design has been focused on obtaining an IRR over 40 dB in both processes, analyzing the most prejudicial mismatch effects, which are the differences between IQ branches in the mixers, and quantizing their limits. Obtaining a maximum difference of 1.4 % and 6.2 % in W/L ratios between IQ mixers in up conversion and down conversion respectively, revealing that mismatch effects are less important in down conversion than up conversion. In addition to common centroid techniques, in up conversion the dimension of the transistors must be selected carefully due to its high impact on the degradation of IRR.

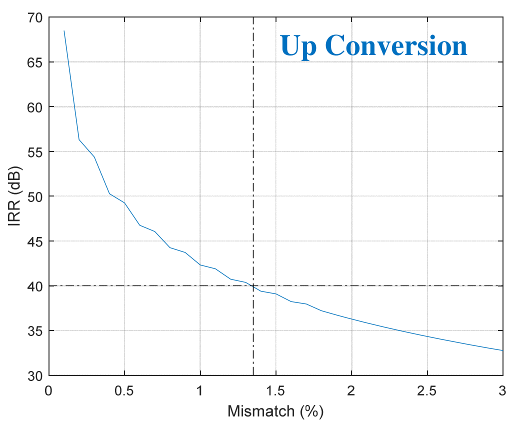

Fig 2. IRR as a function of the mismatch between IQ mixers W/L ratio, in up conversion with a W/L of 96u/200n.

References

[1]. IEEE Std 802.11-2012

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[3]. MORTE, J., MARTÍNEZ-PÉREZ, A.D, AZNAR, F., SÁNCHEZ-AZQUETA, C. and CELMA, S. Simulation Analysis of the Image Rejection Ratio in CMOS Passive Mixers, *European Conference on Circuit Theory and Design*, 2017, under review.

Table 1. IRR Comparison in Up Conversion

W/L	IRR (dB)			
	Mean	*Standard Deviation*	*Minimum*	*Yield (> 40dB)*
96u/200n	56.9	8.2	42.9	100 %
40u/200n	51.8	8.18	38	97 %
40u/60n	50.4	9.4	34.4	92 %

Table 2. IRR Comparison in Down Conversion

W/L	IRR (dB)			
	Mean	*Standard Deviation*	*Minimum*	*Yield (> 40dB)*
96u/200n	78	8.2	63	100 %
40u/200n	80	8.18	67	100 %
40u/60n	71	7.6	57	100 %

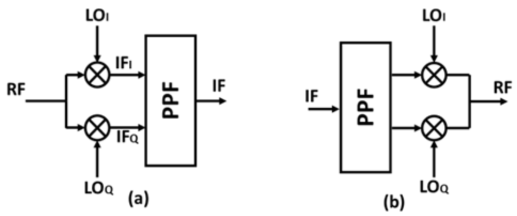

Fig 1. (a) Down conversion and (b) up conversion schemes.

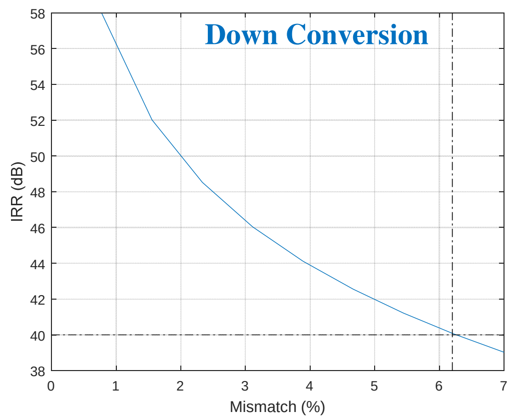

Fig 1. IRR as a function of the mismatch between IQ mixers W/L ratio, in down conversion with a W/L of 96u/200n.