High-image-rejection wireless-receiver architecture with a 3-phase active RC complex filter

Mamoru Ugajin\textsuperscript{1a)}, Yuta Kobayashi\textsuperscript{1}, and Tsuneo Tsukahara\textsuperscript{2}

\textsuperscript{1} Electrical and Electronics Engineering Department, Nippon Institute of Technology, Miyashiro, Minami-Saitama, Saitama 345–8501, Japan
\textsuperscript{2} School of Computer Science and Engineering, University of Aizu, Tsuruga, Iki-machi, Aizu-Wakamatsu, Fukushima, 965–8580, Japan
\textsuperscript{a)} uga@nit.ac.jp

Abstract: This paper proposes a high-image-rejection wireless-receiver architecture with a 3-phase active RC complex filter. The double conversion receiver, in cooperation with RF filter, rejects all image signals. In particular, the double conversion corrects the gain and phase mismatches of the adjacent image, and the image-rejection ratio of the adjacent image depends only on RC mismatches in the complex filter. Thus, the total image-rejection ratio of more than 60 dB can be expected for all the image signals.

Keywords: image rejection, mismatch correction, three-phase analog circuit, complex filter, wireless receiver, low IF

Classification: Integrated circuits

References

1 Introduction

A low-IF architecture is used in narrow-band wireless receivers [1, 2]. A complex filter is an important circuit block in the low-IF wireless receiver to reject the image signal and adjacent interferences [3, 4, 5]. Conventional complex signal processing uses 4-phase (quadrature) signals [1, 2, 6, 7, 8, 9, 10]. However, a 3-phase wireless receiver [11, 12] and a 3-phase complex filter [13] were proposed for reducing analog chip area. In this paper, a high-image-rejection wireless-receiver architecture with a 3-phase active RC complex filter is proposed. Double down conversions with two sets of 3-phase local signals precisely corrects mismatches of the 3-phase second IF signals. The gain and phase mismatches of the second IF signals depend only on the product of the relative errors of the first IF and the second local signals. This error reduction mechanism resembles the 4-phase double-conversion receiver [14, 15], but the architecture is quite different. The final image-rejection ratio is mainly determined by the mismatches of RC values in the 3-phase complex filter.

2 Three-phase double-conversion receiver architecture

Fig. 1 depicts the proposed receiver architecture. RF signal is down converted into 3-phase first IF, then the first IF is down converted into the second 3-phase IF. Both down conversions use 3-phase LO signals. Thus, the second down conversion uses nine mixers. The nine mixer outputs are summed into three phase second IF signals. This second IF signals are inputed into a 3-phase active RC complex filter [9]. The complex filter is a frequency-shifted version of a five-stage low pass filter. The proposed wireless receiver has 3 image frequencies. For example, if the desired RF is 900.1 MHz and the first and the second LO frequencies are 890 MHz and 10 MHz, image frequencies are 899.9 MHz, 880.1 MHz and 879.9 MHz. From here, we name these image frequencies as IM1, IM2, and IM3, respectively. In this case, the IM2 and IM3 are removed not only by the receiver circuit but also by the RF filter. Thus, these two images can be easily rejected as shown in Fig. 2(a). IM1 is rejected only by the complex filter. The proposed double-conversion receiver
corrects the phase and magnitude mismatches of the second IF of IM1. This is because the phase and magnitude mismatches of IM1 depend only on the product of the mismatches of the 1st IF and the second local signals. Therefore, the residuals of IM1 at the filter output is determined by the mismatches of RC values in the complex filter. The RC mismatches can be reduced with careful-layout techniques [14, 15] and the image rejection of more than 60 dB could be obtained [14, 15].

3 Image-rejection performances

Image-rejection performances are simulated with a 0.18-µm CMOS parameter and a 1.8-V power supply. The simulated circuit block is shown in Fig. 1 and consists of 9 switch mixers, a frequency divider and a 3-phase complex filter. Thus, the circuit has three IF inputs (first IF), one clock input (second CLK) and three IF outputs. The second LO signals are 10 MHz and are generated from the second CLK of 30 MHz using the frequency divider. Fig. 3 shows the relation between the phase and magnitude errors of the first IF and image-rejection ratios of IM1, IM2 and IM3. The frequencies and phases of the first IF for IM1, IM2 and IM3 are indicated in Fig. 2(b) and Table I. The phase and magnitude mismatches of IM1 at the second IF are very small because the double conversion circuit corrects the mismatches. So more than 70-dB image rejection is expected if the complex filter does not have RC mismatches. The image-rejection ratio of IM2 depends only on the phase and magnitude mismatches of the second LO, so the image rejection of IM2 is about 45 dB and does not depend on the mismatches of the first IF. The image-rejection ratio of IM3 depends only on the mismatches of the first IF and
more than 30-dB image rejection can be expected with careful layout techniques [8, 9]. The RF filter could remove IM2 and IM3 signals more than 30 dB. Thus, the total image-rejection ratio of more than 60 dB can be expected for the all image signals (IM1, IM2 and IM3).

![Diagram of frequency plan for proposed receiver](image)

Table I. The first IF inputs

<table>
<thead>
<tr>
<th></th>
<th>f [MHz]</th>
<th>φ1 [deg]</th>
<th>φ2 [deg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired</td>
<td>10.1</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>IM1</td>
<td>9.9</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>IM2</td>
<td>9.9</td>
<td>240</td>
<td>120</td>
</tr>
<tr>
<td>IM3</td>
<td>10.1</td>
<td>240</td>
<td>120</td>
</tr>
</tbody>
</table>

Fig. 2. Frequency plan for proposed receiver. Figures (a) and (b) show the signals at the RF input and the first IF, respectively.
Fig. 3. Relation between phase and magnitude mismatches of the first IF and image-rejection ratios of IM1, IM2 and IM3. Figures (a), (b) and (c) are for IM1, IM2 and IM3, respectively. The image-rejection ratios do not include the effect of the RF filter.
4 Conclusion

A new receiver architecture using a 3-phase active RC complex filter was proposed to obtain high-image-rejection performances. The double-conversion receiver corrects the gain and phase mismatches of the adjacent image signals, and the image-rejection ratio of the adjacent image depends only on RC mismatches in the complex filter. By using this receiver architecture, the total image-rejection ratio of more than 60 dB can be expected for all the image signals.

Acknowledgments

This work is supported by VLSI Design and Education Center (VDEC), the University of Tokyo in collaboration with Synopsys, Inc.; and the Grants-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology, Japan (#26420317).