Ultra-low-power 2.4 GHz image-rejection low-noise amplifier

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An ultra-low-power image-rejection low-noise amplifier (IR-LNA) for 2.4 GHz ZigBee applications based on 0.18 μm CMOS technology is presented. By using the third-order active notch filter the proposed IR-LNA can achieve high image-rejection ratio. Measurements show 12 dB gain, 1.8 dB noise figure, 38 dB image-rejection, −3 dBm input third-order intercept point, −18 and −19 dB input and output return loss while dissipating 0.6 mA from a supply voltage of 1.5 V.

Introduction: With the introduction of IEEE 802.15.4 ZigBee standard [1], the demands for low-cost, low-power and small-size wireless transceivers has been increased significantly. The superhererodyne architecture is the most widely used architecture in modern handsets [2]. However, the most critical problem in the superhererodyne architecture is the most active research topic in superhererodyne architecture implementation. In this Letter, an ultra-low-power 2.4 GHz image-rejection low-noise amplifier (IR-LNA) for ZigBee applications is introduced. By using an on-chip third-order active notch filter the proposed IR-LNA can achieve high image-rejection ratio.

Circuit design: The proposed IR-LNA shown in Fig. 1 consists of two parts: the LNA core and the third-order active notch filter. As can be seen from Fig. 1, the LNA core differs by one additional capacitor, $C_{eq}$, in comparison with the conventional inductive degeneration cascode LNA topology. This LNA topology was used to obtain the noise figure equal to the noise figure minimum of the given LNA topology under very low power consumption [3]. In Fig. 1, the DC bias of $M_1$, size of $M_1$ ($W_1$), $C_{eq}$ and $L_2$ are chosen following the design principle of the power-constrained simultaneous noise and input matching technique introduced in [3], and $L_2$ is inserted for the input matching to the signal source impedance of 50 Ω. A simple $L_2$-$C_a$ network is used to match the output impedance of the IR-LNA.

\[ \frac{1}{C_{eq}} = \frac{1}{C_{eq}^{3d}} + \frac{1}{C_f} \]

From (3), the image and wanted signals are located at

\[ f_{im} = \frac{1}{2\pi\sqrt{L_f/C_{eq}}} \]

and

\[ f_{wanted} = \frac{1}{2\pi\sqrt{1/L_f(1/C_a + 1/C_{eq})}} \]

At the image frequency, $Z_{in,filter}$ looking into the filter is minimised such that the entire image signal will be extracted from the original path. Conversely, at the wanted frequency, $Z_{in,filter}$ is maximised such that the wanted signal is not extracted from the original path. As a result, the image signal is suppressed while the wanted signal is not degraded. The proposed IR-LNA is fabricated in a standard 0.18 μm CMOS technology. Fig. 3 shows the microphotograph of the fabricated IR-LNA with a chip area of 0.56 mm².

Measured results: The proposed IR-LNA is optimised for 2.4 GHz ZigBee and a local oscillator signal of 2 GHz for 400 MHz intermediate frequency. Fig. 4 shows the measured S-parameters and NF.
results of the proposed IR-LNA. As can be seen from Fig. 4, the proposed IR-LNA exhibits 12 dB gain, 38 dB image-rejection, 
−18 dB input return loss, −19 dB output return loss, and 1.8 dB NF. Fig. 5 shows the measured third-order nonlinearity (IIP3) of the proposed IR-LNA. For the IIP3 measurement, two tones were applied with equal power levels at 2.4 and 2.41 GHz. As can be seen from Fig. 5, the obtained result of IIP3 is about −3 dBm. The proposed IR-LNA dissipates 0.6 mA from a 1.5 V supply.

Conclusion: An ultra-low-power image rejection LNA is designed for 2.4 GHz ZigBee applications based on 0.18 μm CMOS technology. Using the proposed on-chip third-order active notch filter very high image-rejection ratio is achieved. The IR-LNA exhibits 12 dB gain, 1.8 dB NF, 38 dB image rejection, and −3 dBm IIP3 while dissipating 0.6 mA from a 1.5 V supply.

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References