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A 900-MHz Low-Noise Amplifier with High Tolerance for Noise Degradation due to a Leakage Signal from a Transmitter

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1. Introduction

Since many kinds of wireless systems have been introduced around the world, a desired signal accompanied by various undesired blocking signals is input to a receiver (RX). In the case of an amplifier [1] and a mixer [2], gain, noise and intermodulation performances are degraded by large blocking signals.

In this paper, a 900-MHz low-noise amplifier (LNA) with high tolerance for noise degradation due to a leakage signal from a transmitter (TX) is proposed. Suitable designs of an input matching circuit and a trap circuit are adopted to improve the tolerance for a TX leakage signal.

2. Circuit Design

One of features of the WCDMA transceiver specified by the 3GPP [3] is simultaneous operation of the RX and TX. As shown in Fig. 1, a leakage signal from a TX is always input to an LNA and the NF of the LNA is degraded. The maximum TX signal power specified by the 3GPP is +24 dBm. The leaked power of the TX signal at the input of the LNA, depends on the performance of external elements such as duplexers (DUP) and an antenna (ANT). In this paper, the TX leakage signal power is assumed to be −26 dBm (attenuated by 50 dB) at the input of the LNA.

In the case that only small signals are input to the LNA, it is unnecessary to consider a frequency conversion of noise. However, in the case that a large leakage signal from the TX is input to the LNA, the LNA is operated in nonlinear mode and frequency conversion of noise should be included in the noise figure (NF) [1, 2]. As shown in Fig. 2, adding to the small signal noise at the frequency of f_{RX}, noise at the frequency of $f_{RX} + f_{TX}$ and $f_{RX} - f_{TX}$ is converted to f_{RX}, where f_{RX} is the frequency of the desired RX signal and f_{TX} is the frequency of the TX signal. In [2], frequency conversion noise due to a bias circuit is suppressed by using a trap circuit. In our LNA, the noise due to the bias circuit is very small and frequency conversion noise due to the amplifier itself should be suppressed to improve the NF degradation.

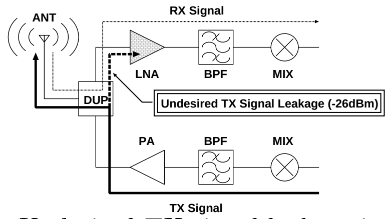

Figure 1: Undesired TX signal leakage in front-end

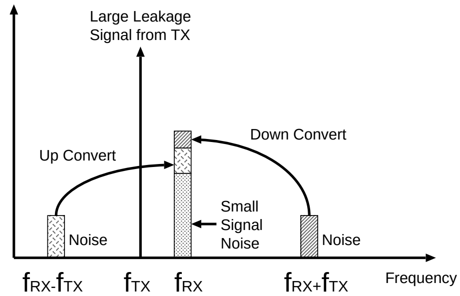

Figure 2: Frequency conversion of noise

Fig. 3 shows equivalent noise sources ($\overline{v_i^2}$ and $\overline{i_i^2}$), an on-chip trap circuit and an off-chip matching circuit. To improve the NF degradation due to the TX signal leakage, frequency converted term of $\overline{v_i^2}$ and $\overline{i_i^2}$ should be suppressed. For exact discussion, the noise optimum signal source impedance (Zs) should be considered, but in the case of our LNA, the noise source of $\overline{i_i^2}$ is dominant. So, design techniques for suppressing the frequency conversion of $\overline{i_i^2}$ are proposed.

As shown in Fig. 3, the trap circuit composed of C1 and L1 is integrated on a chip and resonated at the frequency of $f_{RX} + f_{TX}$. At $f_{RX} + f_{TX}$, the noise current generated by the dominant noise source of $\overline{i_i^2}$ mainly flows to the trap circuit. So, the down converted noise from the frequency of $f_{RX} + f_{TX}$ is suppressed by using on-chip trap circuit.

On the other hand, the up converted noise from the frequency of $f_{RX} - f_{TX}$ is suppressed by using the external capacitor Cx1. A large Cx1 value brings

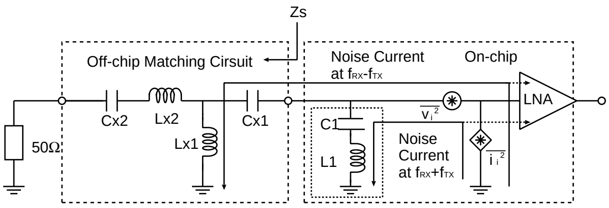

Figure 3: Input matching and trap circuits

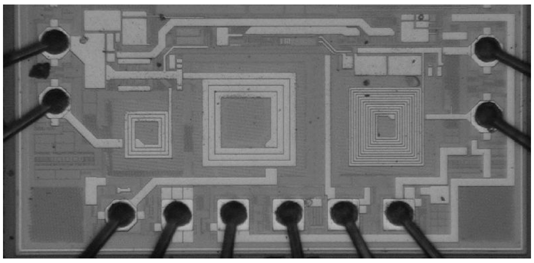

Figure 4: Die photograph of the proposed LNA

Table 1: Summary of measured results

	HG Mode / LG mode
Frequency [MHz]	880
Gain (S_{21}) [dB]	16.8 / −2.97
NF (without TX) [dB]	1.65 / 10.2
Δ NF with TX (HG) [dB]	0.12
Input VSWR	1.57 / 1.73
Output VSWR	1.42 / 1.29
IIP3 [dBm]	−9.47 / −0.90
Supply Voltage [V]	2.9
Current Consumption [mA]	3.0 /1.1

about small Zs, and the noise current generated by the dominant noise source of $\overline{i_i^2}$ mainly flows to the off-chip matching circuit via Cx1. So, the up converted noise from the frequency of $f_{RX} - f_{TX}$ is suppressed by using a large Cx1 value.

Fig. 4 shows die photograph of the proposed LNA fabricated by using SiGe-BiCMOS process with the maximum f_T value of the npn transistors is 75 GHz. The effective chip area including pads is 1500μm × 400μm. The trap and the output matching circuits are integrated on a chip.

3. Measured Results

The LNA is mounted on a plastic package and evaluated with the off-chip matching circuits. Measured results are summarized in Table 1.

Fig. 5 shows measured frequency responses of the gain in both high-gain (HG) and low-gain (LG) modes. At 880 MHz, the gain values are 16.8 dB for the HG mode and −2.97 dB for the LG mode. Owing to the on-chip trap circuit, a notch appears near 1.715 GHz ($f_{RX} + f_{TX}$). The gain values at 1.715 GHz are −20.2 dB for the HG mode and −31.9 dB

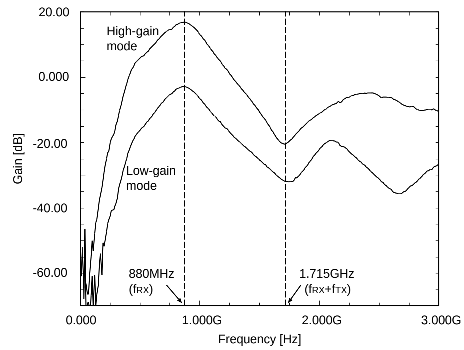

Figure 5: Frequency response of gain

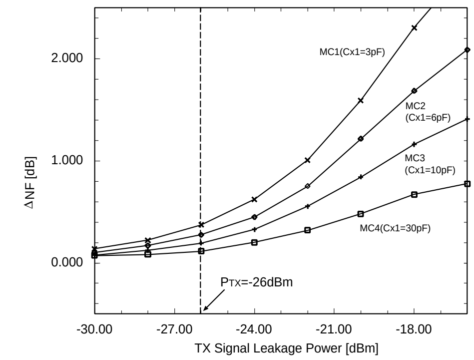

Figure 6: Degradation of NF due to TX leakage

for the LG mode.

Fig. 6 shows measured NF degradation due to the TX signal leakage in the HG mode. At the TX signal leakage power of −26 dBm, the degradation values of the NF are 0.37 dB, 0.28 dB, 0.19 dB and 0.12 dB for using the various matching circuits of MC1, MC2, MC3 and MC4, respectively. Using large Cx1 value, the measured NF degradation due to the TX signal leakage is improved.

4. Conclusion

A 900-MHz LNA with high tolerance for a TX leakage signal is designed and fabricated using SiGe-BiCMOS process. Suitable designs of an input matching circuit and an on-chip trap circuit are adopted to improve the tolerance for leakage signal from the TX. Using the proposed technique, degradation of measured NF due to the leakage signal from the TX is suppressed to only 0.12 dB.

References

[1] R. G. Meyer et al., IEEE JSSC, VOL. 30, NO. 8, pp. 944 - 946, AUGUST, 1995

[2] K. L. Fong et al., IEEE JSSC, VOL. 32, NO. 8, pp. 1166 - 1172, AUGUST, 1997

[3] 3GPP TS 25.101 version 7.2.0 Release 7, http://www.3gpp.org/