A SiGe Low Power RF Front-End Receiver for 5.8GHz Wireless Biomedical Application

Hyunwon Moon

Abstract—It is necessary to realize new biomedical wireless communication systems which send the signals collected from various bio sensors located at human body in order to monitor our health. Also, it should seamlessly connect to the existing wireless communication systems. A 5.8 GHz ISM band low power RF front-end receiver for a biomedical wireless communication system is implemented using a 0.5 μm SiGe BiCMOS process. To achieve low power RF front-end, the current optimization technique for selecting device size is utilized. The implemented low noise amplifier (LNA) shows a power gain of 9.8 dB, a noise figure (NF) of below 1.75 dB, and an IIP3 of higher than 7.5 dBm while current consumption is only 6 mA at supply voltage of 2.5 V. Also, the performance of a down-conversion mixer is measured as a conversion gain of 11 dB and SSB NF of 10 dB.

Keywords—Biomedical, low noise amplifier, mixer, receiver, RF front-end, SiGe.

I. INTRODUCTION

VARIOUS wireless communication systems, such as 2G/3G/LTE cellular, Bluetooth, WiFi, and GPS etc., are widely used in our life [1]-[3]. The data rate transmitted using a wireless communication system has been rapidly increased and many different wireless applications have appeared recently. Also, the demand and need of biomedical applications about the seamless connection to the existing wireless communication networks have been emerged and developed a variety of applications. To seamlessly monitor the status of human body, a lot of different kinds of biosensors are utilized and connected with each other to implement the sensor network.

Power consumption is a very important issue for a biomedical wireless system because it is very difficult to easily replace the battery. Therefore, to implement an efficient sensor network for a biomedical wireless system, the low power RF transceiver is very important because it occupies a large portion of total power consumption. And it should have very low noise performance due to very small amplitude signals acquired from many bio sensors in human body because there are many harmful interference signals in human body due to human activity. To achieve the robust biomedical wireless communication system against many strong blocker signals, the RX font-end, such as an LNA and a down-conversion mixer, is very important block in the overall RF transceiver. And very high current consumption will be required for high linearity characteristic to detect very low level wanted signal against many harmful interference signals.

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In this paper, the low power low noise RX front-end (RXFE) for a 5.8 GHz ISM band receiver is designed utilizing a current optimized technique and implemented using an IBM 0.5 μm SiGe BiCMOS process. The implemented LNA and down-conversion mixer is very appropriate for a biomedical application.

II. RECEIVER ARCHITECTURE

The proposed RF receiver architecture for our 5.8 GHz biomedical communication system is selected as the dual-conversion structure because it shows best performance between sensitivity and selectivity characteristics as shown in Fig. 1 [4]. Although the heterodyne receiver can transfer to the digital baseband modem with a higher signal quality, it should require additional many blocks such as an image rejection filter, 2nd down-conversion mixer, and 2nd IF LO frequency synthesizer etc. To overcome these problems of the general heterodyne receiver architecture, a sliding-IF receiver structure was proposed for using only one voltage-controlled oscillator (VCO) and one phased-locked loop (PLL) to impellent a frequency synthesizer structure [5]. The frequency synthesizer is realized using an integer-N PLL structure because of its simple and low power consumption. Also, the I/Q LO generator block for second down-conversion mixer can be easily implemented by using a frequency divider (÷ 8) of the first LO frequency signal without an additional PLL. So, the first IF frequency is determined as 8/9 ω_{RF} and its frequency is varied according to the RF input frequency. For example, if the RF frequency at the receiver input is 5796 MHz, the first LO frequency is 5152 MHz and IF frequency is 644 MHz as shown in Fig. 1.

Two external SAW filters are used for the wanted band selection and the unwanted image signal rejection. Therefore, the input and output impedance of LNA should be matched at 50 ohm which is the impedance of two external bandpass filters (BPFs). Also, an LNA should have a high gain, low noise, and high linearity performance because it is the first gain stage of the receiver. To meet the requirement of total receiver performance, the target specifications of LNA are determined as a gain of 12 dB, NF of below 2 dB, IIP3 of higher than 0 dBm while its power consumption should be minimized. The first RF down-conversion mixer converts the RF input signal from the LNA to the first IF frequency signal. It has to maintain high linearity performance because the wanted and in-band interference signals amplified from LNA The target specifications of the first RF down-conversion mixer are selected as the conversion gain of 10 dB, single-sideband (SSB) NF of below 10 dB and IIP3 of higher than 3 dBm.
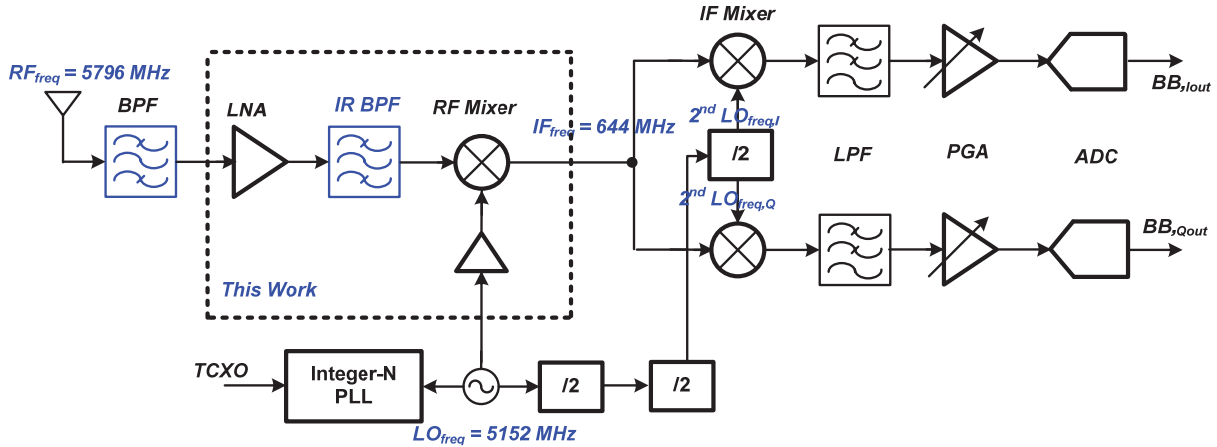
Fig. 1 Block Diagram of receiver architecture for 5.8GHz biomedical wireless communication application

III. DETAIL CIRCUIT DESIGN

A. Selection of Device Size of LNA Core BJT Transistor
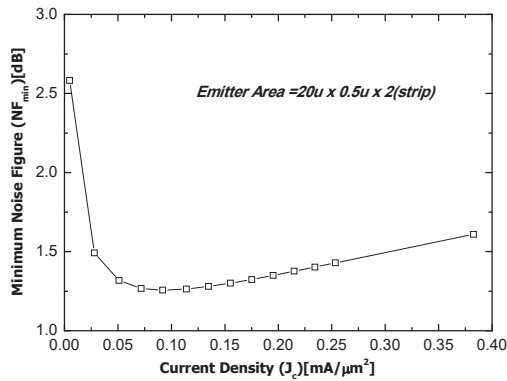
(a) Minimum NF characteristic
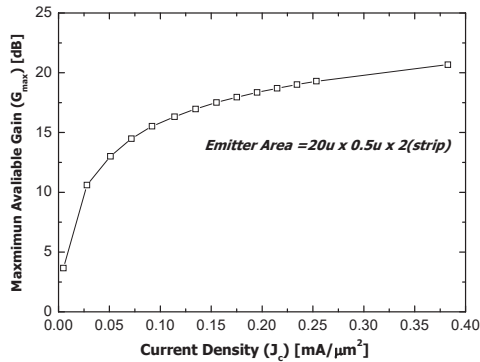
(a) Maximum available gain characteristic

Fig. 2 SiGe BJT device (20 μm x 0.5 μm x 2) characteristic simulation results of NF_{min} and G_{MAG} about a current density

The SiGe BJT transistor size is very carefully determined because its intrinsic noise performance and maximum available gain (MAG) characteristic is very sensitive to its current density [6]. The bias current of LNA core and its transistor size will be chosen to obtain lower NF performance considering the characteristic of the minimum noise figure (NF_{min}) of device according to the bias current. Therefore, the characteristic of LNA core transistor according to the current density should be examined in order to apply current optimization process. Fig. 2 shows the NF_{min} and MAG characteristics about current density of 20 μm emitter size BJT with two strip structure. In general, a BJT with a small emitter size has the lower NF_{min} at low current density. However, at this point it has very small MAG and shows the sharp change about current density. So, the size of LNA core transistor and bias current is selected to obtain wide range NF_{min} and MAG characteristic as shown in Fig. 2.

B. LNA structure

In general, a common-emitter (CE) structure with an inductive degeneration for LNA is widely used because it can easily make input impedance 50 ohm for matching with an external BPF without the degradation of NF performance [7]. So, the LNA circuit structure is selected as cascade structure that shows the best noise performance and enough gain characteristic as shown in Fig. 3. Also, it has excellent stability characteristic due to high isolation between input and output terminals. To reduce silicon area, the wire bonding inductor of a plastic package is used as a degeneration inductor. In order to obtain better linearity and maintain almost constant characteristics against PVT variations, g_m-bias circuit is utilized. Also, the ground shielded pad structure is used to isolate the lossy Si substrate and reduce the effects of a signal pad about NF performance.
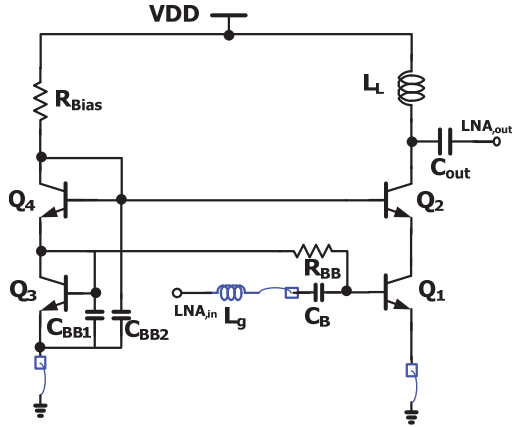
Fig. 3 Schematic of SiGe BJT inductive degenerated cascode LNA
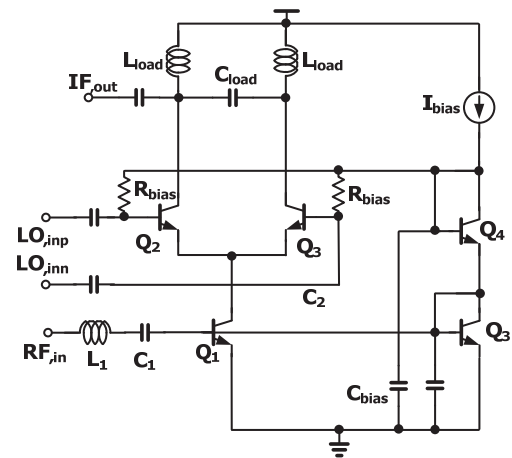with a g_m-bias circuit

Fig. 5 Schematic of LO buffer with balun function

(a) Power gain & NF

Fig. 4 Schematic of single balanced down-conversion mixer with
single-ended output converter

(b) 3rd-order input intercept point (IIP3)

Fig. 6 Measurement results of the implemented LNA

C. Down-Conversion Mixer

A double balanced Gilbert cell structure is commonly used as a RF down-conversion mixer. But, this structure is not a good choice because it requires two times current to maintain fully balanced structure. Also, it shows the higher noise performance than that of single balance structure. Therefore, single balance down-conversion mixer is more suited to the biomedical application for the low power consumption as shown in Fig. 4. The LO signal quality is very important for RF mixer because its signal level and transient characteristic determine NF and linearity performance [8], [9]. In order to improve LO-to-RF isolation characteristic, differential LO signal is produced by LO balun circuit as shown in Fig. 5. The LO balun circuit is composed of a differential amplifier structure and it plays a role of LO buffer amplifier. To maintain the phase difference of 180 degrees between two output signals, the layout of LO balun should be carefully and symmetrically carried out. To transform the differential output of the down-conversion mixer into a single-ended output form, LC output load is used and it also rejects unwanted sideband signal generated by the down-conversion mixer.
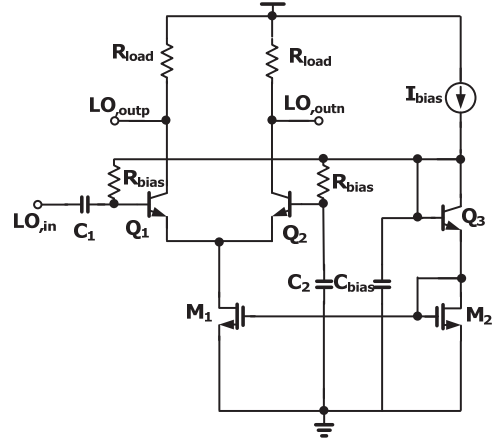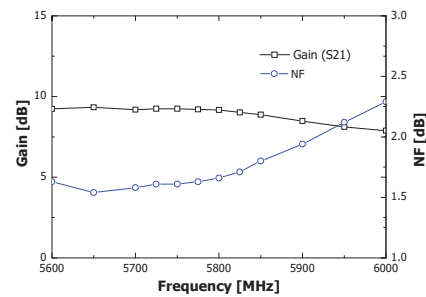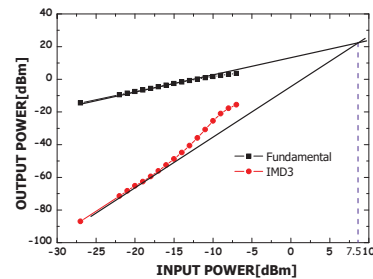
IV. EXPERIMENT RESULTS AND CONCLUSION

A 5.8 GHz current optimized LNA and RF down-conversion mixer for biomedical communication application is designed and implemented using an IBM 0.5 μm SiGe BiCMOS process. The simulation results of the designed LNA are obtained as the signal power gain (S21) of 12.3 dB, NF of 1.77 dB, and the IIP3 of 0.3 dBm with 4.3 mA current flow at 2.5 V power supply. And the performance of a single-balanced RF down-converter shows the conversion gain of 11 dB, the SSB NF of 10.2 dB, and the IIP3 of -7 dBm. The fabricated chip is packaged by a micro lead frame (MLF) type and evaluated. Figs. 6 and 7 show the measurement results of power gain, NF and IIP3 of LNA and RF down-conversion mixer. Also, the performance of RXFE is summarized in Table I.
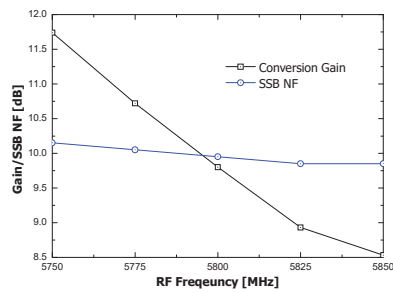
(a) Conversion gain & SSB NF
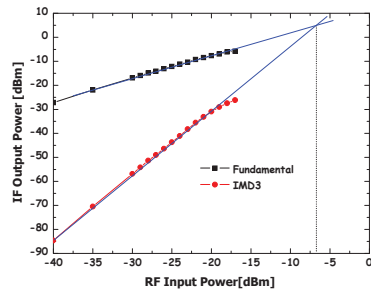
(b) 3rd-order input intercept point (IIP3)

Fig. 7 Measurement results of the implemented RF down-conversion mixer

TABLE I
MEASURED PERFORMANCE SUMMARY

Block	Parameter	Results
LNA	Frequency	5.75 – 5.825 [GHz]
	S11, S22	< -10 [dB]
	S21	9.8 [dB]
	NF	1.72 [dB]
	IIP3	7.5 [dBm]
	Current	6 [mA]
Down-conversion Mixer	Conversion Gain	11 [dB]
	SSB NF	< 10 [dB]
	IIP3	-7 [dBm]
	Current	14 [mA]

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