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Short Communication

2.4 GHZ HETERODYNE RECEIVER FOR HEALTHCARE APPLICATION

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ABSTRACT

Objective: The objective of this research was to design a basic 2.4 GHz heterodyne receiver for healthcare on a 130 um CMOS process. The ultimate goal for the wireless industry is to minimize the trade-offs between performance and cost, and between performance and low power consumption design.

Methods: In the first part, a low noise amplifier (LNA), which is commonly used as the first stage of a receiver, is introduced and simulated. LNA performance greatly affects the overall receiver performance. The LNA was designed at the 2.4 GHz ISM band, using the cascode with an inductive degeneration topology. The second part of this proposal presents a low power 2.4 GHz down conversion Gilbert Cell mixer. In the third part, a high-performance LC-tank CMOS VCO was designed at 2.4 GHz. The design uses using PMOS cross-coupled topology with the varactor for wider tuning range topology.

Results: In the first part, a low noise amplifier (LNA) design reached the NF of 2 dB, had power consumption of 2.2 mW, and had a gain of 20dB. The second part of this proposal presented a low power 2.4 GHz down conversion Gilbert Cell mixer. The obtained result showed a conversion gain of 14.6 dB and power consumption of 8.2 mW at a 1.3V supply voltage. In the third part, a high-performance LC-tank CMOS VCO was designed at 2.4 GHz. The final simulation of the phase noise was-128 dBc/Hz, and the tuning range was 2.3 GHz-2.5 GHz while the total power consumption was 3.25 mW.

Conclusion: The performance of the receiver meets the specification requirements of the desired standard.

Keywords: LNA, Healthcare, VCO, mixer, Heterodyne receiver

Currently, remote monitoring applications are extremely important mobile technologies, because they can detect and prevent the illness. Thus, they could reduce hospital readmission rates, saving hospital resources. Remote monitoring systems help patients effectively be aware of their physical conditions, and commute more efficiently get in touch with their physicians [1].

Fig. 1 shows that the basic sensing unit can collect physiological signals (e. g.: such as EEG, ECG, body temperature, pressure etc.), blood when individual sensors are attached to the human body [2]. The processing unit processes all the sensed signals, then processes all the data based on the communication protocols. All the processed data will be transmitted through a wireless link to a portable personal base-station.

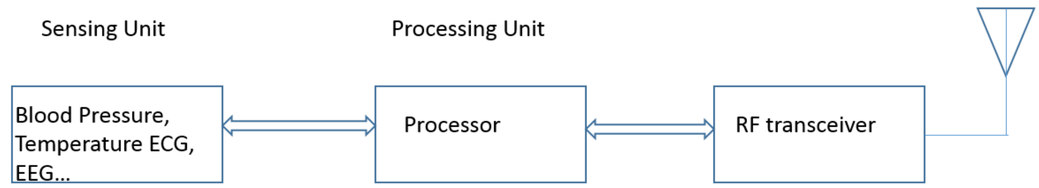


Fig. 1: Block diagram of a typical sensor node

The main challenge of such remote monitoring systems is the high power consumption of portable devices. A solution to this challenge is the integration of the portable devices' digital part and the RF part onto one chip.

When the transmitter sends out the data, the receiver will pick up the signal and will perform DSP processing [2]. The requirement of this transmitter and receiver is that both should have low power. For the front-end receiver, the major objectives are 1) receiving the RF signals and 2) recovering the biosignal classification. This paper proposes a low power receiver design. This system can be used in wireless ECG acquisition systems. In order to meet the standards, the system is designed as shown in table 1.

Table 1: System design requirement

	NF	Gain	Power
LNA	3dB	15dB	<5 mW
Mixer	16dB	5dB	<10m W
VCO	Oscillation Freq	Phase Noise	Power
	2.4GHz	-100dBc/Hz	<5 m W

The objective of this research is to build a 2.4 GHz Heterodyne receiver, which consists of an LNA, a mixer and a VCO.

In this proposal, LNAs use cascode inductor degeneration topology, mixers use gilbert cells, and VCOs use LC tank topologies. All of these components use 2.4 GHz. First, the LNA has a cascode topology and an input matching network with a series inductor to achieve a high gain of the LNA. This is shown by our simulation, which consumes only 1.7 mA with a 1.3 V power supply and achieves a gain of 20 dB and NF of 1.9 dB.

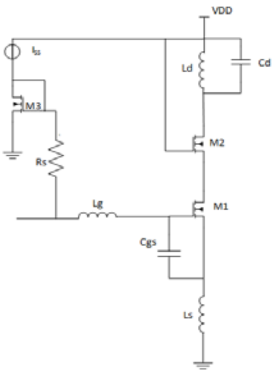


Fig. 2: 2.4GHz LNA design schematic design

Second, the mixer is a double balanced active mixer using gilbert cell topology, which has a high conservation gain. Again, our simulation results show that the mixer consumes only 6.3 mA with a 1.3 V power supply and achieves a gain of 5 dB and NF of 15 dB. Lastly, the VCO has a cross-coupled PMOS pair to achieve negative resistance, and it has a LC tank which be use to reach a resonant frequency of 2.4 GHz. Simulation results show that, the VCO consumes only 2.5 mA with a 1.3 V power supply and achieves a phase noise of-129 dBc/Hz, KVCO is around 3 MHz/V.

The detailed value can be referred as table 2.

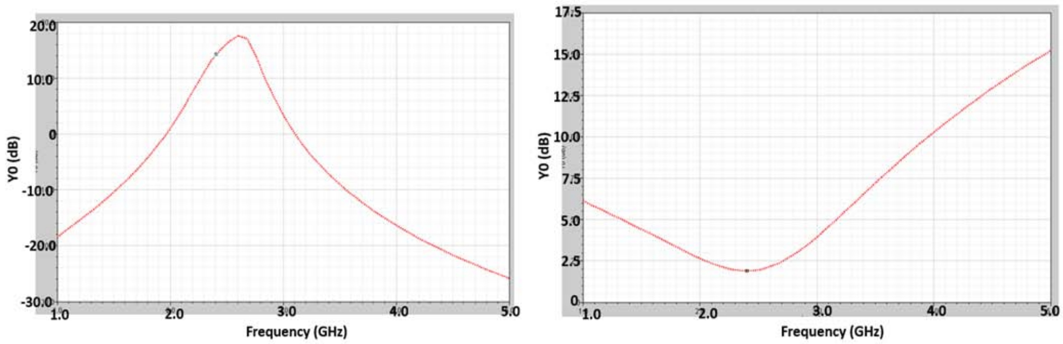
Table 2: 2.4GHz LNA component

Parameter	Size (Unit)
M1,M2	W/l=10um/180um
M3	W/l=10um/180um
L_s	500 pH(Q=20)
L_g	30 pH(Q=20)
L_d	8 nH(Q=20)
C_{gs}	120 fF
C_d	440 fF
R_s	10K

In fig. 2, there is a cascode common-source with inductive degeneration [4]. The M1 and M2 consisted of cascode opamp and the tank circuit consisted of by C_d and L_d. The transistor M3 was used for amplifier biasing. The purpose of inductors L_g, L_s and capacitor C_{gs} was to match to the 50 input. The degeneration inductor L_s had better linearity at the cost of lower gain for linearity. R_s was used to isolate the RF biasing signals. Other capacitors were used to block DC signals.

As seen in fig. 3 (a), the gain is 15. As seen in fig. 3(b), the NF in is around 1.9 dB at 2.4 GHz, and that the major contribution of the noise is from M1 and Ls, also, the total power of the LNA is 2.2 mW.

As seen in fig.4, the frequency is at 2.4 GHz the S11 is less than-10 dB. Kf is larger than 1 for all frequencies from 1 to 5 GHz, so this circuit is totally stable.



(a) (b)

Fig. 3: (a) Gain plot (b) Noise figure

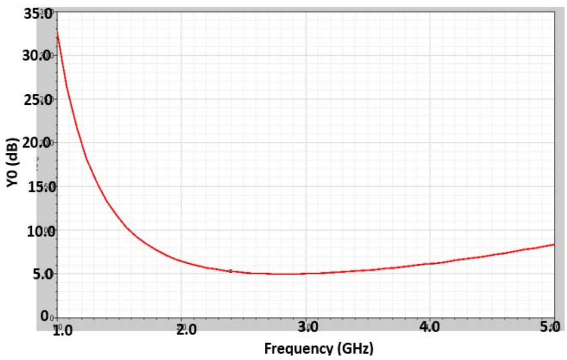


Fig. 4: LNA Kf simulation

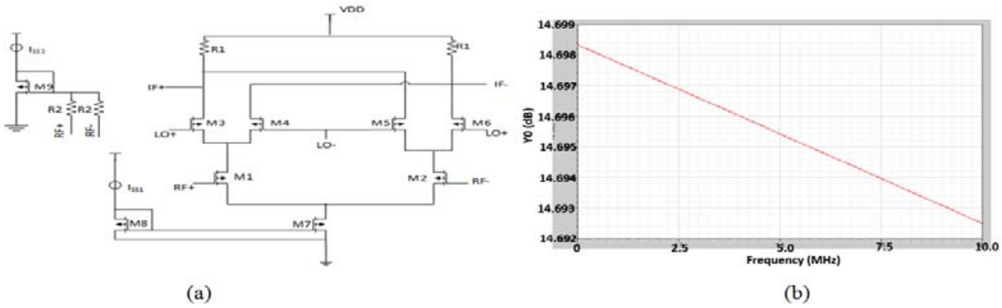


Fig. 5: (a) 2.4 GHz gilbert mixer schematic (b) Mixer NF

Gilbert mixer, as seen in fig. 5 (a), provides good port-to-port isolation with some conversion gain [4]. The M1 and M2 are the input stages operating in the saturation region.

LO signals need to make the M3, M4, M5 and M6 transistors full switch, which means which transistor M3 M5 and M4 M6 are turning on alternately. In other words, LO signals must be kept at an appropriate large magnitude to ensure transistors switching accurately. Linearity is the greatly contributed decided by the trans-conductance stage.

The transistors components values can be seen in table 3.

Table 3: 2.4GHz mixer component

Parameter	Size (Unit)
M1,M2,M3,M4,M5,M6	W/l=10um/180um
M7	W/l=60um/180um
M8	W/l=30um/180um
M9	W/l=12um/180um
R_1	5K
R_2	3K

As seen fig. 5 (b), based on the PSS simulation, the conversion gain VS RF power at 2.4 GHz is 14.6 dB. Also, NF is 15dB while the power consumption is 8.2 mW.

The VCO schematic as shown in fig. 6 (a) was chosen for several reasons. The PMOS pair determines the oscillation amplitude of this structure, which would also be beneficial to the low phase noise.

The cross-coupled MOS pair would get a negative resistance as shown in fig.6 (a). The negative resistance cancels the LC element's parasitic resistance [6]. The transistor value can be seen in table 4.

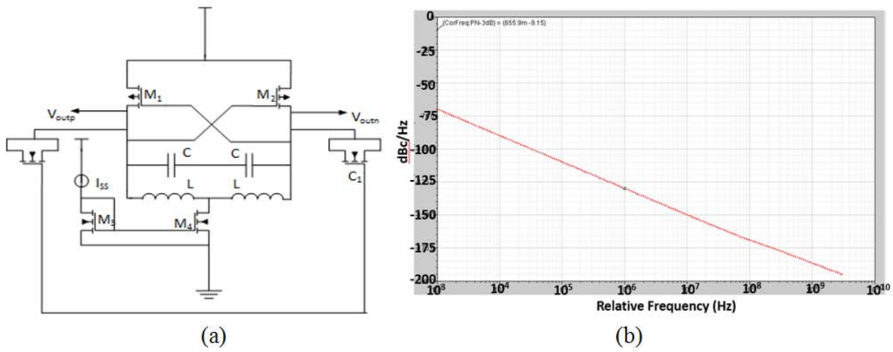


Fig. 6: (a) 2.4 GHz VCO schematic (b) VCO phase noise

Table 4: 2.4GHz VCO component

Parameter	Size (Unit)
M1,M2	W/l=10um/130um
M3,M4,M5,M6	W/l=1um/180um
M7	W/l=4um/180um
C	30 fF (Q=20)
L	8 nH (Q=20)
C1	W/l=10um/130um

The oscillation frequency is around 2.4 GHz. As we can see fig.6 (b) phase noise at 1 MHz offset frequency is 129 dBc/Hz, the major noise source is the current source and the two differential pair. For simulation results at [7].

In hospital healthcare, the monitoring system can help doctors to monitor the patient's physiological parameters. Using proposed technology, a pregnant woman can be checked for such parameters as Blood Pressure (BP) and heart rate of the woman and heart rate and movements of fetal to control their health condition. In her proposed system, a coordinator node can be attached to a patient's body to collect all the signals from the wireless sensors and sends them to the base station. The attached sensors on a patient's body form a wireless body sensor network and they are able to sense the heart rate, blood pressure and so on. The main advantage of this system in comparison to previous systems is to reduce the energy consumption to prolong the network lifetime, speed up and extend the communication coverage to increase the freedom for enhance patient quality of life. Patients can reduce the cost of staying hospital, and doctors can monitor patients' conditions at any time. Thus, poor people can receive better healthcare, and do not have to worry about money.

CONFLICT OF INTERESTS

Declared none

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