A transmitter front-end design for 5GHz WLAN applications

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Abstract

Up-conversion mixer and driver amplifier for 802.11a Wireless LAN application are designed and fabricated on 0.18• • CMOS technology. The proposed up-conversion mixer adopts source degeneration transconductance stage to control the conversion gain, and driver amplifier uses cascode topology to control the gain and linearity. The fabricated up-mixer shows –6 ~ 10 dB of conversion gain and –18.5 dBm of OP_{-1dB} at 10 dB gain, and the driver amplifier shows –8 ~ 8 dB of power gain and 2 dBm of OP_{-1dB} at 6 dB gain. The up-mixer and the driver amplifier consume 12mA and 9mA from 1.8 V supply, respectively.

1. Introduction

In the last few years, there have been strong demands for the mobility and convenience of wireless communications network. Commodities based on IEEE 802.11a WLAN standard are under active research and development. With the advent of short channel technology, CMOS becomes an attractive solution for 5GHz range applications. Currently, many researchers are going on to integrate all the transceiver blocks into a single chip to reduce the cost and complexity [1], [2], [3]. In this paper, integrated double balanced up-conversion mixer and driver amplifier with variable gain are presented.

2. Up-conversion mixer Design

A mixer is an indispensable component in wireless system for frequency conversion. The major three aspects of mixer design are conversion gain, noise figure, and linearity. In the transmitter, the conversion gain and linearity are the major two parameters to concern, when designing the front-end blocks. For high conversion gain and linearity, normally large amounts of DC currents in the transconductance stage are required.

There are two types of mixer: active and passive mixer. Passive mixer has high linearity and high noise figure. Active mixer is categorized into balanced and unbalanced structure. For this research, double-balanced active mixer topology is adopted for low local oscillator (LO) signal leakage.

Fig. 1 (a) shows a double balanced mixer with source degeneration. The mixer is divided into three sections: transconductance stage, time-variant switching pair and radio frequency (RF) section. In the transconductance stage, differential amplifier with source degeneration converts the input voltage to current that is multiplied by a square wave generated by the switching pair [4], [5]. Fig. 1 (b) shows differential amplifier with composite p-MOS type source degeneration. With this topology, transconductance of composite p-MOS is increased to $g_m = g_{mp}(1+g_{mn}r_o)$ [6], [7]. Transconductances of Fig. 1 (a) and (b) can be expressed as, respectively.

$$G_{ma} = \frac{g_{mn1}}{1+g_{mn1}R_S} \quad \text{and} \quad G_{mb} = \frac{2g_{mn5}g_{mp1}r_{o1}}{1+2g_{mn5}g_{mp1}r_{o1}r_{ds7}}$$

$$\left(r_{ds7} = \frac{1}{\beta_{p7}(V_{SG7}-V_{TP7})}\right) \qquad (1)$$

From equation (1), variable gain can be achieved by changing the value of V_{ctrl} due to r_{ds7} dependence on V_{ctrl}.

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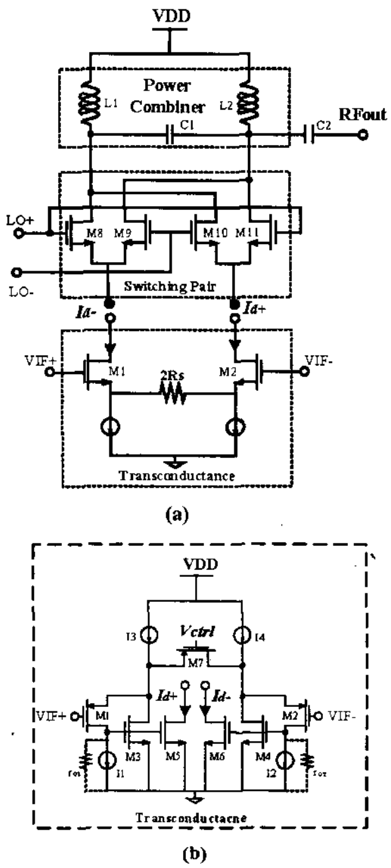


Fig. 1. (a) Double balanced mixer with source degeneration transconductance stage (b) Variable gain transconductance stage

3. Driver amplifier Design

Driver amplifier precedes power amplifier that is the final stage of RF transmitter. To make it possible for power amplifier to transmit high power through antenna, driver amplifier should have high gain and linearity [4]. This paper presents one stage driver amplifier with cascode topology. Fig. 2 (a) shows the driver amplifier. Variable gain can be obtained, by controlling V_{ctrl}. As the basic operating principle for CMOS transistor suggests, CMOS have high linearity with low gain in linear region and low linearity with high gain in saturation region.

When V_{ctrl} is in high-level state, input transistor M1 stays in saturation region, and high gain can be obtainable. On this condition, when the input signal is low, the distortion component at the output is low with respect to output signal because the input power is far away from IIP3 point. On the contrary, when the input signal is high and V_{ctrl} is in low-level state, the input transistor M1 stays in linear region, and low gain with low distortion can be achieved. [8]

Fig.2 (b) and (c) shows the gain characteristics of proposed driver amplifier with respect to V_{ctrl}. When V_{ctrl} is in low-level state, M1 is in linear region. On the contrary, when V_{ctrl} is in high-level state, M1 is in saturation region. For both cases M2 stays in saturation region.

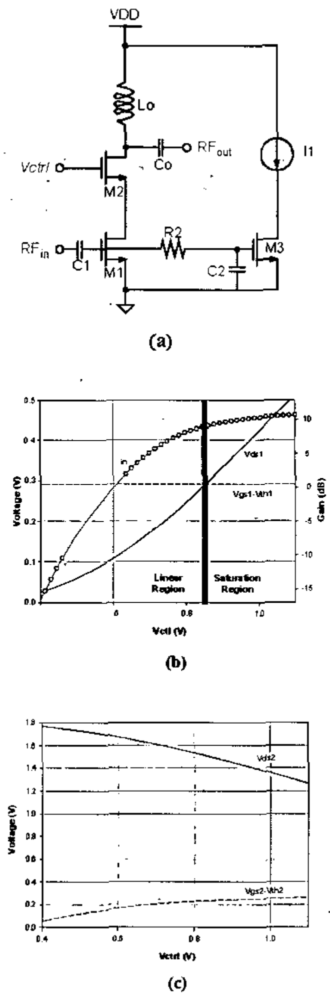


Fig. 2. (a) Schematic of driver amplifier with variable gain (b) Simulation result of gain with respect to V_{ctrl} (c) Simulation result of Vds2, Vod2 with respect to V_{ctrl}

4. Experimental Results

The up-mixer and driver amplifier are fabricated on 0.18• •CMOS technology. The chip microphotographs are shown in Fig. 3. For differential input of baseband (BB) and LO signal, transformer and ring type balun are used. The BB, LO and RF frequencies are 5MHz, 5.25GHz and 5.255GHz, respectively.

Fig. 4 shows the variable gain range for each block. For the up-mixer, as the control voltage increases, r_{ds7} increases, G_{mb} decreases and thereby the gain decreases. But for the driver amplifier, as the control voltage increases, g_m increases, and thereby the gain decreases.

Fig. 5 shows the gain compression characteristics for each block. Table.1 shows the measurement summary for up-mixer and driver amplifier.

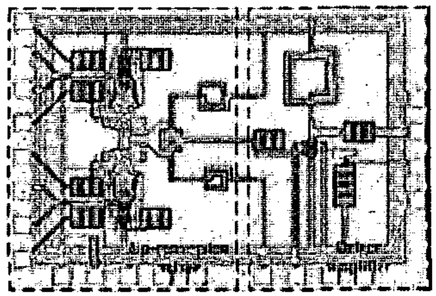
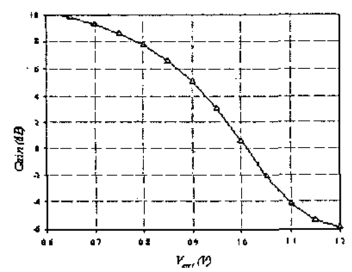
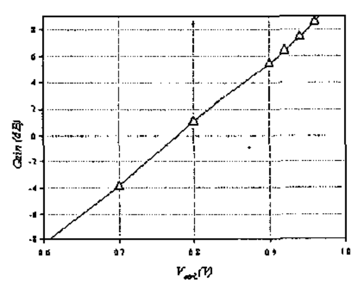


Fig. 3. Chip microphotograph of the fabricated transmitter

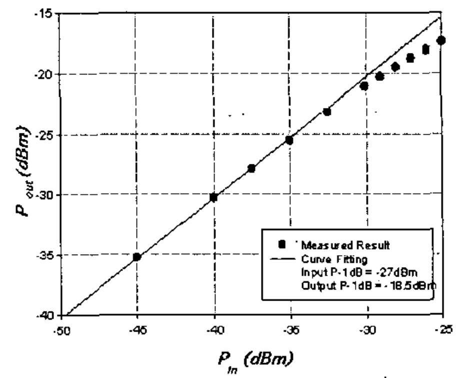


(a)

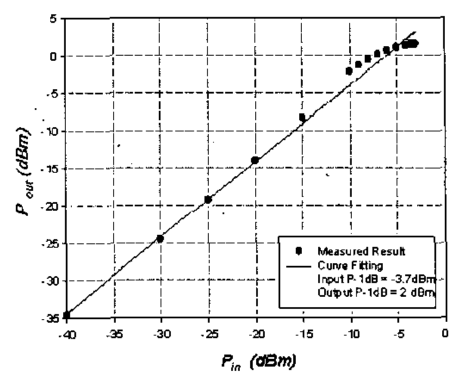


(b)

Fig. 4. (a) Variable gain characteristics of up-mixer (b) Variable gain characteristics of driver-amplifier



(a)



(b)

Fig. 5. (a) P_{-1dB} characteristics of up-mixer (b) P_{-1dB} characteristics of driver amplifier

Table 1. Measured Performance summary

Parameter	Up-Mixer	Driver Amplifier
VDD	1.8 V	1.8 V
Current Consumption	12 mA	9 mA
Gain	-6 ~ 10 dB	-8 ~ 8 dB
OP_{-1dB}	-18.5 dBm (at Gain 10dB)	2 dBm (at Gain 6dB)
LO-to-RF Isolation	40 dB	-

5. Conclusions

Variable gain up-mixer and driver amplifier which operate in the frequency range of 5.15 ~ 5.35 GHz are designed. The mixer includes source degeneration transconductance stage to control the conversion gain, and driver amplifier uses cascode topology to control the gain and linearity.

The fabricated up-mixer shows -6 ~ 10 dB of conversion gain and -18.5 dBm of OP_{-1dB} at 10 dB gain, and the driver amplifier shows -8 ~ 8 dB of power gain and 2 dBm of OP_{-1dB} at 6 dB gain.

References

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