Chapter 9
The Design of Ultra Low Power RF CMOS LNA in Nanometer Technology

Kavyashree P.
UTL Technologies Ltd., India
Siva S. Yellampalli
UTL Technologies Ltd., India

ABSTRACT

In this chapter, an ultra low power CMOS Common Gate LNA (CGLNA) with a Capacitive Cross-Coupled \( g_m \) boosting scheme is designed and analysed. The technique described has been employed in literature to reduce the Noise Figure (NF) and power dissipation. In this work we have extended the concept for low voltage operation along with improving NF and also for significant reduction in current consumption. A \( g_m \) boosted CCC-CGLNA is implemented in 90nm CMOS technology. It has a gain of 9.9dB and a noise figure of 0.87dB at 2.4GHz ISM band and consumes less power (0.5mw) from 0.6V supply voltage. The designed \( g_m \) boosted CCC-CGLNA is suitable for low power application in CMOS technologies.

INTRODUCTION

The IEEE 802.15.4 standard was specially designed to cater for the fundamental lower network layers of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices (Oh & Lee, 2005). The emphasis is on very low cost communication of nearby devices with low power consumption and little to no underlying infrastructure. The concept of IEEE 802.15.4 standard is to provide communications over distances up to about 10 meters and with maximum transfer data rates of 250 kbps. Low power consumption has been the centre of attention for this technology. In the context of mobile wireless applications, lower power consumption can lead to longer battery life or in another word longer time over which a mobile device can be used without having to recharge. The IEEE 802.15.4 frequency bands align with the license free radio bands that are available around the globe. Of the bands available, the 2.4 GHz band is the most widely used in view of the fact

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that it is available globally and this brings many economies of scale. Figure 1 shows the generic radio frequency (RF) mobile receiver.

The generic RF receiver consists of antenna, low noise amplifier (LNA), mixer, local oscillator, low pass filter and a data converter. From the Figure 1 it is seen that LNA is the first active amplification block in the receiving path. Being the first block of the receiver, the LNA plays a crucial role in amplifying the received signal while adding little noise to it. In addition, the input of the LNA needs to be matched to the output of the filter following the antenna to prevent the incoming signal from reflecting back and forth between the LNA and the antenna. While the LNA is a relatively simple design compared to other RF components in a cellular receiver chain, the performance tradeoffs challenge the LNA design engineer. LNA design typically involves making choices between directly competing performance parameters such as: noise, gain, linearity and power consumption. In the IEEE 802.15.4 standard, the noise figure (NF) and linearity requirement can be relaxed in order to achieve other important parameters such as gain and power consumption.

In this chapter we develop a thorough understanding of low-power LNA design and introduce to new ultra low power LNA design for IEEE 802.15.4 standard. The LNA is optimized for low noise figure and low power consumption.

1. TOPOLOGIES OF CMOS LNA

In Low noise amplification, two topologies are widely adopted: common source amplifier with inductive degeneration and common gate amplifier (Lee, 1998).

1.1 Common Source LNA (CSLNA)

The variable resistive input impedance can be achieved by adding an inductance in series with the source of the MOSFET to degenerate the common source amplifier as shown in Figure 2 and its small signal model is shown in Figure 3.

1.1.1 Input Impedance of CSLNA

It is instructive to calculate the input impedance looking into gate of MOSFET when its source is degenerated by inductor Ls. The input impedance of CSLNA is

\[
Z_{in} = \frac{V_{in}}{I_{in}} = SL_s + \frac{1}{SC_{gs}} + \left( \frac{g_m}{C_{gs}} \right) L_s
\]