NOISE ANALYSIS FOR LOW NOISE AMPLIFIER

By

Mai Mostafa Goda Ghareeb

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Communications Engineering

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Title of Thesis:

Noise analysis for low noise amplifier

Key Words:
Low noise amplifier; Global system for mobile communication; Global positioning system; Wireless local area network; Radio Frequency.

Summary:
The Low Noise Amplifier (LNA) is the first block in the receiver chain and is used to amplify the weak Radio Frequency (RF) signal arriving from external antenna, duplexer switch, and band select filter. To minimize the various noise contributions of the amplifier circuits, the noise source needs to be carefully analyzed and subsequently optimized. As wireless products such as cellular phones, Global System for Mobile communications (GSM), Global Positioning Satellite (GPS), Wireless Local Area Network (WLAN) ...etc become an everyday part of people's lives. The need for high performance at low cost and low power consumption becomes even more important in addition to the size of the wireless device.
The objective of the thesis is to enhance the performance of Salama and Soliman Low Voltage Low Power (LVLP) CMOS RF LNA circuit using 90 nm Complementary Metal Oxide Semiconductor (CMOS) technology.
And studying the wideband Balun-LNA with different topologies for different application then propose a new design to boost the gain with a moderate Noise Figure (NF) to cover a wideband frequency range from 3 GHz to 10 GHz .

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Nomenclature

Abbreviations:

ADS	Advanced Design System
Balun	Balanced-Unbalanced
CG	Common-Gate
CS	Common-Source
CMOS	Complementary Metal Oxide Semiconductor
dB	Decibel
DC	Direct Current
FCC	Federal Communication Commission
GSM	Global System for Mobile Communication
GPS	Global Positioning Satellite
IC	Integrated Circuit
ISM	Instrumentation, Scientific and Medical
LNA	Low Noise Amplifier
LO	Local Oscillator
LVLP	Low Voltage Low Power
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
NF	Noise Figure
OFDM	Orthogonal Frequency Division Multiplexing
Q	Quality Factor
RF	Radio Frequency
SNR	Signal to Noise Ratio
SID	Source Inductive Degeneration
UWB	Ultra Wide Band
UNII	Unlicensed National Information Infrastructure
WLAN	Wireless Local Area Network
WPAN	Wireless personal Area Network
WMTS	Wireless Medical Telemetry Service

Abstract

The Low Noise Amplifier (LNA) is the first block in the receiver chain and is used to amplify the weak Radio Frequency (RF) signal arriving from external antenna, duplexer switch, and band select filter. The main goals of designing LNA circuit are minimizing the NF, providing sufficient gain and linearity and providing a 50Ω input impedance to terminate the transmission line delivers signal from the antenna to the amplifier.

To minimize the various noise contributions of the amplifier circuits, the noise source needs to be carefully analyzed and subsequently optimized. As wireless products such as cellular phones, Global System for Mobile communications (GSM), Global Positioning Satellite (GPS), Wireless Local Area Network (WLAN) ...etc become an everyday part of people's lives. The need for higher performance at low cost and low power consumption becomes even more important in addition to the size of the wireless device [**1**].

As the first active stage of receivers, LNAs play a critical role in the overall performance and their design is governed by a trade-off among the following parameters.

1) Power Dissipation

2) Noise Figure

3) Linearity

4) Gain

5) Bandwidth

6) Input Matching (antenna-LNA matching)

Doing the analysis for the proposed circuits and calculate the gain, the input referred noise and the Noise Figure (NF) trying to minimize the NF as much as possible to achieve higher performance for the overall design then studying the S-parameter for each design to know the incident, reflected power and the power loss in order to achieve good matching and enhance it by adding an inductor. The objective of the thesis is to get better performance of Salama and Soliman Low Voltage Low Power (LVLP) CMOS RF LNA circuit using 90 nm CMOS technology. Studying different designs of a wideband Balun-LNA for many applications then achieve a new design to boost the gain with a moderate NF for a wideband frequency range from 3 GHz to 10 GHz.

Chapter 1 : Introduction

The high-speed wireless communication systems development puts growing request on integrated low-cost RF devices with multi-GHz bandwidth which operate at the lowest power consumption and supply voltage. The main block in designing broadband receivers for multiband wireless communication standards is the wideband LNA [**2**]. Still the challenge in designing CMOS RF front end circuit is to provide high performance, low cost, low power consumption [**3**], [**4**]. Today the present goal is to reduce the power consumption, which leads to an increase in the battery-use time and in cost as well [**5**].

1.1 RF design is challenging

In spite of many decades of work on RF and microwave theory and two decades of research on RF Integrated Circuits (ICs), the design and implementation of RF circuits and transceivers remain challenging. Because of three reasons:

First, as shown in Figure 1-1, RF design depends on a multitude of disciplines, which requires a good understanding of fields that are seemingly irrelevant to integrated circuits. Most of these fields have been under studying for more than half a century, presenting a massive body of knowledge to a person entering RF IC design.

Second, the persistent need for higher performance, lower cost and greater functionality continues to present new challenges. The early RF IC design work in the 1990s struggled to integrate one transceiver, perhaps along with the digital baseband processor, on a single chip.

Third, RF circuits and transceivers must deal with plentiful trade-offs, summarized in the “RF design hexagon” of Figure 1-2. For example, consuming a greater power or scarifying linearity is a must to lower the noise of a front-end amplifier.

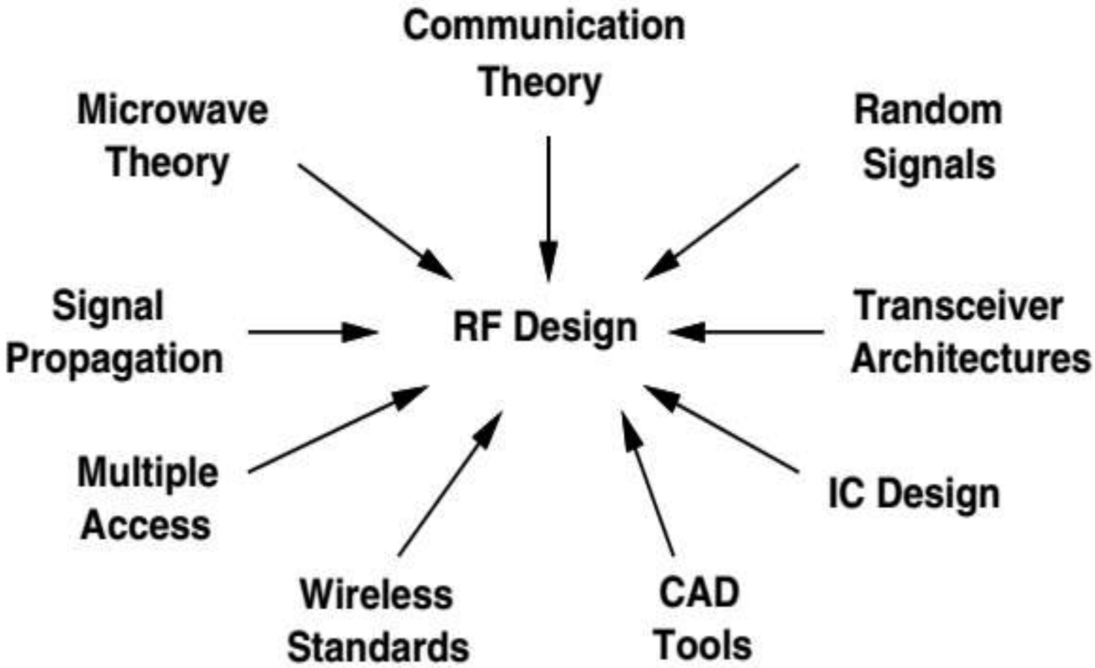

Figure 1-1: Various disciplines necessary in RF design [1].

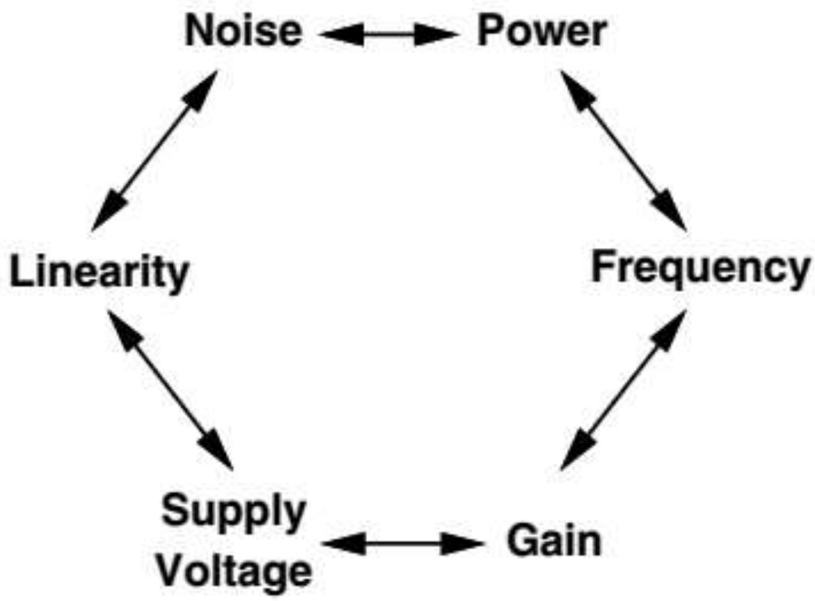

Figure 1-2: RF design hexagon [1].

1.2 Receivers Architectures

A transmitter, a receiver and a communication channel, in which the transmitted signals propagate, are the main blocks of a communication system. In the case of wireless systems, the information sent by the transmitter is involved in a RF signal via a modulation process, i.e. by varying at least one of the signal's characteristics (amplitude, frequency or phase). Once signal arrives at the receiver, the information needs to be recovered from the original RF signal through a demodulation process. The communication medium, mainly air (in the case of wireless communications), is not ideal since the signals received are usually very weak (~ microvolts) and are liable to suffer interference from other, possibly stronger, signals. So it is important to be capable of eliminating unwanted signals and isolating the signal of interest, so that it can be subsequently amplified and converted to baseband to go through demodulation, permitting the information contained in the signal to be recovered.

To carry more information in a signal, the signals are converted to high frequency for transmission and then converted back for the baseband for reception. The size of the antenna is also depends on the frequency of the transmitted signal. As the size is typically proportional to the wavelength of the signal, the required antennas are smaller. Unfortunately, the effect of parasitics (impedances, capacitors, etc.) is higher at high frequencies.

1.3 Signal propagation

1.3.1 Impedance matching

Impedance Matching was originally developed for electrical power, but can be applied to any other field where a form of energy (not necessarily electrical) is transferred between a source and a load. The first impedance matching concept in RF domain was related to antenna matching. Designing an antenna can be seen as matching the free space to a transmitter or a receiver.

The main objective of impedance matching is to match two different terminations (R_{source} and R_{load}) through a specific pass-band, without having control over stop-band frequencies. We may assume that component losses are negligible but parasitic effects need to be considered.The main role in any impedance matching scheme is to force a load impedance to be similar to the complex conjugate of the source impedance, and maximum power can be transferred to the load.