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Comparative study of Noise Figure for recent Ultra-Wideband 45-nm CMOS Low-Noise Amplifiers (LNAs)

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Abstract: At receiving front end, the low noise amplifier design, being the first building block to receive the signal puts a tremendous challenge on modern day radio frequency engineers to meet real world problems involving trade-off in design issues. In this paper the recent trends for noise figure are streamlined in concurrence to Ultra Wide Band (UWB) radio transmission spectrum. A comparative study is made between design of single-stage differential low-noise amplifier and inductor-less broadband LNAs in a digital 45 nm CMOS technology.

Keywords: Low noise amplifier (LNA), WLAN, Bluetooth, noise, gain, topology, ADS, CADENCE.

I. INTRODUCTION

The field of radio frequency analog signal processing is presently going under renaissance, given the fact that radio frequency operations have become a part and parcel of day to day human life, not only influencing the life style, thinking process but also explosively growing into the new fields of research, development and new frontiers of excellence. Radio frequency integrated circuit design using CMOS is entirely different from conventional radio frequency integrated circuit design. As radio frequency consumer market is growing at a very fast pace, low noise amplifiers are poised to be the research area. UWB being precisely operational at low emission levels such as device peripherals, handhelds, a UWB system extend only for indoor applications. Ultra-wide band wireless radios send short signal pulses over a broad spectrum. For example, a UWB signal centered at 5 GHz. The wide signal allows UWB to commonly support high wireless data rates of 480 Mbps up to 1.6 Gbps at distances up to a few meters. At longer distances, UWB data rates drop considerably. The very first stage of a receiver is a low-noise amplifier (LNA), whose main function is to provide enough gain to overcome the noise. Aside from providing this gain while adding as little noise as possible, an LNA should accommodate large signals without distortion and frequently must also present specific impedance, such as 50 ohms to the input source [1].

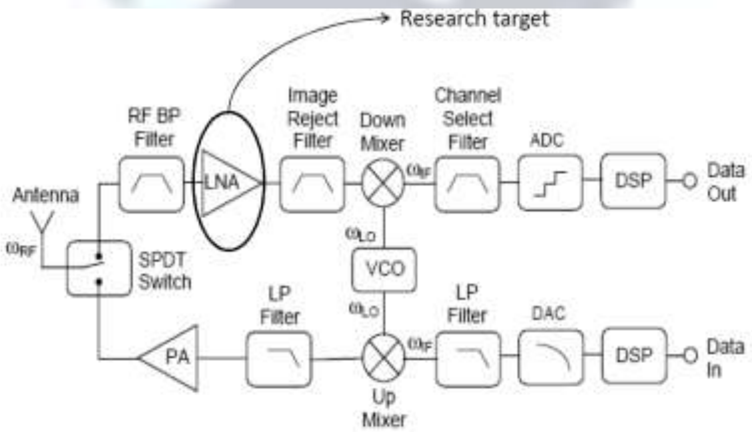

Fig. 1: Block diagram of IF trans-receiver

The power gain, noise figure for a receiver is dominated by the power gain, noise figure provided by LNA. The LNA is a non-linear characteristic device causes two main problems one is blocking and other is inter-modulation [2]. Low noise amplifier is use to reduce the external as well as internal noise. An amplifier will not only amplify the signal but also amplify the noise as well. So amplifier with minimum noise addition is required.

A. Bluetooth

It is a low-cost low-power technology for wireless personal area networks (WPANs), and is commonly used in hands free.

Table I. Summary of Bluetooth IEEE 802.15 specifications [3].

Parameter	Value
Frequency	2402-2480 MHz
Channel spacing	1 MHz
Number of channels	79
Multiple access method	Frequency hop (1.6K hops/s)
Duplex method	TDD
Users per channel	200(7 active)
Modulation	GFSK
Symbol rate	1 MS/s

II. DESIGN TRADE-OFFS

The design of a low noise amplifier revolves around six design trade-offs.

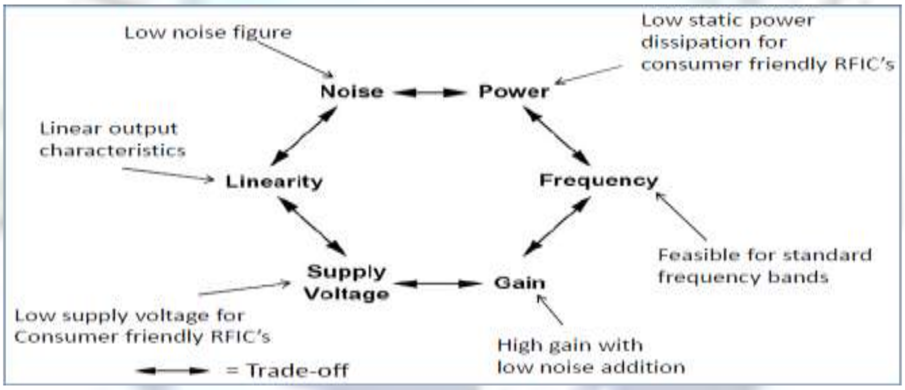

Fig. 2: Design trade-offs for LNA

The design trade-offs gives a clear view about the amount of complexities involved in designing a LNA which includes the choice of operating frequency which depends upon the application, the amount of external as well as internal noise added by LNA taking the amount of power dissipation and gain into consideration [4]. The power supplied and biasing provided depends upon the nano-meter (nm) technology used along with the range for which the LNA provides linear operation. The above discussed trade- offs are repeatedly simulated and emulated for the desired response varying for varying applications for which design of LNA is sought [5].

III. LNA OPERATING FREQUENCY

The foremost is the determination of the frequency spectrum for which the design of LNA is sought.

Table II. Microwave frequency allocations according to IEEE [4]

Band	L	S	C	X	Ku
Frequency range	.8-2 GHz	2-4 GHz	4-8 GHz	8-12 GHz	12-18 GHz
Band	K	Ka	V	W	C, X band used for present work.
Frequency range	18-27 GHz	27-40 GHz	40-75 GHz	75-110 GHz	

The C and X bands have been intensively used for mobile and wireless communications and are the area of interest for this paper. Radio frequency (RF) range- 3 KHz to 300 GHz. Microwave is the subset of the RF range [6]. RF covers 3 Hz to 300 Hz while microwave occupies the higher frequency at 300MHz to 300 GHz.

IV. GAIN-BANDWIDTH TRADE-OFF FOR NOISE FIGURE FOR UWB LNA DESIGN

The recent process technologies revolve around 0.13µm, 0.18µm, 0.35µm, 45nm, 65nm, 90nm CMOS and SiGe BiCMOS. The present work revolves about 45nm process technology.

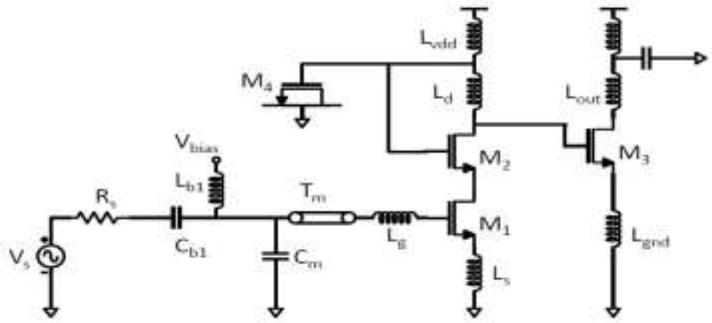

Fig. 3: Circuit schematic of UWB LNA

The foremost requirement for a consumerable design for LNA is the minimum noise figure for the amplifier. The insight study for Gain-Bandwidth trade-off for Ultra-Wideband 45-nm CMOS Low-Noise Amplifiers (LNAs), two state-of-the-art CMOS technologies, a planar bulk one and a SOI FinFET one, featuring 45-nm minimum gate length are considered and compared as follows:

Table III: Gain-Bandwidth trade-off for Ultra-Wideband 45-nm CMOS Low-Noise Amplifiers.

Process Technology	BW (-3 dB) [GHz]	Matching [GHz]	NF [dB] average	Power [mW]
45nm [7]	2.5-12.0	< - 15 dB	5.3	1.5
45nm [7]	2.8-12.0	< -17 dB	5.6	5.3
45nm [7]	2.3-9.8	< - 18 dB	5.7	1.5
45nm [7]	2.5-9.6	< - 15 dB	5.9	5.3
45nm [8]	10.0	0.2 – 8.0	-	32.0
45nm [8]	10.1	3.0 – 8.5	-	30.6

Ponton et al [7] deals with the design of single-stage differential low-noise amplifiers for ultra-wideband (UWB) applications while comparing state-of-the-art planar bulk and silicon-on-insulator (SOI) FinFET CMOS technologies for 45-nm gate length. A. Bevilacqua et al [8] uses shunt-shunt resistive feedback used to design inductorless broadband LNAs in a digital 45 nm CMOS technology give 18 dB gain over a 10 GHz bandwidth. When the work of Ponton et al. and A. Bevilacqua et al we find superior cutoff frequency of planar devices in the inversion region, which allows the achievement of noise figure and voltage gain comparable to the FinFET counterpart, with a smaller power consumption. As we move from inductor less impedance to capacitive impedance, the noise figure decreases in decibel scale which is a significant development when low noise amplifiers are operated for UWB frequency spectrum.

V. CONCLUSION AND FUTURE WORK

The present work provides a sightful guide for various facets involved in design of a low noise amplifier for UWB. Future work involves selection and concretization of various parameters into a simulation model to evolve prospective design stategies for LNAs.

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