A 5.4-9.2 GHz 19.5 dB CMOS UWB Receiver Frontend Low Noise Amplifier for **Confocal Imaging System**

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1. Introduction

Ultra-wide-band (UWB) wireless communication in 3.1-10.6 GHz is essential for confocal imaging in breast cancer detection [1]. For this application, receiver frontend low noise amplifier (LNA) is an important component because the sensitivity and the bit error rate of the UWB signal transmission depends on the quality of LNA. This work presents a UWB CMOS LNA for wireless communication in 5.4-9.2 GHz bandwidth. A wideband 50 Ω matching circuit was designed at the input of LNA with reduced number of elements to match antenna. 3-stage cascade LNA was designed for improving gain [2-5]. In this paper we demonstrate a wireless communication of Gaussian monocycle pulse (GMP) by horn antennas and LNA. This work also gives the measured noise figure (NF) and the third order input intercept point (IIP3) of the LNA.

2. Low Noise Amplifier and Experimental Setup

Figure 1 shows a die photograph of a differential ended LNA using 180 nm CMOS technology on a standard Si substrate with the resistivity of 10 Ω ·cm. Figure 2(a) shows a schematic diagram of a 3.7 mm² 3-stage differential-ended LNA including a 50 Ω two section reactive networks to get the wideband match with an off-chip antenna. A cascode topology with shunt peaking inductive load has been designed to improve the gain and reverse isolation of LNA. Each stage of LNA contains different size of cascode MOS transistors to raise the gain in the wide bandwidth. A buffer circuit (Fig.2(b)) of passive elements is added after LNA for 50 Ω output impedance matching with measurement equipment.

Figure 3 shows a schematic of 'on wafer' measurement setup for measuring S-parameters, NF and IIP3 of the LNA in a single connection using N5242A PNA-X Vector Network Analyzer (VNA). Noise source and power sensor were used for the calibration of NF and IIP3 measurements, respectively. An Ecal module was used to get variable matching with VNA and input of LNA around 50 Ω to get a very accurate NF. Figure 4 shows the measurement setup for wireless communication of GMP using horn antennas and LNA. 3 cascade impulse forming networks (IFN) were used in order to get the 3rd order derivative of rectangular pulse so that the center frequency of GMP can be increased. A low k (k=1.03) interposer was also placed between the PCB and metal stage of measurement setup.

3. Results and Discussion

Figure 5 shows the measured transmission co-efficient S_{21} and NF of the LNA. The measured maximum value of transmission coefficient, S21, of the LNA is 19.5 dB at 7.4 GHz. The 3 dB bandwidth (BW) is from 5.4 to 9.2 GHz. On the same figure, the measured NF of the LNA has been shown which is less than 5 dB from 4 to 9 GHz, while the minimum value of NF is 3.5 dB from 5.5 to 7 GHz. The input reflection coefficient, S_{11} of LNA, shown in Fig. 6, is < -10 dB from 4.5 to 9.3 GHz. Also Fig.6 shows the output reflection coefficient, S₂₂, which is less than -10 dB from 6-7 GHz. By improving buffer characteristics, it is possible to get wideband S₂₂ and higher S₂₁. However, buffer is not necessary, for an operation of system on chip where LNA will be connected directly with the next stage mixer [4]. Measured input impedance, Z₁₁ of the LNA, is shown in Fig.7, which has absolute value of 50 -70 Ω -105from 4 -10 GHz. Fig.8 shows the measured output power, Pout of fundamental signal and 3rd order intermodulation signal as a function of input power, Pin. The measured value of IIP3 of LNA comes -3 dBm at 7 GHz.

Figure 9(a) shows generated GMP wave form which was directly input to the LNA. A peak-to-peak voltage (Vpp) was 27 mV and pulse width was 0.5 ns. The center frequency of the GMP was 5 GHz. The signal was amplified to a peak-to-peak 104 mV by the LNA (Fig.9(b)).

Figure 10 shows the normalized voltage gain versus frequency of LNA which has a center frequency, Fc at 7 GHz. This figure also shows the normalized values of Fast Fourier Transform (FFT) of generated GMP to the input of LNA and the FFT of the amplified output of LNA. The FFT of LNA output contains 2 peaks around 5 and 7.3 GHz, which correspond to the center frequencies of generated GMP and LNA, respectively. The ringing occurred at the end of the amplified GMP as shown in fig.9(b). It is attributed to the differences in center frequencies of generated GMP, LNA and voltage gain of LNA around 5GHz.

Figure 11 shows the received and amplified time domain GMP signal for wireless communication with horn antennas and LNA at a distance of 20 cm. The V_{pp} comes 208 mV after reception and amplification. The performance of the LNA has been shown in the Table-1, comparing with other works in UWB range. This work shows highest power gain in the specified 5.4-9.2 GHz BW with highest IIP3 at 7GHz.

4. Conclusion

A CMOS low noise amplifier has been presented having 19.5 dB gain with 3 dB bandwidth of 5.4 to 9.2 GHz. The measured minimum noise figure of LNA is 3.5 dB and IIP3 is -3 dBm@7 GHz. A wireless communication of GMP has been demonstrated using horn antennas and the LNA. The measured result gives V_{pp} of 208 mV after reception and amplification at a transmission distance of 20 cm.

	TW	[2]	[3]	[4]	[5]
F _c [GHz]	7.3	4.25	6	3	5.2
S ₂₁ [dB]	19.5*	26	10.4	14 **	12.4
BW [GHz]	5.4-9.2	3.5-4.5	2.4-9.5	.1-6	.4-10
NF [dB]	3.5	4+	4.2	4	4.4
IIP3 [dBm]	-3@7G		-8.8@6G		-6@6G
Power [mW]	59.4	59.4	9	16	12
Supply volt [V]	1.8	1.8	1.8	1.2	1.8
Architecture	Diff	diff	Sin	diff	Sin
Technology	0.18µm	0.18µm	0.18µm	.13µm	.18µm

Table-1. Performance Comparison

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References

*with buffer **without buffer *Simulation

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Fig. 1 Chip Photograph of 3-stage cascade differential ended amplifier on 180 nm Technology.



Rf. Measuremen $R_{L5} \lesssim$ Equipment R₄ $R_{L3} \gtrsim$ R_{L4} ${}^{\circ}_{0}L_{L6}$ R LI3 Lisg C_4 L Rf C_{de} M1 M3 (b) M5. M7 M9∠ L_{G2} C_d C_{d6} L_{GI} Off-chip ത്ത M2 000 M4 / Balun M6 M8≰ M10 M12 Rf_{in} gL2 **Rx** Horn graf I R3 antenna V_{b1} V_{b3} I/P Matching Circuit (a) Fig. 2 Schematic diagram of Circuits. (a) Differential ended LNA. (b) Buffer circuit.



by antenna and LNA. IFN=Impulse Forming Network; Amp=Power Amplifier

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Fig.3 Setup for the measurement of S-parameters of differential amplifier.





1.2

Normalized FFT, Normalized LNA output voltage 70 90 80 80



Frequency(GHz)

--- Normalized FFT

of LNA o/p

of i/p GMP

voltage o/p

·Nor malized FFT

Normalized LNA



VDD

R_{L6}

Rf_{qu}

M11







0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Frequency (GHz)

100



Fig. 11 Received and amplified GM Pulse at the end of LNA in a wireless communication by off-chip antenna at 20 cm distance.