

A 22FDX CMOS Feedback-Cascode UWB LNA for IEEE 802.15.4z Automotive Applications

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Abstract— This paper presents the design and post-layout evaluation of a low-noise amplifier (LNA) for ultra-wideband (UWB) automotive applications based on the IEEE 802.15.4z standard. The proposed circuit is implemented in GlobalFoundries 22FDX technology and targets the frequency range between channels 5 and 9 of the standard, from 6.5 to 8 GHz. The LNA adopts a feedback-cascode topology. Post-layout simulations show a power gain between 13.1 and 14.1 dB, a noise figure from 2.63 to 2.99 dB, and input matching below -10 dB across the target band, with a power consumption of approximately 2.7 mW. The circuit also achieves an input 1-dB compression point of -14.1 dBm and an input third-order intercept point of -3 dBm at 7.3 GHz. Process, supply-voltage, temperature, and Monte Carlo analyses are performed to assess the robustness of the design under automotive operating conditions. Compared with state-of-the-art LNAs in 22-nm and 28-nm technologies, the proposed design provides a competitive trade-off between gain, noise figure, linearity, and power consumption, while maintaining a compact single-stage architecture suitable for future IEEE 802.15.4z UWB receiver integration.

Index Terms— Automotive applications, IEEE 802.15.4z, GF 22FDX, low-noise amplifier (LNA), UWB.

I. INTRODUCTION

Ultra-wideband (UWB) technology has become a key enabler for short-range wireless systems requiring accurate positioning, low power consumption, and high robustness against multipath propagation. In automotive applications, UWB is especially attractive for secure vehicle access, digital key systems, in-cabin presence detection, and precise ranging [1]. In these cases, a reliable receiver front-end capable of operating under demanding environmental conditions while maintaining low noise, adequate gain, and reduced power consumption is required.

The IEEE 802.15.4z standard has further strengthened the role of UWB in secure and accurate ranging applications by introducing improvements in the physical layer and ranging protocols [2]–[4]. In particular, channels 5 and 9 are widely adopted in commercial and automotive solutions. Therefore, receiver circuits targeting a frequency range around 6.5–8 GHz are of particular interest for practical IEEE 802.15.4z implementations.

The low-noise amplifier (LNA) is one of the most critical blocks in the UWB receiver chain, since it directly affects the overall receiver sensitivity. Its design involves several trade-offs between gain, noise figure, input and output matching, linearity, stability, area, and power consumption. These trade-offs become more challenging in wideband operation, where the LNA must maintain acceptable performance over a broad frequency range instead of a single narrowband operating point. In addition, automotive applications impose further constraints, including operation over process variations and a wide temperature range [5].

Several CMOS and SOI LNAs have been reported for wideband, 5G, 6G, and FR3 applications, achieving competitive

gain and noise performance. However, many of these works are not specifically optimized for IEEE 802.15.4z automotive UWB operation, or they focus on broader frequency ranges and higher power consumption [6]–[9]. Moreover, only a limited number of reported designs combine low-power operation, advanced 22-nm-class technologies [10]–[14], post-layout validation and robustness analysis under automotive-oriented process, supply-voltage and temperature conditions.

This work presents a low-power UWB LNA implemented in GlobalFoundries 22FDX technology and targeting the 6.5–8 GHz frequency range associated with IEEE 802.15.4z channels 5 to 9. The proposed circuit is based on a feedback-cascode topology with input and output matching networks and a resistive-capacitive feedback path. Post-layout simulations show a gain of 13.1–14.1 dB, a noise figure of 2.63–2.99 dB, input matching below -10 dB across the target band and a power consumption of approximately 2.7 mW. The design is also evaluated under process corners, temperature variations, supply-voltage deviations and Monte Carlo simulations.

This paper is organized as follows. Section II summarizes the automotive requirements considered in this work. Section III presents the feedback-cascode LNA architecture and the design methodology followed. Section IV discusses the layout implementation and post-layout simulation results. Section V compares the proposed LNA with the state of the art. Finally, Section VI concludes the paper.

II. REQUIREMENTS AND AUTOMOTIVE DESIGN TARGETS

This work targets the frequency range between channels 5 and 9 of the IEEE 802.15.4z standard, approximately from 6.5 to 8 GHz. This range is widely used in commercial UWB solutions for consumer, IoT and automotive applications, including devices from Qorvo, NXP, Samsung, and Apple [15]–[18].

From the receiver perspective, the LNA must provide sufficient gain, low noise figure, good input and output matching and low power consumption across the target band. Since the circuit is intended for automotive operation, its performance is evaluated under process variations and a temperature range from -40 °C to 150 °C. In addition, supply-voltage variations of ± 10 % are considered as a robustness check. Monte Carlo simulations are also performed to assess the statistical sensitivity of the circuit to device and component mismatch.

III. PROPOSED LNA ARCHITECTURE AND DESIGN METHODOLOGY

A. LNA Architecture

The proposed LNA is implemented in GlobalFoundries 22FDX, a 22-nm FD-SOI CMOS technology suitable for RF and low-power applications due to its reduced parasitic capacitances, improved isolation, and availability of RF-optimized active and passive devices.

Fig. 1 shows the schematic of the proposed LNA. The circuit is based on a single-stage feedback-cascode topology composed of an input matching network, a cascode amplification core, a resistive-capacitive feedback path, an output matching network, a biasing current mirror and supply decoupling capacitors. The cascode core is implemented using super-low-voltage-threshold NFET devices, selected to provide suitable RF performance and low-noise operation in the target band.

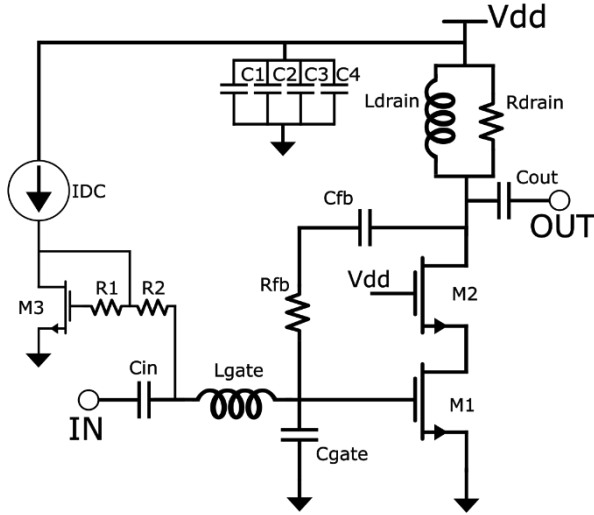


Fig. 1. Single-stage feedback-cascode LNA

The input matching network is formed by the inductor L_{gate} and the capacitors C_{gate} and C_{in} . This network is designed to provide 50Ω input matching while keeping the noise figure as low as possible across the 6.5–8 GHz band. The resistive-capacitive feedback path, implemented with R_{fb} and C_{fb} , contributes to broadband impedance matching and helps boost the gain across the frequency range.

At the output, the matching network is composed of the drain resistor R_{drain} , the inductor L_{drain} , and the output capacitor C_{out} . The drain resistor provides a broadband load, while the reactive elements are adjusted to improve the output matching and maintain sufficient gain. The complete circuit also includes a current mirror for bias generation and decoupling capacitors on the supply line.

B. Design Methodology

The design methodology starts with the selection of the bias point for low-noise operation. The input transistor is biased close to the current density that minimizes the noise figure, while a current mirror is used to define the operating current of the LNA. This step establishes the initial trade-off between the noise figure, gain, and power consumption. Fig. 2 shows the bias current sweep for different M1 widths. A drain current of 3 mA was selected for the cascode branch. The bias current is generated by a current mirror that operates with a reference current of $100 \mu A$.

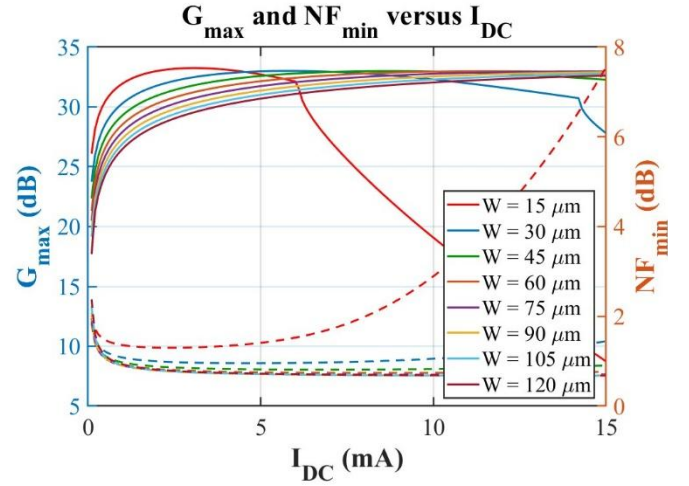


Fig. 2. Bias current selection

After the bias condition is fixed, the input matching, feedback, and output matching networks are initially adjusted using ideal passive components. Then, ideal passive elements are replaced by real components from the 22FDX PDK, including integrated inductors, APMOM capacitors, and resistors. Since these components have finite quality factors, series losses, parasitic capacitances, and layout-related constraints, the circuit is readjusted after the PDK replacement. Fig. 3 shows the nominal schematic simulation results of the adapted LNA. Under nominal conditions, the circuit achieves a gain between 17 and 17.4 dB, a noise figure from 2.62 to 2.97 dB, and both S_{11} and S_{22} below -10 dB across the 6.5–8 GHz band. The power consumption is approximately 2.8 mW.

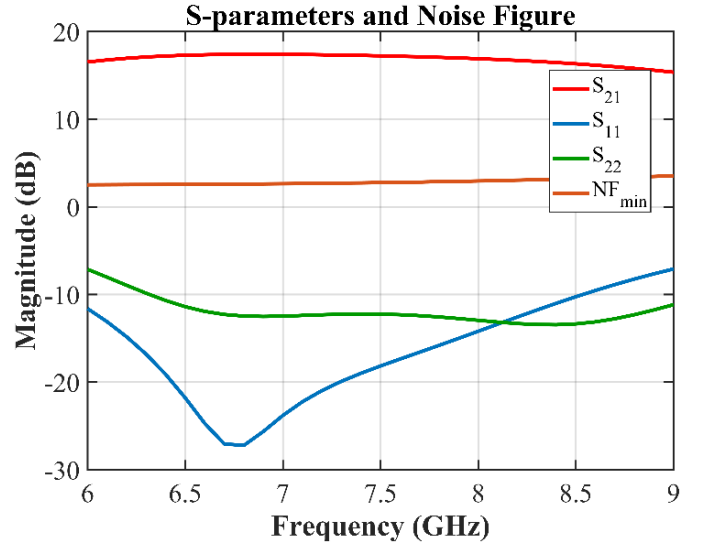


Fig. 3. Nominal schematic simulation results of the adapted PDK-based LNA

IV. LAYOUT AND POST-LAYOUT RESULTS

Fig. 4 shows the complete layout of the proposed LNA. The core dimensions are approximately 300x400 μm .

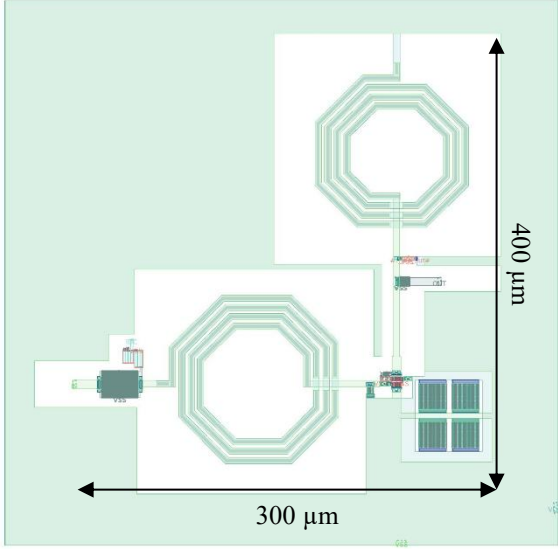


Fig. 4. Layout of the proposed feedback-cascode UWB LNA

Fig. 5 shows the nominal post-layout simulation results. Across the 6.5–8 GHz target band, the LNA achieves a gain between 13.1 and 14.1 dB and a noise figure between 2.63 and 2.99 dB. The input matching remains below -10 dB over the complete frequency range, while the output matching shows some degradation at the beginning of the band. The circuit consumes approximately 2.7 mW under nominal operating conditions.

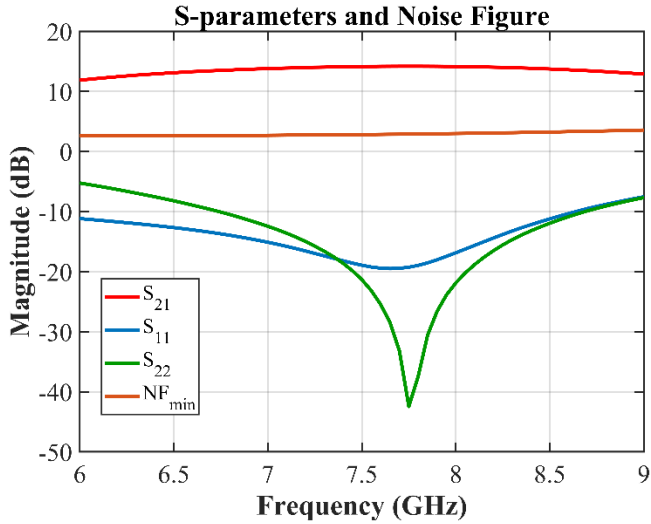


Fig. 5. Nominal post-layout simulation results of the proposed LNA

The linearity of the post-layout LNA was evaluated at 7.3 GHz. The extracted circuit achieves an Input $P_{1\text{dB}}$ compression point of -14.1 dBm [Fig. 6(a)]. In addition, the simulated IIP3 and OIP3 are -3 dBm and 11 dBm, respectively [Fig. 6(b)]. These results indicate that the proposed LNA provides adequate linearity for the targeted UWB receiver front-end while maintaining low power consumption.

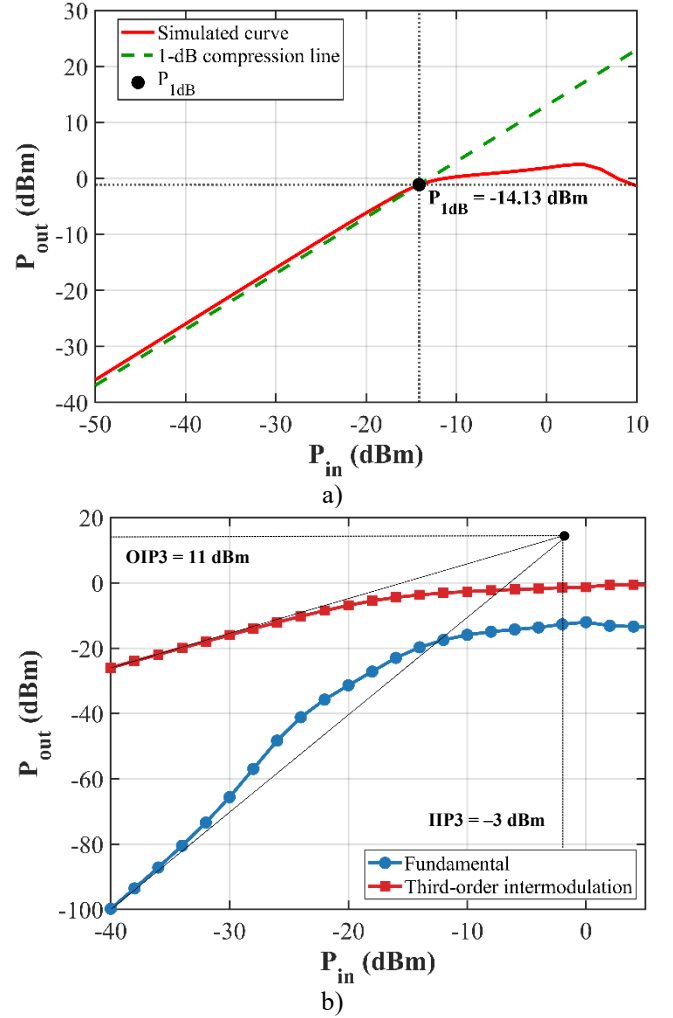


Fig. 6. Post-layout linearity results: a) $P_{1\text{dB}}$ and b) IP3

The robustness of the layout design was evaluated through corner simulations. Fig. 7 shows the post-layout results under the SS, FF, SF and FS process corners, evaluated at -40 $^{\circ}\text{C}$ and 150 $^{\circ}\text{C}$, including a $\pm 10\%$ supply-voltage variation.

Across all evaluated cases, the gain remains between 12.1 and 14.8 dB over the 6.5–8 GHz band, showing little dispersion with respect to the nominal post-layout response. The noise figure curves are mainly grouped according to temperature. The lowest NF values are obtained at -40 $^{\circ}\text{C}$, while the highest values correspond to 150 $^{\circ}\text{C}$, due to the increase of thermal noise with temperature. Process and supply-voltage variations introduce smaller deviations within each temperature group. The input matching remains acceptable in all corners, with S_{11} between -29 and -11 dB, thus staying below the -10 dB target across the complete band. In contrast, the output matching is the most sensitive parameter after layout extraction, with S_{22} ranging from -50 to -7.6 dB. The worst S_{22} values occur at the lower edge of the band, around 6.5 GHz, where corner cases exceed the -10 dB target, but are accepted because it is mainly limited to the lower edge of the band.

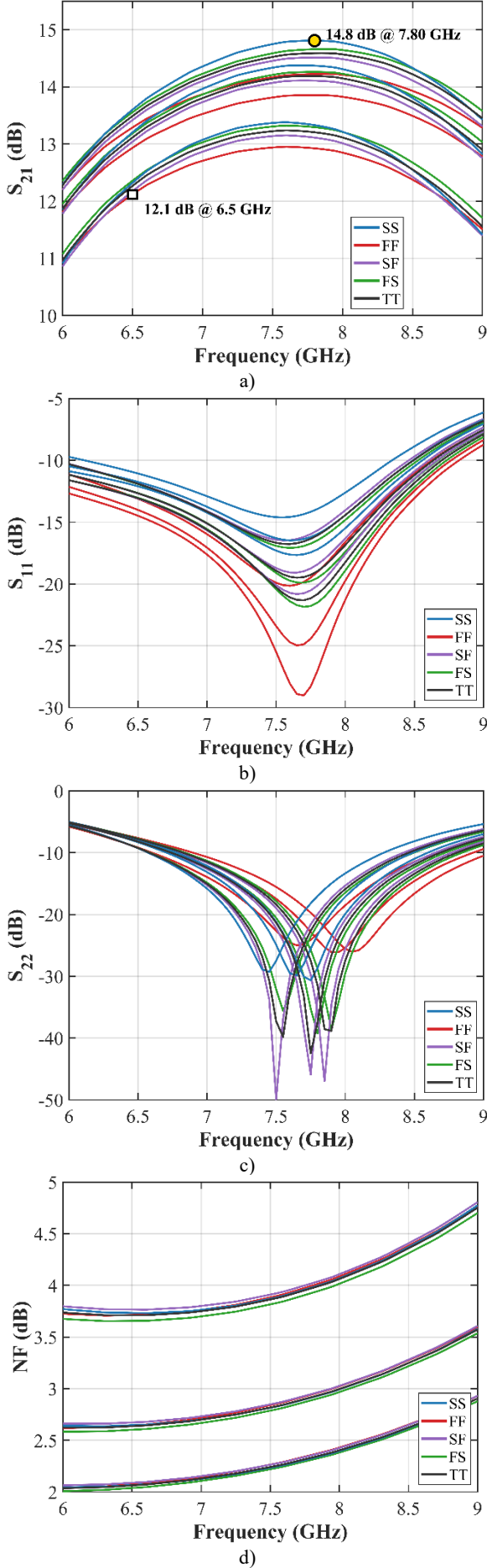


Fig. 7. Post-layout corner simulation results: a) S_{21} , b) S_{11} , c) S_{22} and d) NF

Monte Carlo simulations were also performed after layout extraction in order to evaluate the statistical sensitivity of the circuit. A total of 1000 samples were considered to assess the variability of the main RF performance parameters.

Table I shows the resulting dispersion of the main RF metrics, including gain, noise figure, input matching, output matching, and power consumption. The Monte Carlo results confirm that the proposed architecture maintains stable behavior around the nominal response, with limited dispersion in the main performance parameters.

Table I
Montecarlo Simulation Results

Metric	Minimum (-3σ)	Average	Maximum ($+3\sigma$)	σ
S_{21} (dB)	12.5	13.5	14.8	0.2
NF (dB)	2.55	2.75	3.09	0.28
S_{11} (dB)	-20.3	-16	-11.4	0.8
S_{22} (dB)	-29	-15.3	-7.7	1
Power (mW)	2.2	2.7	3.2	0.2

The final post-layout results demonstrate that the proposed LNA remains fully functional under all evaluated conditions. Despite the performance dispersion introduced by process variations, temperature extremes, supply-voltage deviations and mismatch, the circuit preserves the key requirements across the complete 6.5–8 GHz band. In particular, the LNA maintains a usable gain level, a competitive noise figure, and robust input matching in all simulated scenarios.

The Monte Carlo analysis with 1000 samples further confirms that the design response remains consistently close to the nominal post-layout behavior, proving that the proposed topology is not only valid under nominal conditions, but also reliable against statistical and corner variations. Therefore, the final extracted design validates the feasibility of the feedback-cascode architecture for IEEE 802.15.4z UWB automotive receiver applications, showing stable operation regardless of the considered process, supply-voltage, temperature, and mismatch conditions.

V. COMPARISON WITH THE STATE OF THE ART

Table II compares the proposed LNA with other reported LNAs implemented in advanced CMOS technologies. The figure of merit (FoM) used for the comparison is defined in (1), taking into account the main RF performance parameters, linearity and power consumption.

As shown in Table II, some previous works achieve higher gain or lower noise figure under nominal conditions. For instance, the LNA in [13] reports a gain of 23 dB and a noise figure between 1.6 and 1.8 dB. However, this performance is obtained with a significantly higher power consumption of 20 mW and a larger occupied area of 0.18 mm². In contrast, the proposed LNA achieves a gain between 13.1 and 14.1 dB and a noise figure from 2.63 to 2.99 dB while consuming only 2.7 mW, which represents a more power-efficient solution for UWB receiver front-ends.

$$FoM(\text{GHz/mW}) = \frac{\text{Gain}(\text{lin.}) \times BW(\text{GHz}) \times IIP3(\text{lin.})}{P_{DC}(\text{mW}) \times (NF(\text{lin.}) - 1)} \quad (1)$$

The calculated FoM of this work is 1.46, which is higher than that of [13] and confirms the competitiveness of the proposed design when power consumption and linearity are considered together with RF performance. Although [8] and [12] present

Table II
COMPARISON WITH THE STATE OF THE ART

	Tech.	BW (GHz)	Gain (dB)	NF (dB)	S ₁₁ (dB)	S ₂₂ (dB)	Power (mW)	IIP3 (dBm)	Area (mm ²)	FoM
[8] AEU	CMOS 28 nm	1.7–12.52	12.5–15.3	1.21–4.9	< −10	> −10	1.8	−2.6@6.5 GHz	0.011	16.03
[12] ASICON ^a	CMOS 22 nm	0.2–7.3	10.3–13.3	2.83–4	< −10	< −10	5.5	6.7@5.5 GHz	0.0016	19.65
[13] JSSC	22FDX	5.3–9.4 ^b	23	1.6–1.8	> −10	> −10	20	−12.7	0.18	0.32
This work ^a	22FDX	6.5–8	13.1–14.1	2.63–2.99	< −10	< −10 ^c	2.7	−3@7.3 GHz	0.13	1.46

^aPost-layout simulated results ^bLFB Mode ^c> −10 dB at the beginning of the band

higher FoM values, they are not evaluated under the same post-layout automotive-oriented conditions. In this work, the LNA has been verified including corners, temperature extremes from −40 °C to 150 °C and ±10 % supply-voltage variations.

Therefore, the proposed LNA demonstrates stable operation under all evaluated corners and statistical conditions. This makes it a viable solution for IEEE 802.15.4z UWB automotive receiver applications, where robustness, low power consumption, and post-layout reliability are especially relevant.

VI. CONCLUSION

A low-power UWB LNA for IEEE 802.15.4z automotive receiver applications has been presented in this work. The proposed feedback-cascode design, implemented in GlobalFoundries 22FDX technology, covers the 6.5–8 GHz band with post-layout gain of 13.11–14.14 dB, noise figure of 2.63–2.99 dB, and power consumption of approximately 2.7 mW. The extracted circuit was extensively verified under corner variations, including process corners, temperature extremes from −40 °C to 150 °C, ±10% supply-voltage variations, and Monte Carlo simulations with 1000 samples. The results confirm that the LNA remains operational under all evaluated conditions, maintaining the key receiver-front-end requirements regardless of process, supply-voltage, temperature and mismatch variations. Therefore, this work demonstrates a robust and power-efficient LNA solution suitable for future IEEE 802.15.4z UWB automotive receiver integration.

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