

Design and Performance Analysis of a High-Gain GaN HEMT Low Noise Amplifier Using 150 nm Technology

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Abstract—Using a variety of methods, this paper reports on LNA. The subject of LNA has been covered in a number of publications. Additionally, researchers have discovered methods to determine merit as well as performance. Low power and high speed were needed for the IOT devices. Circuits that run at high frequency and low voltage are in great demand these days. CMOS devices also have several drawbacks, such as high output conductance, velocity, saturation, and mobility degradation. Because LNA is a crucial part of the receiver circuit, overall performance has also improved. Our primary goal is to create an LNA with strong linearity, low noise, stability, and a solid third order intercept point.

Index Terms—component, formatting, style, styling, insert

I. INTRODUCTION

The Low Noise Amplifier is the first active stage in the receiver chain of contemporary RF and microwave systems, and its performance directly affects the overall signal quality and sensitivity of the system. For weak incoming signals to be amplified without deterioration, a well-designed LNA must offer significant gain while reducing additional noise. However, in crowded spectrum environments like 5G, radar, and satellite communication systems, excellent linearity is crucial to preventing distortion and intermodulation products when numerous strong signals are present. LNA design is a challenging but essential endeavor since the trade-off between noise figure, gain, and linearity necessitates careful optimization of device biasing, matching networks, and transistor selection.

II. REFERENCES

A. A 19–31GHz K/Ka-band Broadband Low Noise Amplifier with High Gain and High Flatness. This paper introduces a Ka-band (32–36 GHz) GaN MMIC single-chip front end that was constructed using OMMIC's 100-nm and 60-nm GaN-on-Silicon technology. The semiconductor is a compact 4.7×3.0 mm design that incorporates a high-power amplifier, a low-noise amplifier, and T/R switches for phased-array antenna purposes. In the receive mode, it obtains a gain of approximately 30 dB and a noise figure of approximately 3.2 dB. It produces 35 dBm output power and a "16" PAE when

operating in transmit mode. The design enhances both noise and power performance by maintaining transistor channel temperatures below 160 °C and employing mixed gate-length devices (100 nm + 60 nm). It is also one of the most high-frequency integrated GaN-on-Silicon front ends that has been reported to date.

B. A 120-GHz Bandwidth, 20-dBm Pout, 6-dB Noise-Figure Distributed Amplifier MMIC in a GaN-on-SiC HEMT Technology. A Ka-band GaN MMIC single-chip front-end (SCFE) constructed with OMMIC's 100-nm and 60-nm GaN-on-Silicon technology is shown in this research. For use in active electronically scanned antennas operating between 32 and 36 GHz, the 4.7×3.0 mm chip combines a low-noise amplifier, a high-power amplifier, and T/R switches. It achieves a strong gain and a low noise figure of 3.2 dB in receive mode. It produces 35 dBm of output power with 16 PAE while in transmit mode. To maintain the transistor channel temperature below 160°C, thermal and bias trade-offs are examined. Overall noise and power performance are improved by using both 100-nm and 60-nm GaN transistors. In continuous-wave testing, this SCFE performs similarly to GaN-on-SiC solutions and operates at the highest reported frequency for GaN-on-Si MMICs.

C. A 19–31GHz K/Ka-band Broadband Low Noise Amplifier with High Gain and High Flatness. The design of a high flatness broadband monolithic microwave integrated circuit low-noise amplifier (LNA) based on 100-nm gallium-nitride-silicon-carbide (GaN-on-SiC) technology for 19–31 GHz is shown in this study. For all transistors, the input match and noise figure (NF) have been fitted using a common-source (CS) design with inductive degeneration. To increase gain flatness at a wide frequency band, broadband matching networks and parallel RC networks have been deployed concurrently. With a chip area of 2.1×1.3 mm², the suggested three-stage LNA has a low NF of 1.4-1.8 dB, a high gain of 20.1-21.1 dB, and a gain flatness of ± 0.5 dB. The output third-order intercept point (OIP3) and output 1-dB compression point (OP1dB) at 26GHz are 32.3 dBm and 20.8 dBm, respectively.

D. Optimizing Low Noise Amplifiers: A Two-Stage Ap-

proach for Improved Noise Figure and Stability. A novel low-noise amplifier (LNA) design is presented in this study, which comprises two stages and capitalizes on the inherent lossy properties of the input matching components. By doing so, the design achieves a balance between stability and the minimal noise figure (NF), thereby removing the complexities and challenges that feedback networks introduce.

TABLE I
LITERATURE SURVEY

Topology	Frequency (GHz)	NF (dB)	Gain (dB)	OIP3 (dBm)
Inductive Source Degeneration (Common-Source)	1–40	1.0–3.5	10–20	28
Drain-to-Gate Feedback	1–40	1.5–3.0	15–25	15
CS with Inductive Source Feedback	10–35	1.8–3.0	12–20	22
Frequency-Selective Parallel Feedback	8–40	1.5–3.0	17–21	25
Cascode LNA	0.5–20+	0.4–2.5	15–25	28
Folded-Cascode/ Stacked LNA	2–50	1.0–3.5	12–22	25
Distributed Amplifier (DA) LNA	5–110	3–8	8–15	20
Resistive-Feedback Broadband LNA	0.5–40	1.5–4.0	10–18	22
Transformer/ Balun-Matched LNA	1–40	0.8–2.5	12–22	28
Noise-Canceling LNA	1–40	0.5–2.5	10–18	21
Neutralized/ Positive-Feedback LNA	1–30	1.0–3.0	15–23	24
Common-Gate Input LNA	10–70	1.5–4.0	8–15	20

The table above presents a comparative summary of various wideband LNA (Low Noise Amplifier) topologies that have been reported in the literature. It concentrates on their typical operating frequency range, noise figure (NF), gain, and linearity performance (OIP3).

Inductive source degeneration and cascode LNAs are frequently employed due to their ability to achieve a satisfactory equilibrium between high gain, low noise figure, and robust linearity across a broad frequency spectrum. matched transformer/balun LN. Additionally, competitive performance is demonstrated through enhanced impedance matching. Feedback-based LNAs (resistive and drain-to-gate) provide stable gain and wideband operation; however, they typically have a slightly higher noise figure. Distributed amplifier LNAs are capable of achieving an exceptionally wide bandwidth; however, they are limited by their reduced gain and higher NF, which renders them unsuitable for ultra-wideband applications. While maintaining broadband gain, noise-canceling LNAs further enhance noise performance.

In conclusion, this table is a critical reference for the selection of an appropriate LNA topology that meets the design requirements of minimum NF, high gain, broad bandwidth, and high linearity. It also assists in the justification of the selected topology for the proposed project design.

III. LAYOUT

The PCB layout of a two-stage cascode Low Noise Amplifier (LNA) utilized in RF receivers is illustrated in the figure. It enhances sensitivity by amplifying feeble input signals with

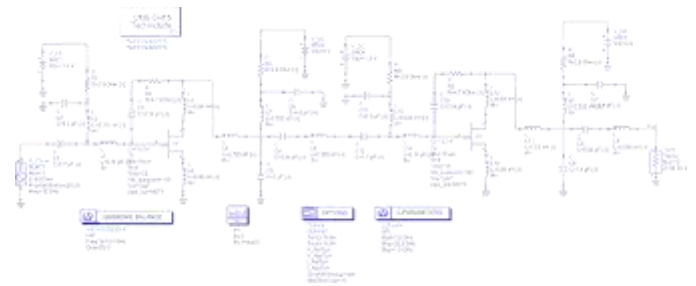


Fig. 1. Circuit Diagram

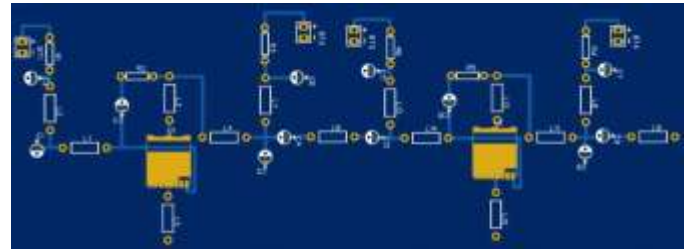


Fig. 2. PCB layout

minimal added noise. Each stage employs a cascode configuration to ensure stable wideband performance, high gain, and excellent isolation. Biasing components establish the transistor operating point and mitigate supply noise, while matching networks ensure 50 impedance matching. The parasitics are minimized by the compact layout and grounding, ensuring dependable high-frequency operation.

IV. OUT PUT

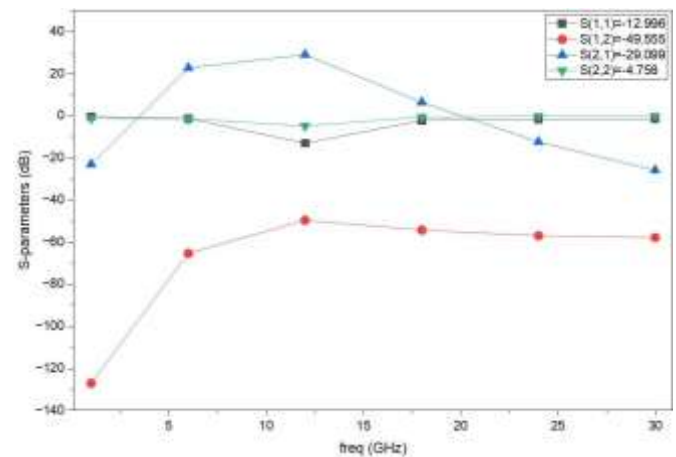


Fig. 3. S-parameter

The S-parameters, which are derived from ADS simulation, are employed to evaluate the Low Noise Amplifier (LNA)'s performance. These parameters characterize the gain, matching, and isolation characteristics of the LNA throughout the operating frequency range. The forward gain of the amplifier is

denoted by the parameter S21, and Based on the plot, it reaches approximately 29 dB at 12 GHz, suggesting that feeble RF signals are amplified significantly. The parameter S12, which denotes reverse isolation, has a value of approximately -49 dB, indicating exceptional isolation. This value reduces feedback from the output to the input and enhances stability. The input return loss (input impedance matching) is indicated by the parameter S11. A value of approximately -13 dB confirms that the input port has minimal reflection, indicating that the input matching is acceptable. The parameter S22 denotes output return loss (output matching), and its value of approximately -4.7 dB indicates that output matching is relatively inadequate, indicating that some output power is reflected back. Consequently, output matching can be enhanced further. In general, the LNA exhibits reasonable input matching performance, exceptional isolation, and high gain.

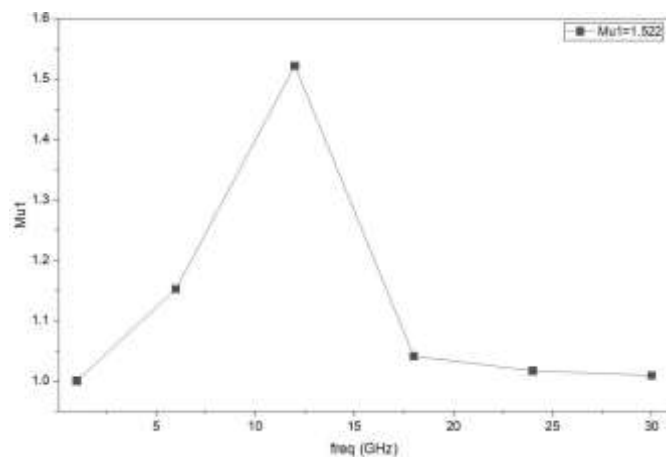


Fig. 4. LNA's 1 (Mu1 stability factor)

The ADS plot illustrates the frequency-dependent variation of the LNA's 1 (Mu1 stability factor). 1 is a critical stability parameter, and the amplifier must maintain unconditional stability by ensuring that $1 < 1$ throughout the operating spectrum. The graph indicates that 1 experiences a significant increase in the mid-range and subsequently decreases progressively, achieving a near-constant value at higher frequencies. The LNA is regarded as stable and is unlikely to oscillate, as 1 remains above 1 for the majority of the frequency range.

The LNA's NFmin (minimum noise figure) is plotted against frequency in the ADS plot. The lowest achievable noise figure under optimal noise matching is denoted by NFmin, and lesser values suggest improved noise performance. The graph indicates that NFmin initially decreases, reaches a minimum at mid-frequency, and then increases at higher frequencies, indicating that the LNA performs optimally at the frequency where NFmin is lowest.

The ADS plot shows the LNA output spectrum (dBm vs frequency). The main peak represents the amplified fundamental signal, while the smaller peaks indicate harmonics/distortion

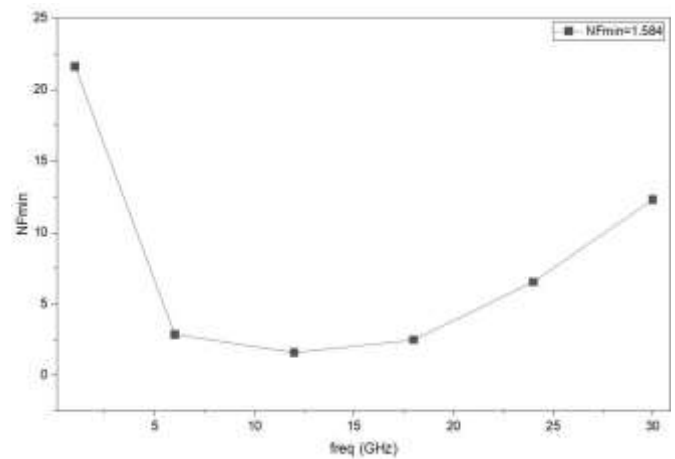


Fig. 5. LNA's NFmin (minimum noise figure)

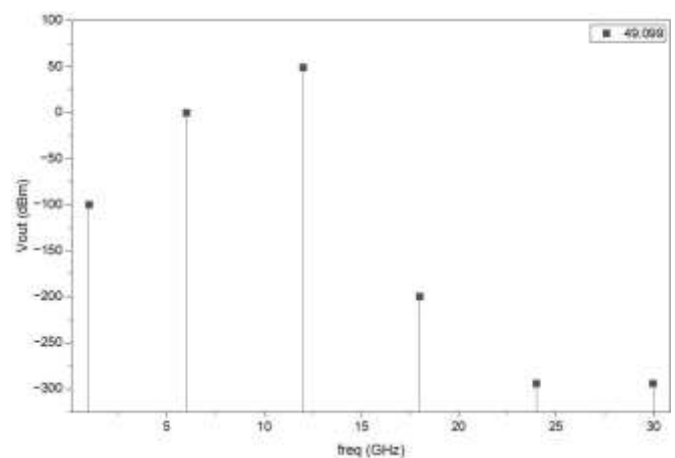


Fig. 6. LNA output spectrum (dBm vs frequency)

due to nonlinearity. Lower harmonic levels confirm good linearity and proper amplifier performance.

V. CONCLUSION

In this endeavor, we utilized a GaN HEMT transistor to develop an RF amplifier that produced a stable, robust, and clear output. In order to ensure that the signal is amplified without distortion or noise, the circuit was modified with appropriate biasing and matching. The amplifier operates efficiently, as indicated by the findings. In conclusion, this design demonstrates that GaN HEMT devices are an excellent choice for the construction of effective and rapid RF amplifiers.

VI. REFERENCE

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