A Design of Low Noise InP HEMT LNA based on device modeling

1st Ji-Seung Seo
ICT Device & Packaging Research Center
Korea Electronics Technology Institute
Gyeonggi-do, Korea
sjseung@keti.re.kr

2nd Soo-Chang Chae
ICT Device & Packaging Research Center
Korea Electronics Technology Institute
Gyeonggi-do, Korea
sc.chae@keti.re.kr

3rd Kwang-Ho Ahn
ICT Device & Packaging Research Center
Korea Electronics Technology Institute
Gyeonggi-do, Korea
khajoh@keti.re.kr

4th Ki-Jin Kim
ICT Device & Packaging Research Center
Korea Electronics Technology Institute
Gyeonggi-do, Korea
sergeant@keti.re.kr

***Abstract*— In this paper, we propose an InP HEMT low noise amplifier that can be used in the n79 band. In order to use an undefined InP HEMT in the design, ASM-HEMT Modeling is adopted to create a model for the active component. In addition, the model is completed to improve the accuracy of the noise parameter through source-pull measurement. The proposed LNA is off-matched into a single stage using InP HEMT transistors, a low-noise compound semiconductor, and passive components from Murata. It can be used in systems that require a low noise figure in the n79 band. Measurements confirm that the fabricated LNA has a noise figure characteristic of 0.52 dB or less in the 4.4 GHz - 5.0 GHz band.**

Keywords—5G, InP HEMT, LNA, Low Noise Amplifier, Device modeling, ASM-HEMT, n79, Source-pull, Noise model

I. Introduction

5G network is a communication technology that can provide ultra-high speed, ultra-connected, and ultra-low latency services (eMBB, URLLC, mMTC). By using 5G communication, machines and devices can be controlled quickly and precisely in real time, enabling industrial applications such as smart factories and smart cities. In this paper, we propose a low-noise amplifier for the n79 band (4.4 GHz - 5.0 GHz), a private-5G frequency in Korea.

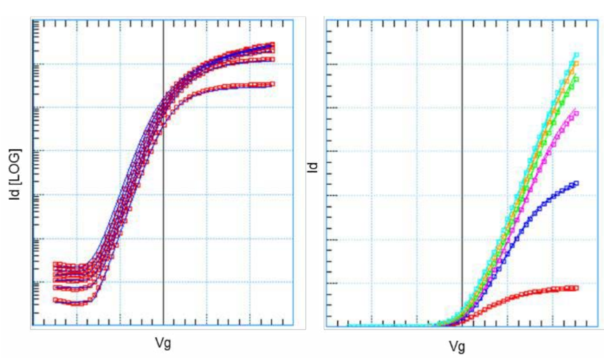
As the system requires high sensitivity, the noise figure of the receiver has a significant impact on the overall system performance. When the LNA is designed and fabricated using a commercial process, the DC and S-parameter models show a similar trend, but the noise parameter shows a significant difference from the simulation value, and the noise model is somewhat less accurate.

In this paper, an InP HEMT developed in a domestic process was modeled as an ASM-HEMT using Keysight's IC-CAP software, and sophisticated noise parameters were extracted through source-pull measurements to supplement the active device model. Based on this, a Low Noise Amplifier with ultra-low noise in the n79 band was designed and fabricated using the InP HEMT among III-V HEMTs, which are transistors with low noise.

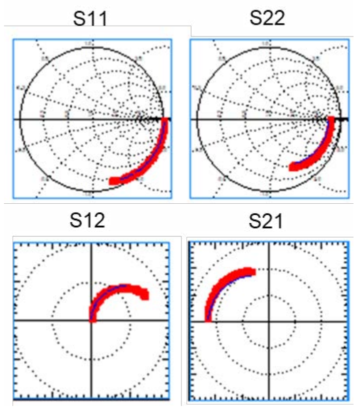
II. Device Modeling

First, in order to design a device using an undefined InP HEMT, a PDK model of the transistor is required. We used Keysight's IC-CAP software to perform ASM-HEMT modeling of InP HEMT. ASM-HEMT is a physics-based model that can be used to model the device's structure. Characteristics such as fermi level can be calculated and represented based on physical figures. Therefore, unlike other modeling techniques that are empirical-based models, it is capable of geometrical scaling and has strengths in analyzing characteristics such as field plate and trapping effect.

IC-CAP's ASM-HEMT can proceed in the order of DC, CV, and AC measurement and fitting, and we have completed the DC and AC measurement and modeling of the active element, InP HEMT, as shown in the figure 1.



(a)



(b)

Fig 1. InP HEMT Model Graph using ASM-HEMT Method
(a) DC Characteristic (b) AC Characteristic

In addition, to accurately model the noise characteristics of InP HEMTs with low noise figure and reflect process variations, the transistors that were modeled with ASM-HEMT were performed source-pull measurements using an impedance tuner from focus. The NFmin measurement environment of the active device is shown in Figure 2. This allowed us to obtain characteristics such as the NFmin (the minimum Noise Figure) value and the noise optimum impedance of the transistor.

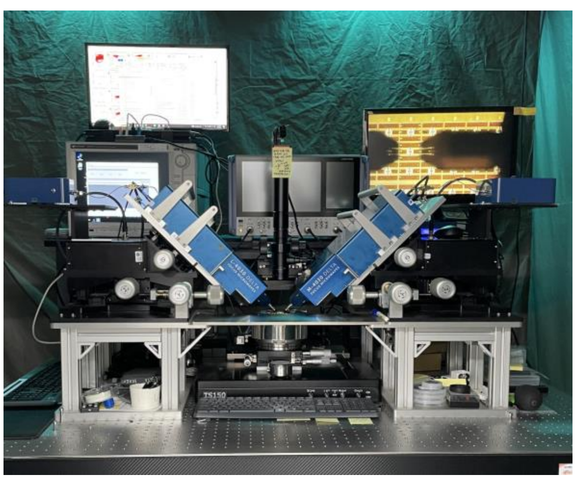


Fig 2. The Minimum Noise Figure Measurement Environment

Based on this, we enhanced the completeness of the InP HEMT PDK model by fitting the noise optimum impedance based on the actual measurement as shown in Figure 3.

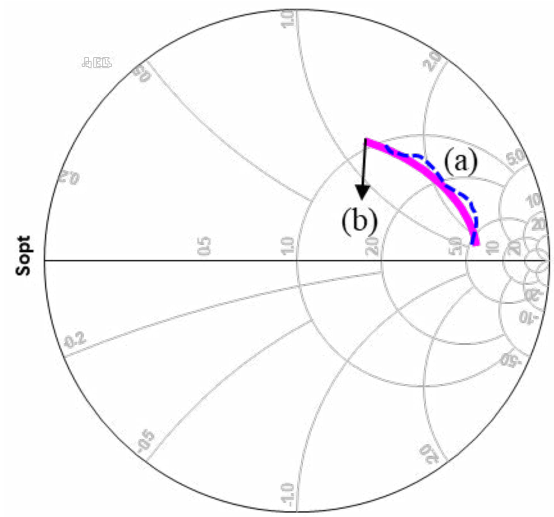


Fig 3. Noise Optimum Impedance Characteristics (a) Measured Sopt
(b) Sopt from the ASM-HEMT model enhanced based on measurements.

III. Device Design & Fabrication

Using the previously obtained InP HEMT model, we designed a single-stage LNA (Low Noise Amplifier) targeting n79 (4.4 GHz - 5.0 GHz). In addition, by using InP HEMT transistors as active component and mounting passive components on a PCB(Printed Circuit Board), an off-chip matching circuit was implemented to produce an LNA with ultra-low noise. Based on measurements and ASM-HEMT modeling, the noise optimum impedance, DC and AC characteristics of the simulated transistors were identified, and the matching circuit was implemented on the PCB board using Murata devices. The fabricated Low Noise Amplifier is shown in Figure 4. Wire bonding was used to connect the active and passive elements, and two 1-mil thick bonds were connected to both ends of the active element to reduce variation.

The Low Noise Amplifier is designed as a single stage, with an inductor inserted at the source of the transistor to match the noise-optimized impedance with the gain-optimized impedance. This allows for a noise figure of less than 0.5 dB and a gain of more than 10 dB. In addition, to account for process variations, multiple source ground pads were placed to adjust the source inductance. To ground the AC signal, a series of parallel capacitors were used in the DC voltage line, and a resistor was inserted in the Drain section to suppress DC oscillations.

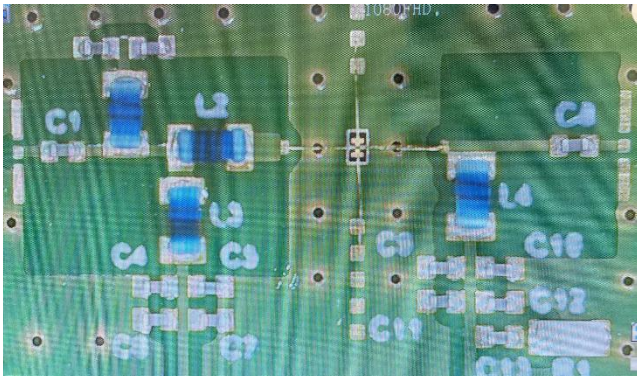


Fig 4. Fabricated Low Noise Amplifier

IV. Measurements

To measure the designed LNA, a PCB board was fabricated using RF35, and a circuit was inserted to suppress the feedback of the signal in the case of low-frequency oscillations. The VNA(Vector Network Analyzer) was a Keysight PNA-X, the DC Supply was a R&S HMP4040, and the RF Probe was a GGB Picoprobe model 40A.

The designed LNA has a noise figure of 0.47 dB or less in the 4.4 GHz - 5.0 GHz band, and the measurement results confirm that it has a noise figure characteristic of 0.52 dB or less. The simulation and measurement noise figure is shown in Figure4.

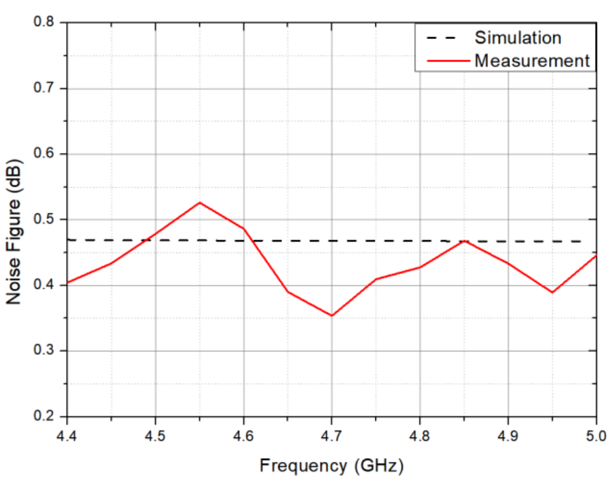


Fig 4. The Noise Figure of Simulation and Measurement of the Fabrication LNA

V. Conclusion

This paper proposes a Low Noise Amplifier based on InP HEMT in the n79 band. In order to use an InP HEMT which is fabricated by an undefined domestic process, we developed a model for the active component, transistor, and adopted the ASM-HEMT Model, a physics-based model that reflects the physical and structural parameters of the device, to add accuracy. In addition, we measured the minimum noise figure and noise optimum impedance through on-wafer source-pull measurement using an impedance tuner. This allowed us to design a single-stage off-chip LNA using the ASM-HEMT Model, which includes an accurate noise model. The resulting low-noise amplifier has a noise figure of less than 0.52 dB in the n79 frequency band.

Acknowledgment

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