A 3-stage Wideband Q-band Monolithic Amplifier for WLAN

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Abstract: The design and fabrication of Q-band 3-stage monolithic microwave integrated circuit(MMIC) amplifier for WLAN are presented using 0.2□ AlGaAs/InGaAs/GaAs pseudomorphic high electron mobility transistor (PHEMT). In each stage of the MMIC, a negative feedback is used for both broadband and good stability. The measurement results are achieved as an input return loss under -4dB, an output return loss under -10dB, a gain of 14dB, and a P1dB of 17dBm at Q-band(36 ~ 44GHz). These results closely match with design results. The chip size is 2.8×1.3mm^2. This MMIC amplifier will be used as the unit cell to develop millimeter-wave transmitters for use in wideband wireless LAN systems.

1. Introduction

Recently the communication systems using micro- and millimeter-wave have rapidly advanced in wireless system due to the shortage of the spectrum at lower frequencies. The Wireless Local Loop(WLL), wireless LAN, and CATV are applied in micro- and millimeter-wave range. With the advent of such communication systems, the development of High Electron Mobility Transistor(HEMT) technology has made it possible to produce monolithic microwave integrated circuit(MMIC)'s in micro- and millimeter-wave range.

Those equipments require a compact size, high reliability, low cost by mass production and so on. In order to satisfy these conditions, all active and passive devices are fabricated on the same semiconductor substrate in the form of MMIC. In micro- and millimeter-wave systems, MESFETs have been dominant device last a few decades. However, the demand of the superior performance drived the development of the heterostructure devices such as Heterojunction Bipolar Transistors (HBTs) and High Electron Mobility Transistors (HEMTs). Especially for millimeter-wave applications, HEMT is preferred due to the high electron mobility in 2DEG.[1]

The amplifier is one of the most critical components of transmitters in wireless systems. Therefore, power amplifier must have a proper gain and good stability as well as superior power characteristics. The design and fabrication techniques for MMIC amplifier in Q-band using AlGaAs/InGaAs/GaAs PHEMT[2-3] with T-shaped gate are described in this paper.

2. PHEMT Device

Pseudomorphic HEMTs(PHEMTs) with excellent high frequency and low noise performances are used for millimeter-wave communication systems. A PHEMT fabricated in Electronics and Telecommunications Research Institute(ETRI) is obtained by the optimization of fabrication technologies such as a wide head T-shaped gate with the selective recess etching and the optimization of epitaxial layer structure. The layer structure of the planar-doped PHEMT including a T-shaped gate is presented in Fig. 1.

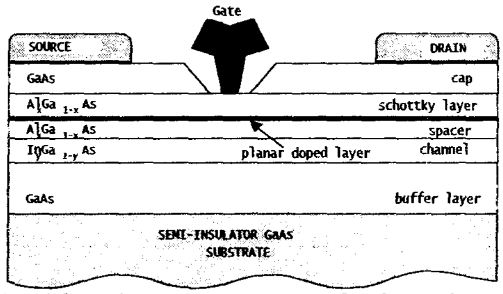


Fig. 1. The layer structure of the planar-doped pseudomorphic HEMT including a T-shaped gate.

The dose split electron beam lithography developed by ETRI is used for wide head T-shaped gate and is employed for the fabrication of 0.2□m gate length AlGaAs/InGaAs PHEMT. The photograph of AlGaAs/InGaAs/GaAs PHEMT is presented in Fig. 2. The DC and RF characteristics of PHEMT device are presented in Fig. 3. The typical transconductance of the PHEMT is 450mS/mm with an average cut-off frequency, f_T, of 62GHz.

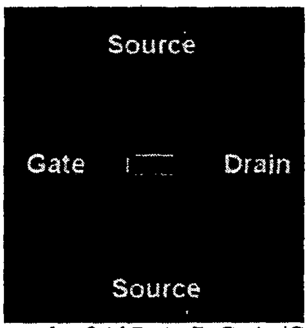
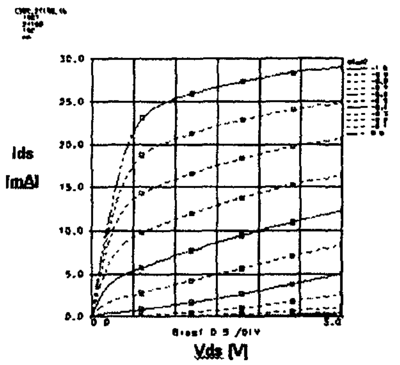
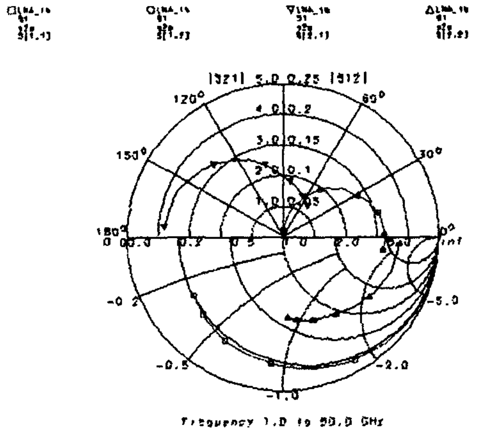


Fig. 2. Photograph of AlGaAs/InGaAs/GaAs PHEMT



0.2µm gate length, 2 gate finger, total gate width 100 µm
Drain Saturation Current = 28mA @ Vds=2V
Threshold Voltage = -0.8V

(a). DC I-V curve



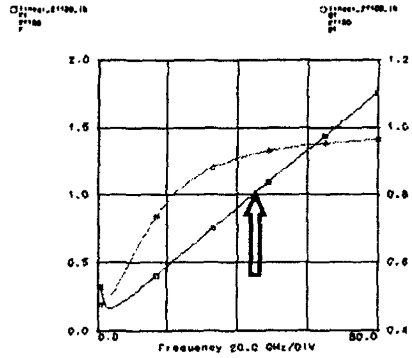
Vds = 2V, Ids = 30%Idss

(b). S-parameter

Fig. 3.DC and RF characteristics of PHEMT

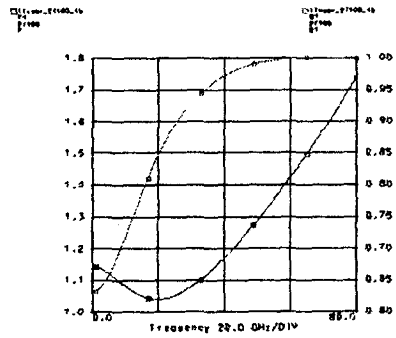
3. 3-stage PA MMIC Design

A 3-stage MMIC PA is designed by using PHEMT device of 4-finger 200□m(4f200) and 8-finger 400□m(8f400). In order to increase the stability of PHEMT device, negative feedback is employed by the resistor network. In the case of employing parallel feedback, gain is decreased to some extent. There are some advantages such as broadband and remarkably increased stability. In addition, the effect of feedback is to make the input and output impedance more convenient for matching. The stability of PHEMT becomes greater than unity and the result is presented in Fig. 4. Negative feedback from the drain to the gate of the PHEMT was established through R and C for broadband match and stable amplification. The PA is a single-ended 3-stage design. The first two stages use PHEMTs with 200□m gate width and operate as class A amplifiers for gain consideration, while the third stage employs a 400□m devices for power and efficiency requirements and operates at class A. All input/output matching, interstage matching, and biasing networks are included in the MMIC design. In the design of matching circuit, an open stub is employed because it is much easier to be fabricated than a short stub. Symmetric open stub conjugate matching scheme was applied to prevent an unexpected oscillation.



Stability Factor, K < 1 @ 0 ~ 45GHz
Stability Measure, B1 > 0 @ 0 ~ 80GHz

(a) Not having negative feedback



Stability Factor, K > 1 @ 0 ~ 80GHz
Stability Measure, B1 > 0 @ 0 ~ 80GHz
R_A = 270Ω, C_A = 18.3pF

(b) Negative feedback insertion

Fig. 4.The variation of stability by negative feedback.

All grounded parts of 3-stage MMIC PA are processed by via-holes. Microstrip thin film capacitor[3] provided in ETRI library is applied to DC-block circuits for isolation between stages and combination of RF signals. The bias networks consist of a high impedance quarter-wave transmission lines, with decoupling capacitors, serving as RF short circuits. The circuit schematic of 3-stage PA for Q-band is shown in Fig. 5.

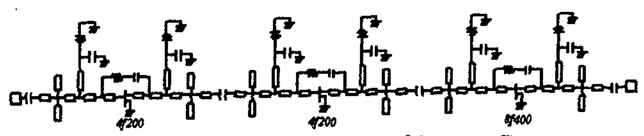
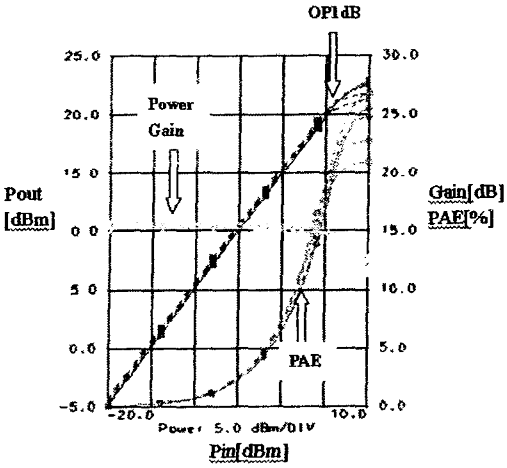
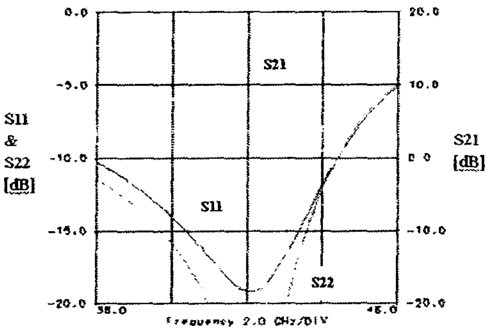


Fig. 5. Circuit schematic of 3-stage PA

The simulation results of 3-stage PA considering layout are shown in Fig. 6. The gain obtained by simulation is 15dB, the output power is 20 dBm and input-output return loss is less than -12dB.



(a) P1dB, PAE and Power Gain



(b) Linear Gain & Input/Output return loss

Fig. 6. Simulation results of 3-stage PA.

4. Measurement results

A 3-stage MMIC PA using PHEMT is designed and fabricated at ETRI. The on-wafer measurement is done using HP8510C network analyser. The photograph of the fabricated MMIC PA is presented in Fig. 7. The fabricated chip size is 2.8 × 1.3□.


Fig. 7. Photograph of fabricated MMIC PA.

In the operating frequency range(36 ~ 44GHz), the measured gain is 14dB, input return loss is less than -4dB, output return loss is less than -10dB, and P1dB is 17dBm as shown in Fig. 8 and Fig. 9, respectively. These results closely match with design results. In the view of circuit stability, the fabricated MMIC PA is stable because oscillation is not observed in s-parameter characteristic. The design and measurement results for s-parameter are compared in Fig. 10.

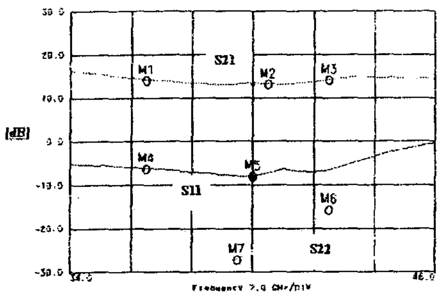


Fig. 8. Measured gain and Input/Output return loss.

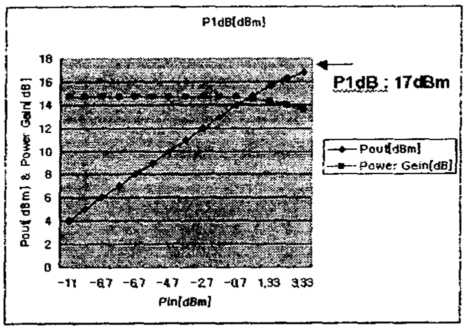
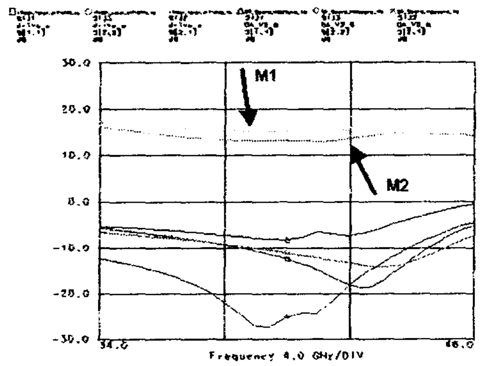


Fig. 9. Measured result of P1dB



M1 : Simulation results, M2 : Measurement results

Fig. 10. Comparison of simulation results and measurement results.

5. Conclusions

A Q-band 3-stage MMIC PA has been designed and fabricated using PHEMT of a gate length of 0.2□ and unit gate width of 50□ in this paper. In the wideband from 36 GHz to 44 GHz, the output power is 17dBm with an associated gain over 14dB. Input return loss is less than -4dB and output return loss is less than -10dB. The chip size is 2.8 × 1.3□. These results closely match with design results. This MMIC amplifier will be used as the unit cell to develop millimeter-wave transmitters for use in wideband wireless LAN systems.

In this paper, the Q-band MMIC design technique is achieved with design and fabrication of Q-band MMIC PA using ETRI's own MMIC library and foundry.

References

[1] C. S. Wu, "Pseudomorphic HEMT Manufacturing Technology for Multifunctional Ka-Band MMIC Application," IEEE Trans. MTT., vol. 43, 1995.

[2] J. H. Lee et al., "Pseudomorphic AlGaAs/InGaAs/GaAs High Electron Mobility Transistors with Super Low Noise Performances of 0.41dB at 18Ghz," ETRI Journal vol. 18, no. 3, 1996.

[3] ETRI GaAs MMIC Design Guide Version 3.1, Electronics and Telecommunications Research Institute 1997.