A 12-16 GHz GaN-on-Si Power Amplifier with >38dBm Output Power and >28% PAE for Very Small Aperture Terminal Application in SatCom

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Introduction

Recently, GaN-on-Si has gained wide popularity for high performance RF/mmWave front end design (PA, LNAs, switches) owing to various advantages:

- High bandgap/voltage allowing high power operation
- High mobility (due to HEMT structure as well) ensures low noise performance
- Ease of heterogenous integration with CMOS processes [1]
- Possibility of using larger Si wafer
- Reduction in cost

Therefore, this work explores 0.1um GaN-on-Si technology to design power amplifier (PA) monolithic microwave integrated circuit (MMIC). The PA MMIC is targeted for Very Small Aperture Terminal (VSAT) application in Ku-band Satellite Communication (SatCom).

Design of Proposed GaN-on-Si PA MMIC

The proposed PA MMIC is designed using D01GH process from OMMIC Semiconductor Corporations. The process parameters are summarized in Table I [2]. The process utilizes AlN-GaN-AlGaN double heterostructure depletion mode FET. In addition, the process provides transistor switches, two different type of capacitors with capacitance densities of 400 and 50 pF/mm², thin film resistors of 50 ohm/☐, spiral inductors, and two metal layers (1.25 & 2.5 um).

Table 1. Summary of D01GH process parameters

Parameter	Typ. Value
Cut-off Frequency	105 GHz
Max. Stable Gain at 30 GHz	14.5 dB
Min. NF/Gain at 40 GHz	1.8 dB / 7.5 dB
RF power density	3.3 W/mm
Peak transconductance	650 mS/mm
Source resistance	0.18 ohm.mm
Low field drain source resistance	0.8 ohm.mm
Breakdown voltage	40 V
Quiescent voltage (V_{dd})	12 V

- To achieve >38dBm output power (Pout), 4 transistors of 8x100um are used in last stage.
- The measured maximum stable gain (MSG) and f_T of 8x100um device are 14dB@14GHz and 77GHz, respectively (Fig. 1).
- The extracted output capacitance is ~230fF which translates to an optimum load impedance of ≈15+j*7Ω (20Ω||230fF) at 14GHz.
- The extracted opt. load impedance is close to the value (12.4 + j*8.4) obtained using load pull simulations (Fig. 2).
- To obtain 30dB gain, 3-stages are cascaded.
- First stage utilizes 4x75 um device.
- Second and Third stage utilizes 8x100 um devices.
- The fabricated die is shown in Fig. 3(a). The die contains PA circuit and other test structures (8x100um & 4x75um transistors, capacitors, etc.) for de-bugging.
- The PA circuit occupies 5x2.3 mm² area.
- Assembled board for testing is shown in Fig. 3(b).
- Fig. 3(c) shows the photograph of measurement setup.

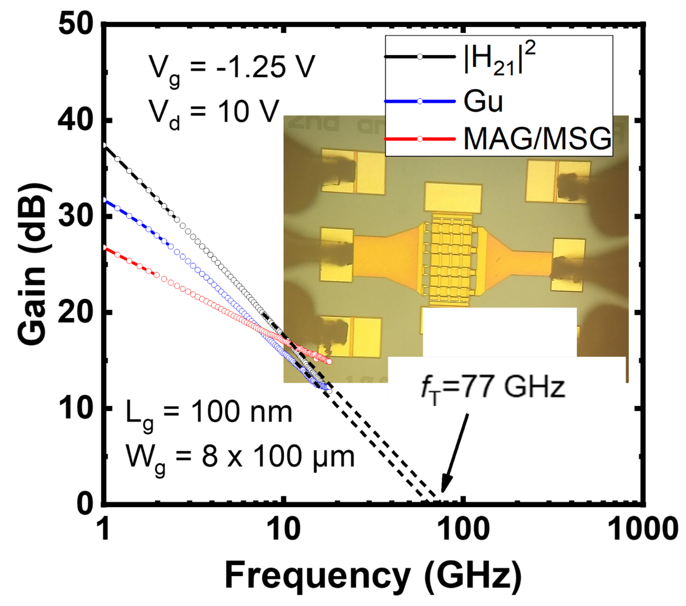


Fig. 1. Measured Gain and f_T of 8x100 um device

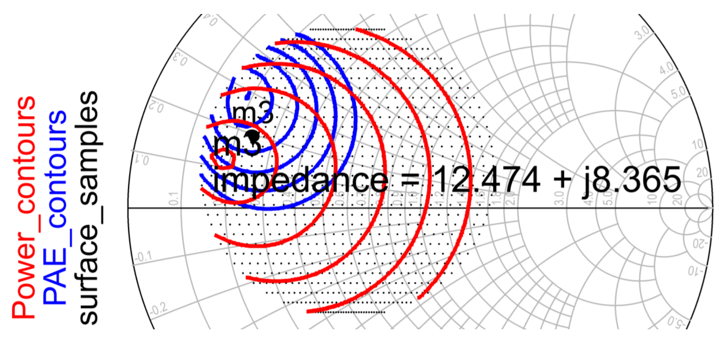


Fig. 2. Simulated loadpull results of 8x100 um device

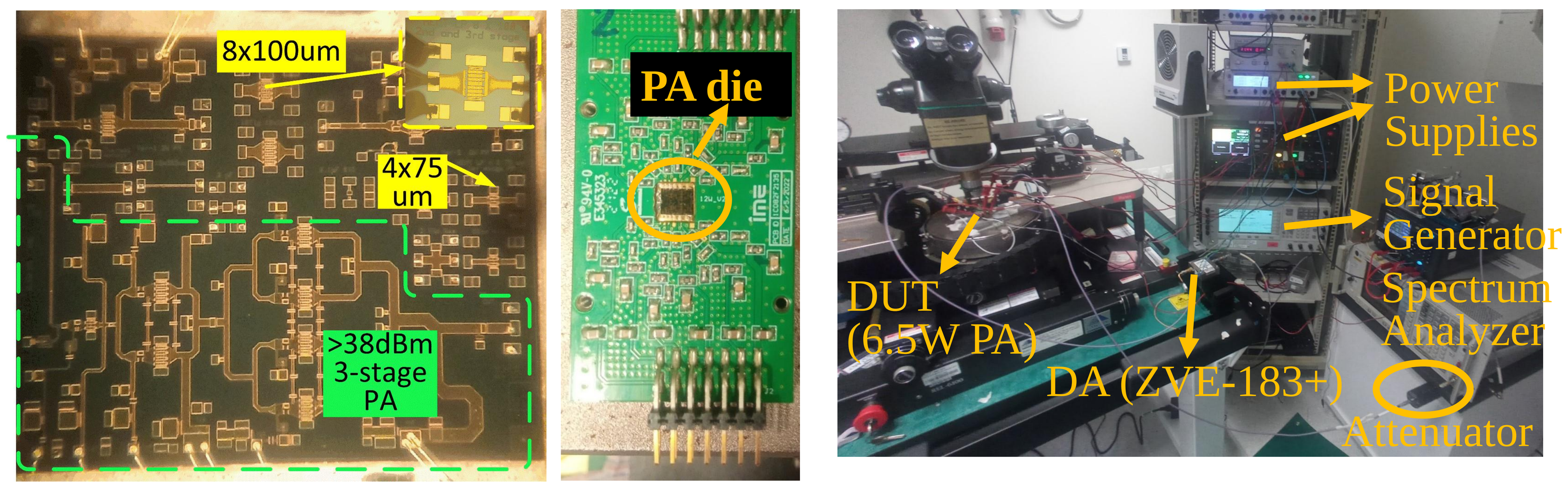


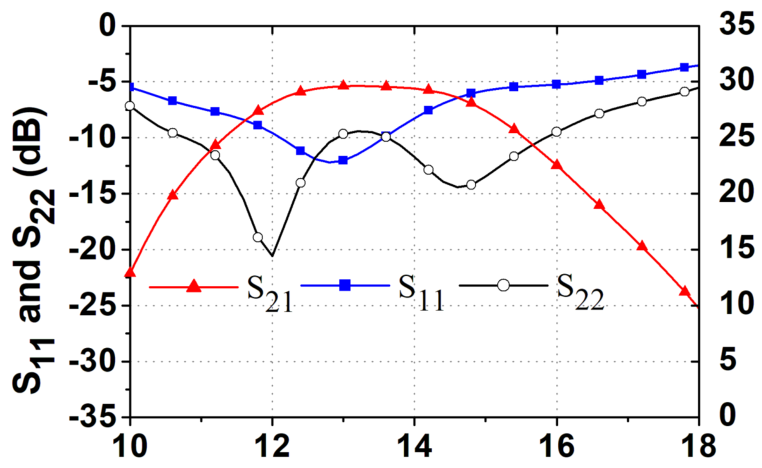
Fig. 2. (a) Photograph of fabricated GaN-on-Si PA MMIC (b) assembled PA MMIC (c) measurement setup

Results and Discussion

For testing, the PA is dc biased at drain voltage (V_{ds}) of 12V and drain quiescent current (I_{DQ}) of 1A. The obtained results are shown in Figs. 4-6.

Small signal results:

- Simulated and measured small signal parameters (*S*-parameters) are shown in Figs. 4(a)-(b), respectively.
- Measured gain (S_{21}) is 32dB with 3-dB bandwidth of 12-15 GHz .
- 3 samples are characterized for small signal parameters and consistency (<1dB gain variation) is achieved as can be seen from Fig. 4(b).
- Both the simulated and measured input/output return losses are better than 6 dB and 10dB, respectively as can be seen from Figs. 4(a)-(b).



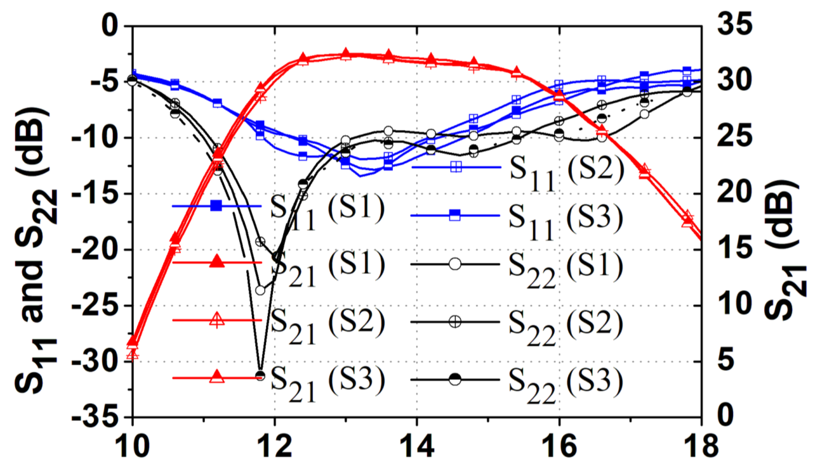
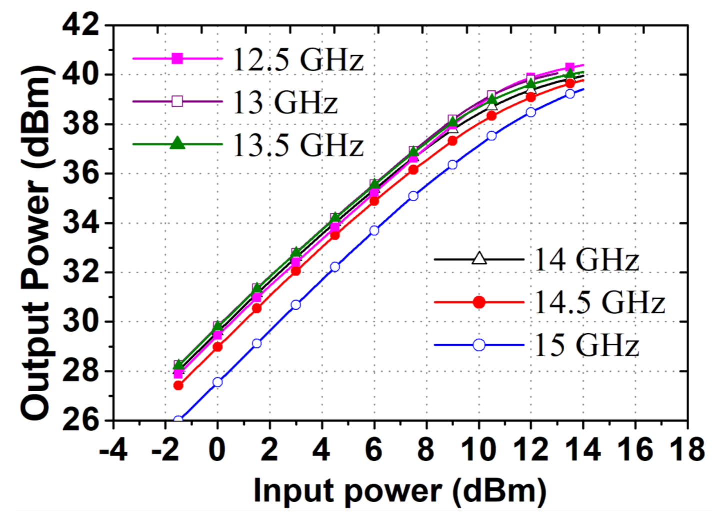


Fig. 4 Small signal parameters of proposed GaN-on-Si PA MMIC (a) Simulated (b) Measured (for 3 samples)



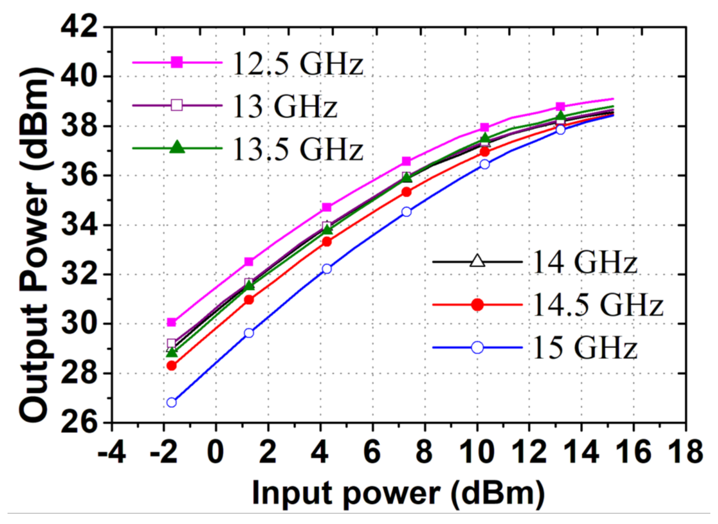
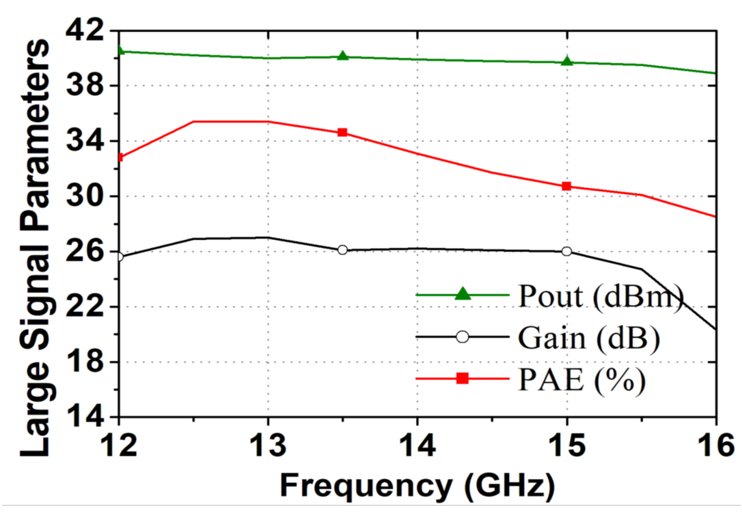


Fig. 5 Output power and PAE vs input power (a) Simulated (b) Measured



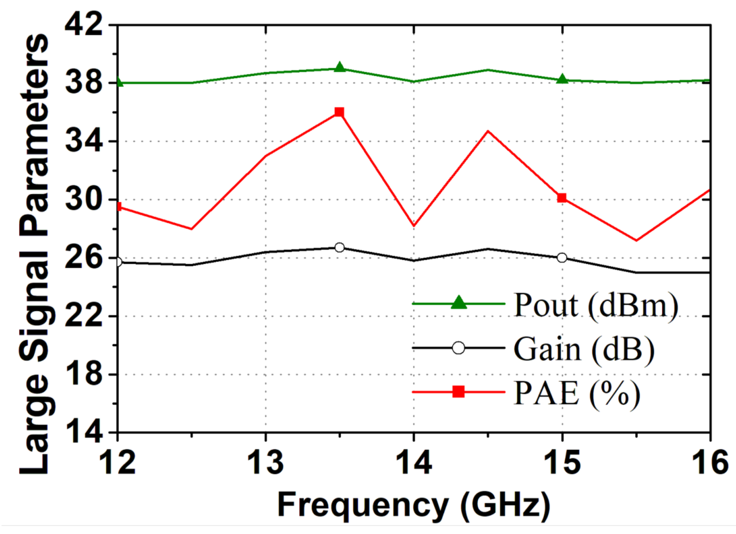


Fig. 6 Output power, Gain and PAE vs frequency (a) Simulated (b) Measured

Large signal results:

- As can be seen from Fig. 5, measured Pout has soft compression as compared to almost linear behavior & hard compression in simulations.
- Measured Pout at sat. is 38-39dBm whereas simulated value is 39-40.2dBm (Fig. 6)
- Both the simulated and measured PAE are almost similar (around 32%).
- Measured Pout is 1-1.2 dB lower than simulated.

Conclusion

This work presents the design and characterization of a 12-16 GHz PA MMIC implemented in 100-nm Gate length GaN-on-Si process. The proposed PA MMIC achieves 32 dB gain, 38-39 dBm Pout with 28-35% PAE. For 39 dBm power level, the achieved results (gain & PAE) are comparable to the reported PAs in GaN-on-SiC process. Moreover, GaN-on-Si can allow (i) possible heterogenous integration, (ii) lower fabrication cost owing to larger Si wafer size. Thus, the proposed PA MMIC is suitable for VSAT application in Ku-band SatCom.

Acknowledgement

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