A 29.6 dBm 29-GHz Power Amplifier for Satellite and 5G Communications Using 0.15-μm GaAs p-HEMT Technology

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***Abstract* — This paper presents a power amplifier that performs well at both 28 GHz and 29 GHz for fifth generation mobile networks (5G) and satellite communications using 0.15-μm D-mode GaAs pseudomorphic high electron mobility transistor (p-HEMT) devices. The power amplifier with two-stage common-source (CS) and four-way direct combining architecture attained a small signal gain of 16.1 dB, the output 1-dB compression power (OP1dB) of 29.1 dBm, and the power-added efficiency at OP1dB of 27% at 28 GHz under 6-V supply voltage. At 29 GHz the small signal gain is 16 dB, the OP1dB is 28.6 dBm, and the power-added efficiency at OP1dB is 24.6% under 6-V supply voltage.**

Index Terms — Satellite communications, 5G mobile communication, Power Amplifiers

I. Introduction

Satellite technology is developing fast, and the applications for satellite technology are increasing all the time. As the demand of high-speed transmission increases, the need for a broader bandwidth is more significant, which can be achieved by applying millimeter wave (mm-wave) frequency in the transmitter system. Ka-band is currently considered the spectrum of the future for satellite communications. Compared with S-band, Ka-band has data transmission rates that are hundreds of times faster.

The 28 GHz frequency is regarded as the candidate frequency of the 5G communication system. Therefore, the fifth generation (5G) wireless communication system is the future trend of mobile networks. In this paper we propose a power amplifier (PA) which has been successfully implemented both at 28 GHz and 29 GHz. Because the power amplifier is a crucial component in a RF transmitter, a proper semiconductor process must be carefully selected. Although CMOS PAs have the advantages of low cost and high integration capability, the low breakdown voltage and lossy substrate make CMOS PAs less attractive compared to GaAs PAs when approaching 1-Watt output power. In previous publications, PAs based on the GaAs p-HEMT process usually has a better performance than CMOS PAs due to its high breakdown voltage and high current densities. GaAs PAs also provide high gain and power-added efficiency (PAE) at mm-wave frequencies.

II. POWER AMPLIFIER CIRCUIT DESIGN

The proposed PA is designed with Class A operation for producing higher output power and better gain performance. To acquire a larger transconductance (gm), the gate and drain bias conditions are fixed at -0.75 V and 6 V. From load-pull and stability simulation results, the size of each transistor in the output stage is chosen to have 4 fingers with a width of 100 μm, which allows the PA to reach 25-dBm peak output power. Based on the considerations of having better driving capability and available gain performance, the size of the transistor in the driver stage is chosen to have 4 fingers with a width of 75 μm. The ratio of output to input total periphery is 3:1. Fig. 1 shows the schematic of the proposed power amplifier. Fig. 2 shows the layout of the proposed power amplifier with chip size of 2.5x2 mm^2 including the dc and RF pad.

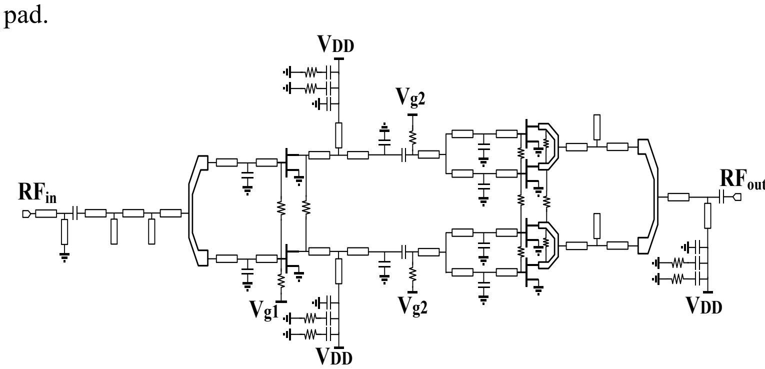

Fig. 1. Schematic of the GaAs p-HEMT Power Amplifier

III. SIMULATION AND MEASUREMENT RESULTS

Fig. 3 shows that the proposed PA under 6-V supply voltage has a 3-dB bandwidth (BW) of 5 GHz from 26.8 GHz to 31.8 GHz with 16.1-dB peak gain at 28 GHz, and the gain flatness of ±0.5 dB (15.6±0.5 dB) within 27.4 GHz to 30.9 GHz. Fig. 4 and Fig. 5 show the measured output power, power gain, and PAE with respect to the input power level. At 28 GHz, the measured saturation power is 29.5 dBm, the OP1dB is 29.1 dBm, the maximum PAE is 27% and the PAE at OP1dB is

24.9%. At 29 GHz, the measured saturation power is 29 dBm, the OP1dB is 28.6 dBm, the maximum PAE is 27.6%, and the PAE at OP1dB is 24.6%. Table I shows the comparison with previously reported GaAs PAs for frequencies around Ka-band.

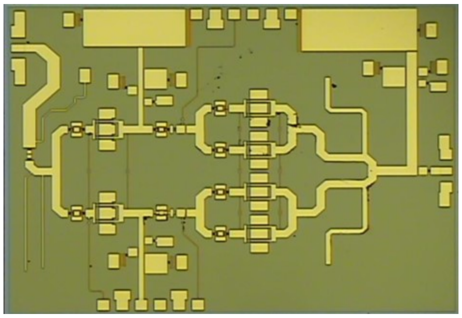

Fig. 2. Layout of the GaAs p-HEMT power amplifier

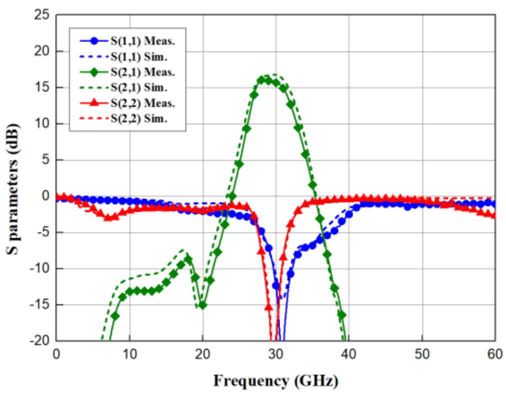

Fig. 3. Simulated and measured S-parameters of the proposed PA under 6-V supply voltage

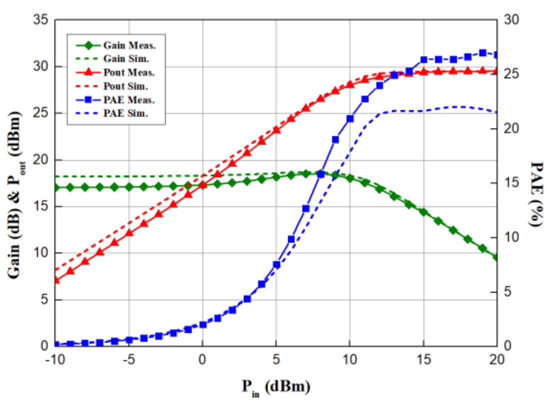

Fig. 4. Simulated and measured large-signal performances of the proposed PA at 28 GHz under 6-V supply voltage

Fig. 6 and Fig. 7 show the IMD3 of the proposed PA with a different gate bias at 28 GHz and 29 GHz. Fig. 8 summarizes the large-signal performances from 27 GHz to 30 GHz including Psat and OP1dB under 6-V supply voltage. Fig. 9 summarizes PAE-max and PAE-1dB from 27 GHz to 30 GHz. In the frequency range of 28 GHz to 30 GHz under 6-V supply voltage, the PA attains a Psat of 29.3±0.3 dBm with 28.4±1.4% PAE-max and an OP1dB of 28.8±0.3 dBm with 26.6±2% PAE-1dB. From above measured results, it can be observed that this proposed PA using capacitor of via for matching networks is not sensitive to process variations. The measured results are in good agreement with simulated results.

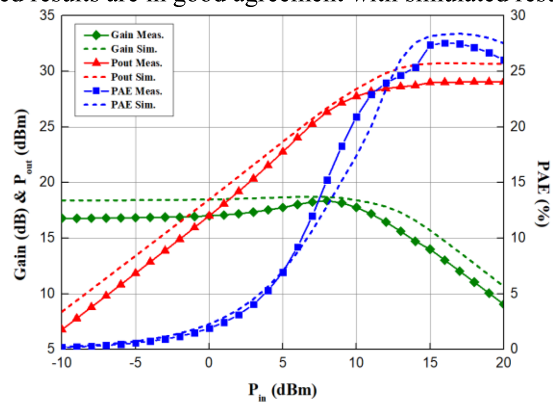

Fig. 5. Simulated and measured large-signal performances of the proposed PA at 29 GHz under 6-V supply voltage

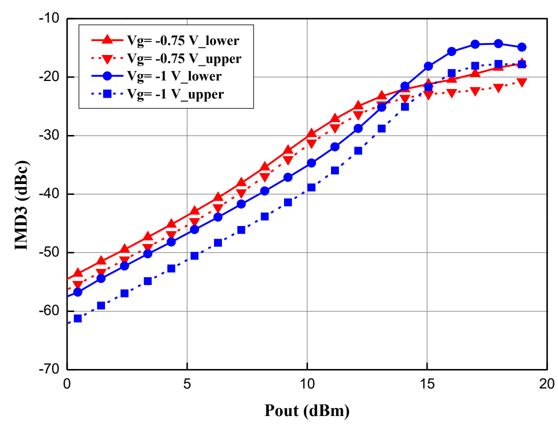

Fig. 6. Measured IMD3 of the proposed PA at 28 GHz under 6-V supply voltage

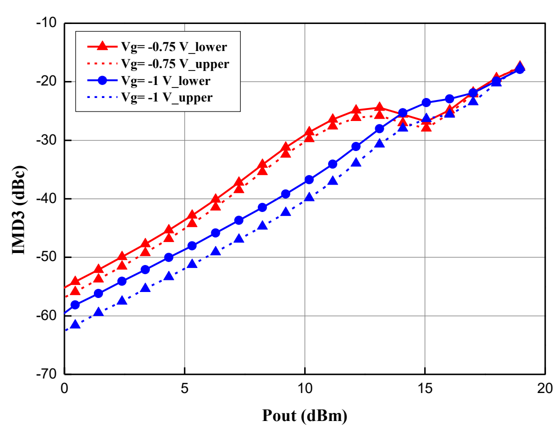

Fig. 7. Measured IMD3 of the proposed PA at 29 GHz under 6-V supply voltage

TABLE I

COMPARISON BETWEEN PUBLISHED KA-BAND PAS AND THESE WORKS

Ref.	Process	Topology	Freq. (GHz)	V_{DD} (V)	Gain (dB)	OP_{1dB} (dBm)	P_{sat} (dBm)	PAE (%)	Area (mm^2)
[1] 2006IMS	0.25- µm GaAs pHEMT	3-stage (4-way)	13-17	5	28	29.5	31	22-35	3.75
[2] 2012APMC	0.1- µm GaAs pHEMT	3-stage (16-way)	28.5-31.5	4.6	10	29.5	N/A	31	6.27
[3] 2012 TMTT	0.15-µm GaAs pHEMT	1-stage (2-way)	17-35	4	9-12	21-22	22.5-23.5	30-40	1.5
[4] 2016 TMTT	0.1- µm GaAs pHEMT	4-stage (8-way)	30-38	4	20-23	37.9	38.5-39.3	20-25	22.75
[5] 2016CSICS	0.15- µm GaAs	1-stage (1-way)	27-33	12	12	N/A	28.5	38.4	0.88
[6] 2017APMC	0.15- µm GaAs pHEMT	Doherty PA	25.8	5	7	N/A	25.1	16.5	2.25
This work	0.15-µm GaAs pHEMT	2-stage (2-way)	27-30	5	18.3	27.2-28.2	27.9-28.9	26.8-30.8	5
This work	0.15-µm GaAs pHEMT	2-stage (2-way)	27-30	6	16.1	28.5-29.1	29-29.6	27-29.8	5

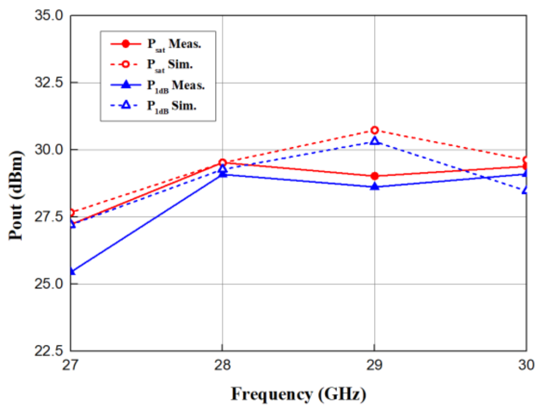

Fig. 8. Simulated and measured Psat and OP1dB of the proposed PA from 27 GHz to 30 GHz under 6-V supply voltage.

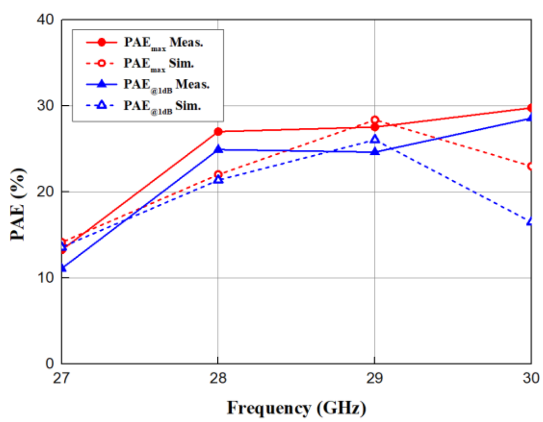

Fig. 9. Simulated and measured PAE-max, PAE-1dB of the proposed PA from 27 GHz to 30 GHz under 6-V supply voltage

IV. CONCLUSION

In this paper, a Ka-band power amplifier for both satellite communications and the fifth generation mobile networks (5G) using 150-nm GaAs p-HEMT technology has been designed, fabricated, and measured. The power amplifier with two-stage CS and four-way direct combining architecture has a small signal gain of 16.1 dB, 29.1 dBm 1-dB compression power, and 29.5 dBm output saturation power with a maximum PAE of 27% and a PAE-OP1dB of 24.9% under 6-V supply voltage at 28 GHz. At 29 GHz the small signal gain is 16 dB, the output 1-dB compression power is 28.6 dBm and 29 dBm output saturation power with a maximum PAE of 27.6% and the power-added efficiency at OP1dB of 24.6% under 6-V supply voltage. The chip size is 2.5 mm x 2 mm. Comparing with the other works, this work can reach higher output power with smaller chip size.

ACKNOWLEDGMENT

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