A Gate Bias Free Power MMIC Module for Ka-Band High-speed Wireless Applications

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Abstract - **A high power and high gain packaged power MMIC module for Ka-band applications operating under a single polarity bias supply has been developed for the first time. This PA module consists of two pseudomorphic HEMT MMICs, with Lg=0.25um, packaged in a single power module. These MMICs operate without a gate bias control voltage when the gate bias is shunted in the package. This PA module provides 30dBm output power and approximately 30dB of gain in the 27-31GHz range. The single bias supply operation provides significant cost advantage to the device manufacture as well as the end user since there is no need to design a gate control bias network.**

1. INTRODUCTION

While there were many papers that report high performance of power MMICs in a Ka-band, there are still many problems associated with cost, assembly, stability and reliability, along with the need for a great deal of design skill to obtain this performance. This paper presents a single bias supply MMIC module for Ka-band application. Generally, MMIC modules need a negative voltage bias network to control gate bias. Because this module utilizes pHEMT technology, it dose not need a negative bias voltage to achieve class-AB operation. This module is valuable to compose amplifier systems for many applications without a negative bias circuits.

2. POWER PHEMT CHARACTERISTICS

We used 0.25um pHEMT for Ka-band MMICs, which are comprised of buffer layer, n-AlGaAs/i-InGaAs/n-AlGaAs double hetero-structure, n-AlGaAs Schottky layer and n-GaAs cap layer. Figure 1 shows the cross section of the power pHEMT. The thickness and doping density of these layers were optimized to achieve the best performance at the gate bias voltage Vg=0V. Figure 2

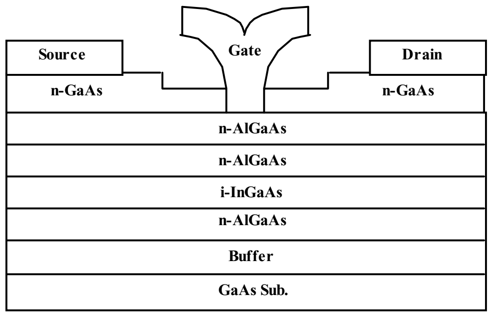

Figure 1 A cross section of power pHEMT

shows typical Id vs. Vd characteristics of the pHEMT with 600um gate width.[1] The maximum drain current (Imax) is 400mA/mm and saturated drain current (Ids) at Vgs=0V is 100mA/mm. Figure 3 shows characteristics of the transconductance (gm) of power pHEMT. The maximum gm are obtained around Id=100mA at Vg=0V. When the gate bias is shunted, we easily obtain class-AB operation at 25 % Imax bias condition. The typical RF performances of this pHEMT is 23.5dBm output power and 10.2dB power gain at 18GHz with Vd=6V operation.

3. MMIC CARACTERISTICS

The module includes two separate MMICs, a driver

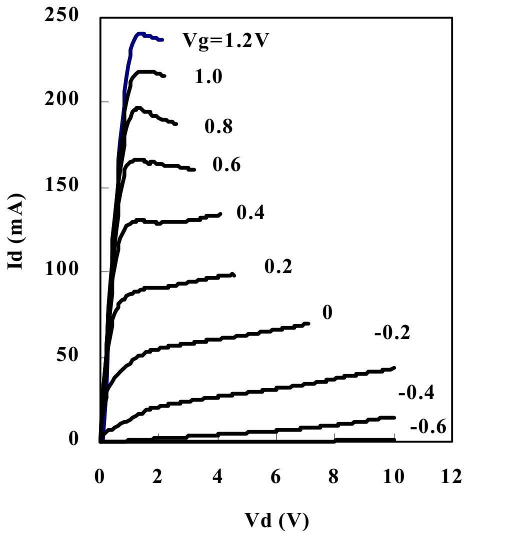

Figure 2 Id vs. Vd characteristics of pHEMT

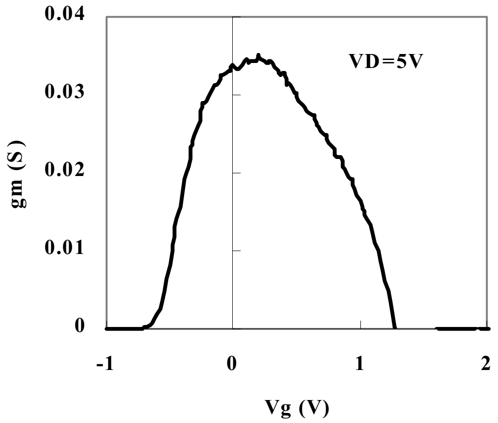

Figure 3 gm characteristics of pHEMT

MMIC and a power MMIC consisting of power pHEMTs. The driver MMIC is 4-stage, 50 ohm-matched MMIC amplifier, 2.6mm x 1.4mm. Figure 4 shows the top view of the driver MMIC. The gate widths of the stages are 600um, 900um, 1050um and 1200um, respectively. The distributed amplifier is adopted for the 1st stage due to its wide frequency response. Figure 5 shows the driver MMIC performance. In the 18-31GHz region, power and gain at 1dB compression point (P1dB, G1dB) are approximately 25dBm and 18 dB with a drain voltage (Vdd) of 6V.

The power MMIC is 3-stage amplifier, 50 ohm matched, 3.4mm x 2.1mm. Figure 6 shows the top view

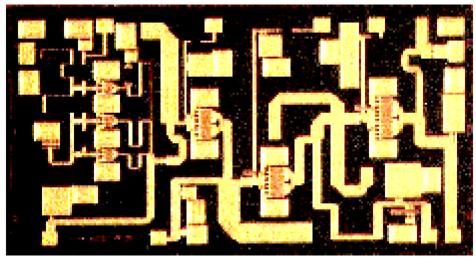

Figure 4 Top view of the driver amplifier MMIC

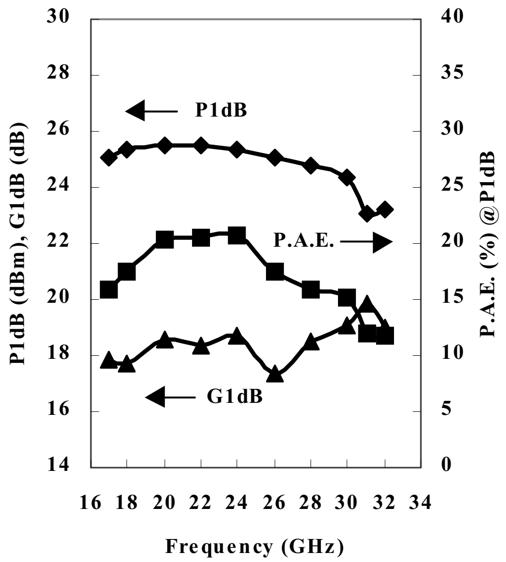

Figure 5 RF performance of the driver MMIC

of the power stage MMIC. The gate widths of the stages are 1.4mm, 1.2mm x 2 and 1.4mm x 4, respectively. Figure 7 shows, in the 28-31GHz region, a P1dB and G1dB of the power MMIC of approximately 29dBm and 15dB with Vdd of 6V.

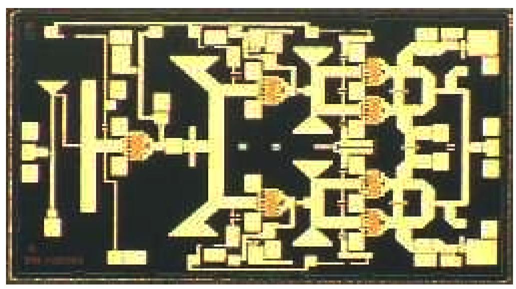

Figure 6 Top view of the power amplifier MMIC

Both the MMICs have adopted air-bridges, MIM capacitors, via hole are realized using plated heat sink

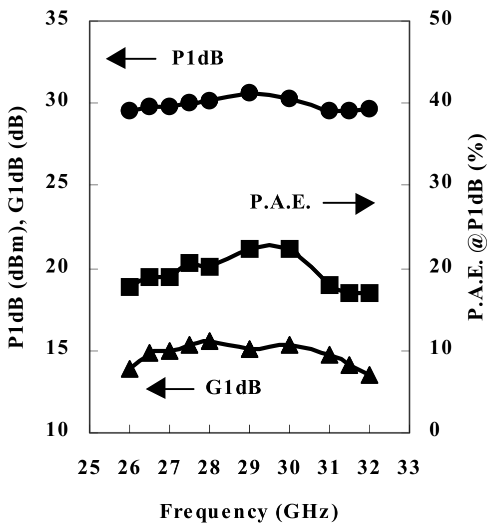

Figure 7 RF performance of the power amplifier MMIC

(PHS) technology. The GaAs substrate thickness is thinned to 28um to reduce thermal resistance. The matching circuits in each MMIC are designed by using distributed small signal FET models as well as large signal impedance optimum active source load pull data generated through measurements.[2]

4. MMIC MODULE

These MMICs are mounted in a newly developed package. Figure 8 shows the external form of the MMIC module. The size of this package is 11.2 x 11.1 x 2.6mm. This package was designed considering small thermal resistance and low mechanical stress to mount big size MMIC chips by stress analysis simulation. Figure 9 shows an internal view of this MMIC module. The two MMIC chips are connected with only a 50ohm line on an alumina substrate and some bond wires. As shown in the photo, the components are very simple and the assembly is very easy. The package is a hermetically sealed and has a copper-tungsten base plate. The thermal resistance of the package is less than 5degC/W. The wall of the package has 50ohm feedthrough lines for RF signals and DC lines for the bias supply. The RF signal port is lead less and RF probe contact type. The insertion loss of the feedthrough line for RF signal is less than 0.4dB and return loss is less than –26dB at 32GHz. The cavity, 9.1mm x 4.8mm x 1.7mm, is designed to accommodate the two MMICs easily while also removing only in-band

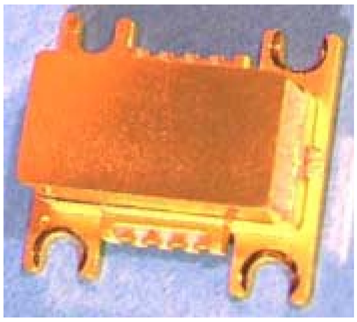

Figure 8 External form of the MMIC module

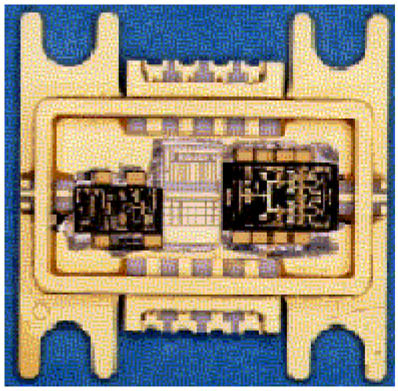

Figure 9 Internal view of the MMIC module

cavity resonance. Figure 10 shows a block diagram of the MMIC module. The drain bias of the two MMICs are connected by a common DC line port in the package to the DC power supply, through parallel chip capacitors for low frequency stability. The gate bias is shunted to ground at the base plate of the package. This sets up the device in class-AB operation, without the need of an external bias circuit for gate control.

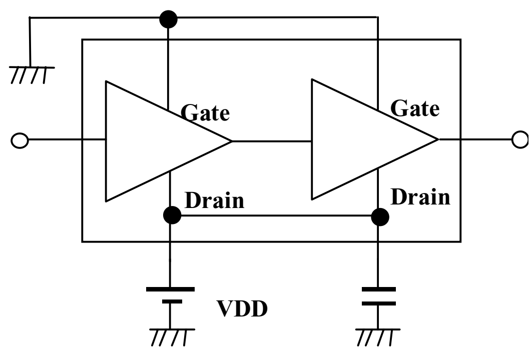

Figure 10 The block diagram of MMIC module

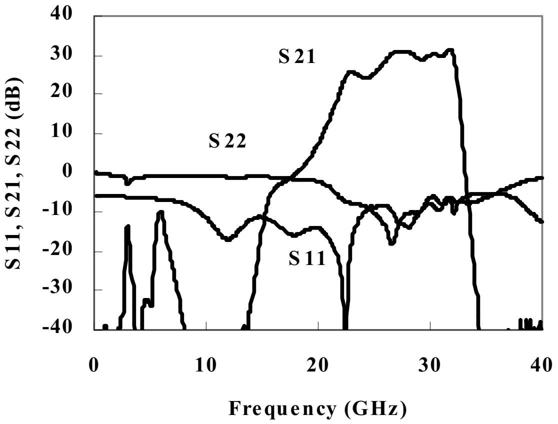

Figure 11 Small signal characteristics of MMIC module

Finally, figure 11 shows the small signal characteristics of this single bias supply MMIC module with a Vdd of 6.5V and a drain current (Idd) of 1300mA. The small signal gain is 30dB at 27- 31 GHz, and the device is stable from DC to 40GHz.

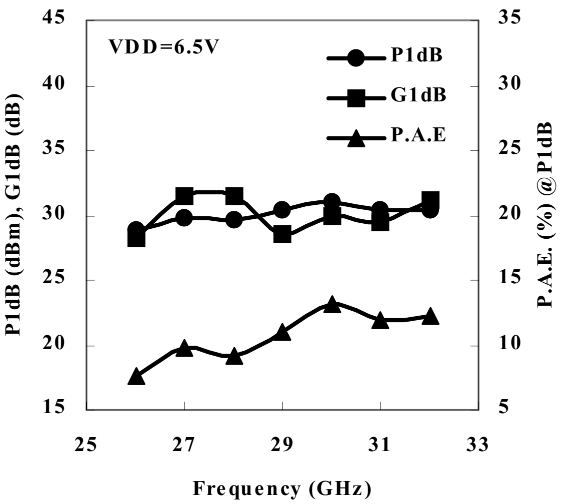

Figure 12 Frequency response of the MMIC module

The large signal characteristics at Vdd=6.5V and Idd = 1300mA are shown in Figure 12 and 13. Continuous wave (CW) measurements in the 27-31GHz range reveal a P1dB and G1dB of 30dBm and 30dB, respectively as shown in Figure 12. The Pin vs. Pout characteristics are shown in Figure 13. At 30GHz, we achieved P1dB of 31dBm, G1dB of 31dB and power added efficiency (P.A.E.) of 13%.

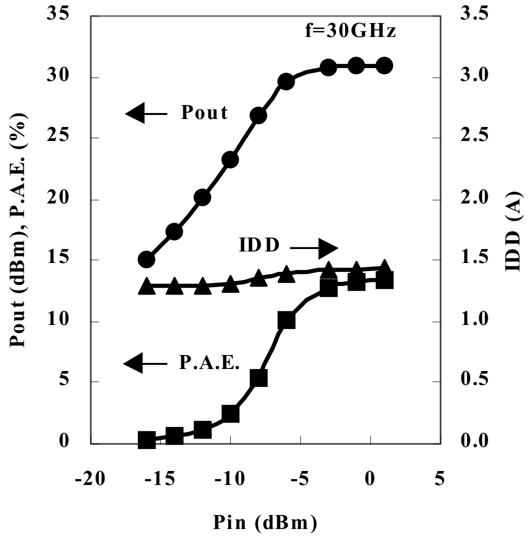

Figure 13 RF performance of MMIC module

5. CONCLUSIONS

A single bias supply, high power, high gain MMIC module for Ka-band application is developed. This packaged module provides 30dBm output power and 30dB gain at frequencies between 27 and 31 GHz. For cost sensitive commercial applications such as LMDS, single supply device has promising future.

6. ACKNOWLEDGMENT

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