Ka-band 4W Power Amplifier MMIC

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***Abstract*—The measured performance of a Ka-band power amplifier MMIC is presented. The MMIC was fabricated using a 2mil 0.15um GaAs pHEMT process. The design achieves saturated output power in excess of 36dBm over a bandwidth of 32 – 38 GHz, with a PAE of 23%. The part specifications exceed competitor performance in terms of chip size ratio and power. The measurement reference plane includes the bond wire transition on and off the die with a probable substrate used for test.**

Keywords—Ka-band; MMIC; Power Amplifier

I. Introduction

The use of Ka-band for both military radar systems and commercial point-to-point applications continues to grow, with several previously published papers demonstrating power, bandwidth and efficiency [1-2]. Worldwide satellite providers are also planning further launches with Ka-band capability with potential applications which include TV and broadband data services, commercial airborne communications and military payloads [3]. In this paper the design and measured performance a compact broadband 4W HPA MMIC for Ka-band operation is presented.

II. CIRCUIT DESIGN

MAAP-015016-DIE is a 4 stage Ka-band power amplifier fabricated on a 2mil 0.15um GaAs pHEMT process. The design process utilised foundry semiconductor device models which have been verified through a combination of small and large signal measurement. This characterisation included s-parameter and Maury load pull measurements taken over temperature.

To achieve optimum RF performance in a multiple gate finger cell at Ka-band, both the gate width and the physical length of the connecting structures need to be considered. An optimum arrangement was determined through simulation which defined the basic cell structure used throughout the design. Thermal performance also needs consideration on a cell level in terms of via arrangement and gate to gate spacing. Optimal performance was verified using a thermal simulation package. This was of significant importance as the device was required to be capable of both pulsed and CW operation. Each cell is stabilized individually using a parallel RC arrangement and the overall circuit stability was verified under drive conditions. Extensive EM simulation has been used to optimize the input, output and interstage matching networks.

Subsequent thermal imaging analysis of the die shows a peak temperature rise of 60°C above base temperature, corresponding to an MTTF of 5e7 hours. ESD diodes have been included on the die and measured performance for CDM and HBM are Class 1 and Class 1B respectively. A photograph of the die is shown in Fig. 1 along with a functional block diagram in Fig. 2.

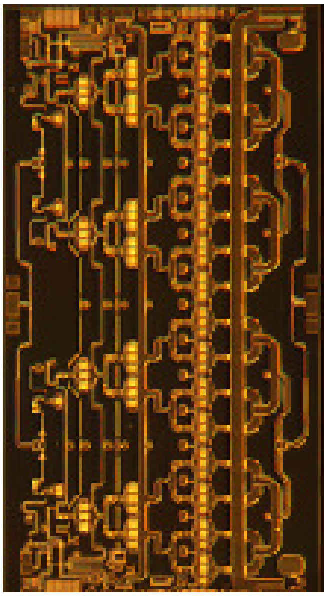

Fig. 1. Photograph of MAAP-015016-DIE

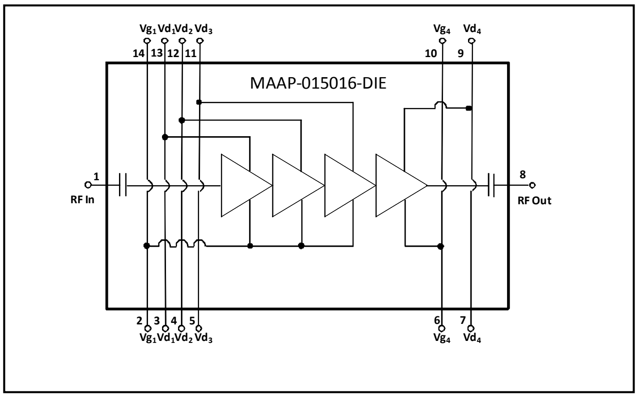

Fig. 2. Functional Block Diagram

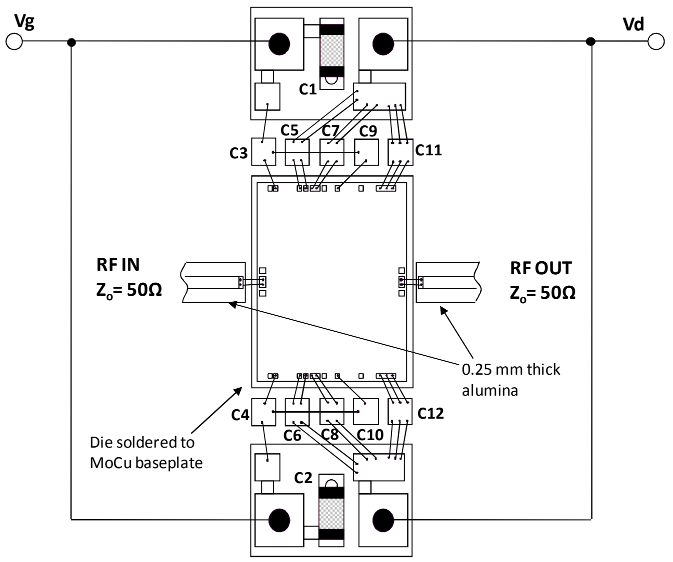

Fig. 3. Application Circuit

The design and measurement reference planes are to an external 50Ω transmission line on an alumina substrate. Bond wire transitions have been 3D EM simulated. The application circuit illustrated in Fig.3 uses a baseplate arrangement designed to match the coefficient of thermal expansion (CTE) of the GaAs die. For measurement, the RF in/out pads are bonded to an external probe pattern, such that the arrangement replicates the 3D EM simulation of the transition. External decoupling capacitors are used to improve low frequency stability. This arrangement facilitates for both drain pulsed and CW operation.

III. Circuit Performance

The MMIC has been designed to operate under both pulsed and CW conditions. Under CW conditions, a reduction in power of only ~0.5dB is observed. Table I shows a comparison of the main performance parameters for this part with the equivalent TQS part. It can be seen that the MAAP-015016-DIE is comparable across many parameters, with significant improvement in terms of real estate and output power across the band.

The measured small signal performance is shown in Fig. 4. The small signal gain is in the region of 19dB, with an input and output return loss of better than 10dB and 13dB respectively across the band of interest. Fig. 5 and 6 show pulsed power sweeps at 1GHz steps across the band. The graph on Fig.7 shows how the output power varies across frequency for various input power levels. It can be seen that the device is capable of delivering ~37dBm across a bandwidth of 33-38 GHz with an output P1dB of ~36.5dBm. Across the full 32-38GHz band, the device achieves the required 36dBm. The PAE performance is shown on Fig. 8 and 9. It can be seen that the device achieves a PAE of between 18% and 27% across the full band.

TABLE I. Performance Comparison

PERFORMANCE COMPARISON		
Parameter	***TQS TGA2575***	***MAAP-015016-DIE***
Size (mm)	4.1x5.4	3.09x5.67
Area (mm^2)	22.14	17.52
Freq Range (GHz)	32-38	32-38
Psat (dBm)	35.5	36.5[a]
Gain (dB)	19	19
IRL (dB)	12	10
ORL (dB)	12	13
Id DRIVE (A)	3.0	3.8
PAE (%)	22	23

[a] CW Performance

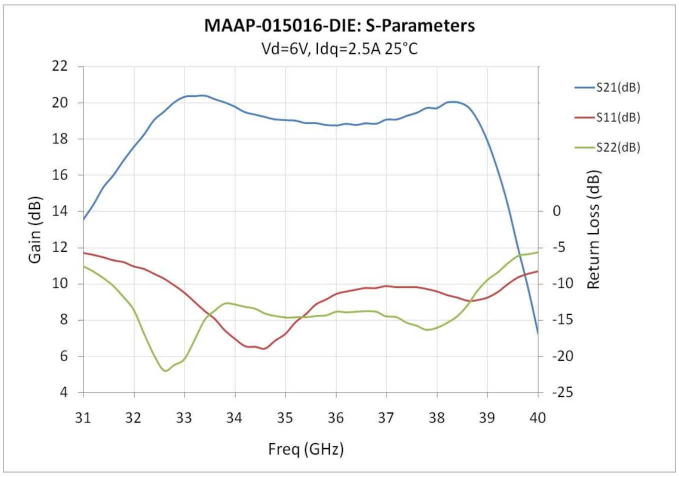

Fig. 4. Pulsed S-Parameter measurements

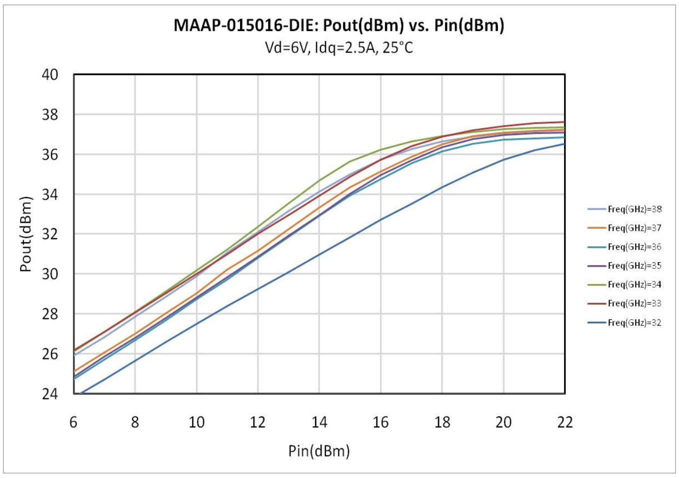

Fig. 5. Output Power vs. Input Power vs. Freq (Pulsed)

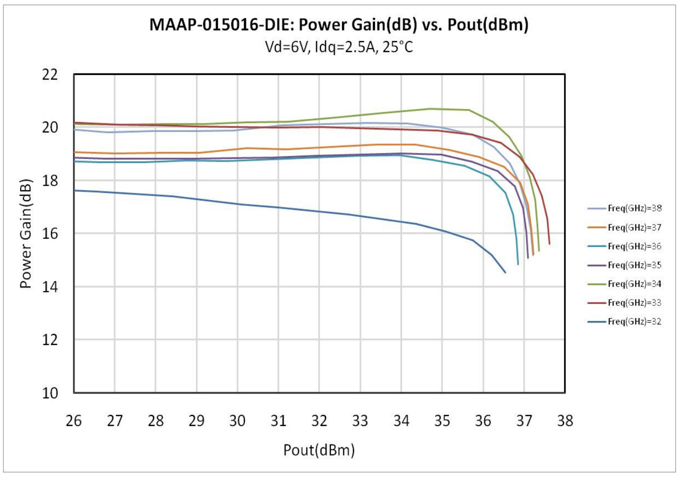

Fig. 6. Power Gain vs. Output Power vs. Freq (Pulsed)

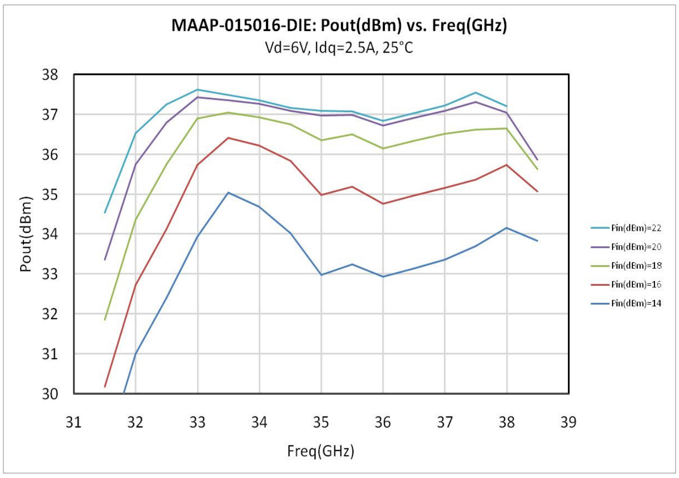

Fig. 7. Output Power vs. Freq vs. Input Power (Pulsed)

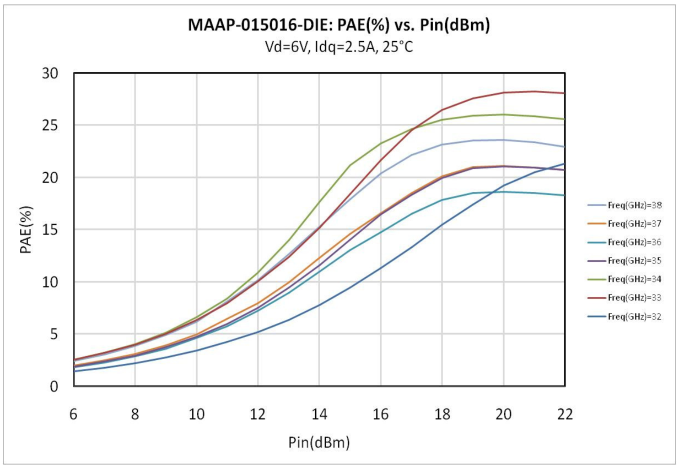

Fig. 8. PAE vs. Input Power vs. Freq (Pulsed)

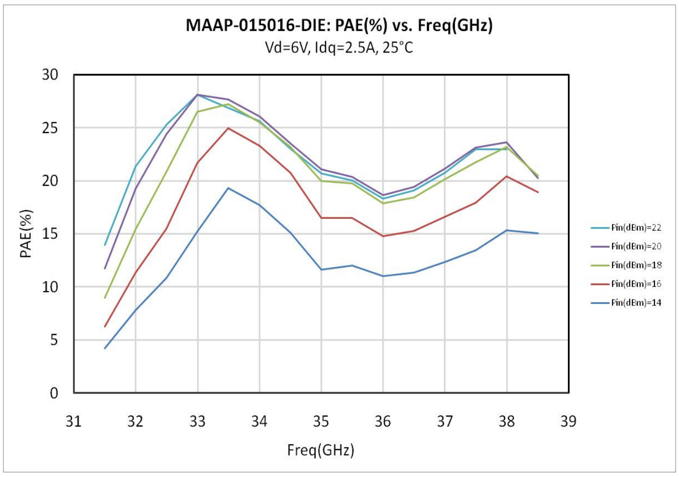

Fig. 9. PAE vs. Freq vs. Input Power (Pulsed)

IV. CONCLUSIONS

A 4W Ka-band power amplifier has been successfully designed and fabricated on a GaAs pHEMT process, achieving better performance than the equivalent competitor part. Measured results have shown that saturated output power in excess of 36dBm is achieved over a 32-38 GHz bandwidth with gain of 19dB and PAE in the region of 23%. The excellent measured results justify the design approach in terms of device modeling, circuit design, EM simulation and thermal considerations. Performance has been verified under both CW and pulsed conditions, and the part is well suited to support both commercial and defense related opportunities.

REFERENCES

[1] Campbell, C.F; Dumka, D.C; Ming-Yih Kao; Fanning, D.M.; , "Design and Performance of a High Efficiency Ka-Band Power Amplifier MMIC," Compound Semiconductor Integrated Circuit Symposium (CSICS), 2010 IEEE, pp.1-4, 3-6 Oct. 2010

[2] S.J Mahon et al., "35GHz Power Amplifier MMICs using 6-inch GaAs pHEMT Commercial Technology" 2008 IEEE Int. Microwave Symp. Dig., pp.855-858

[3] Deepak Gupta "A Market Forecast For High-Frequency, Space-Qualified, TWTs" SATMAGAZINE March 2012