10 W & 25 W GAN HEMT POWER AMPLIFIERS WITH 2 GHZ BANDWIDTH

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ABSTRACT

RFMD has demonstrated broadband GaN HEMT power amplifier with 10 W and 25 W output power and 2 GHz instantaneous bandwidth. The RF3826 is a 10 W device that obtains 12 dB gain, 0.05–2.0 GHz bandwidth, and 9–11 W continuous wave (CW) 100% duty cycle output power over the band with and 54–66% drain efficiency. The amplifier is packaged in a ceramic SO8 package and contains a GaN on SiC device operating at 28 V drain voltage with a GaAs integrated passive matching circuitry. The RF3833 is a 25 W device designed for 48 V drain voltage and obtains 22–32 W CW with 53–69% drain efficiency over the band. This amplifier is packaged in a Cu base package to handle the relatively higher power. These amplifiers are targeted for multi-band communication systems covering VHF / UHF / L-bands. Applications include wideband digital cellular infrastructure and handheld and mobile radios.

1. INTRODUCTION

Software Defined Radio (SDR) architectures support reconfigurable multiband-multimode radios which allow for faster deployment of new standards and improved spectrum utilization. Multi-decade bandwidth, highly efficient, and compact power amplifiers (PAs) covering VHF, UHF and L-band are essential for systems like the Joint Tactical Radio Systems (JTRS) and Public Mobile Radio (PMR), particularly when the amplifier is used in a handheld or mobile unit. These systems are shifting from using individual amplifiers for each band to a single wideband PA. They offer significant cost savings through component count reduction and permit seamless frequency hopping for emerging SDRs [1].

There are inherent limitations in designing a PA for wide bandwidth. High power devices have large periphery and hence large device capacitances that limit bandwidth. In addition the large periphery devices have low optimal load impedances that limit the maximum power that can be driven into a 50Ω system without broadband impedance transformation. Losses in the transformation network further limit output power and efficiency.

RFMD, leader in the design and manufacturing of multi-band power amplifiers for cellular handsets, has developed advance III-V GaAs and GaN processes that facilitate development of next generation power amplifier platforms. Utilizing existing design expertise, proven high volume advanced III-V semiconductor fabrication facilities, and high throughput assembly/packaging channels, RFMD is rapidly commercializing these next generation power amplifier platforms. These platforms strive to provide cost effective solutions that address the need for "DC to daylight" power with efficiencies exceeding typical solutions used today.

GaN HEMT devices with high breakdown voltage and high power density capability offer several advantages for broadband high power amplifiers [2]. They have larger optimal load impedance, smaller device periphery and hence lower capacitances for a given power level compared to other technologies. RFMD's AlGaN/GaN HEMT devices further employ a source connected field modulation plate that enables operation at 48V drain voltage.

2. DEVICE TECHNOLOGY

RFMD's AlGaN/GaN HEMT baseline process incorporates devices with 0.5 μm gate length and advanced source connected field plate that achieves device breakdown voltages in excess of 175 V. A SiC substrate is used for its excellent thermal conductivity, decreased temperature related memory effects and high power density capability. Description of the device topology and fabrication process employed can be found elsewhere [3].

The devices exhibit a typical pinch-off voltage of about -5V and a peak current density of 0.9A/mm. The current and power gain cut-off frequencies (ft and fmax) measured on 2.2 mm periphery devices including the bond-pad parasitic are 12 GHz and 16 GHz respectively at 28 V drain voltage and 11 GHz and 17 GHz at 48 V drain voltage and 44 mA bias current. Under CW operation at 2.1 GHz and class-AB bias, a typical 2.2 mm periphery device at 28V obtains 12 W peak output power and 66 % peak power added efficiency (PAE). At 48V the device obtains 18 W at 69 % peak PAE.

This technology benefits greatly from RFMD's industry-leading scale with wafer fabrication in the world's largest III-IV factory. These fabs start ~25% of the world's GaAs wafers and have demonstrated a 78% learning curve for cost reduction. GaN manufacturing is co-located with this high volume GaAs line and utilizes many of the same process steps, techniques, and expertise. Full technology and initial product qualification for the first generation of the GaN process is expected be completed in the fall of 2009.

3. IMPLEMENTATION

Distributed amplifiers have been frequently used for decade bandwidth amplifiers. At low frequencies like the 0.05–2 GHz band inductive elements in the distributed topology are large and take up excessive die area. Circuit enhancements like a tapered drain line are required to improve the relatively low efficiency due to the reverse termination, but they are hard to implement at high power levels [4]. Alternatively, resistive feedback amplifiers can achieve relatively broadband performance as well as rugged stability due to their negative feedback [5]. However power levels have been typically below 3W and the efficiencies reported are typically less than 25%.

We have used a compact RLC type input matching network that can provide multi-decade bandwidth with very good input return loss. This type of match has been used for a 1 W MMIC amplifier over 2–6 GHz with 30–37% efficiency [6]. The RLC type match is well suited to DC to 2 GHz applications due to its compact size, flat gain response and excellent return loss over broad bandwidth [7]. At these low frequencies the size of the passive components are significant compared to the active device area. A multi-chip (MCM) approach consisting of GaN on SiC active die in combination with a GaAs die containing the integrated passive circuits (IPCs) offers an optimal tradeoff between performance and cost in this frequency range by minimizing the SiC die area compared to a MMIC design. The passive chip includes the input and output matching circuitry, stabilization circuit, and partial bias decoupling components. The space consuming passive circuitry is located on a lower cost substrate, while keeping the overall amplifier size compact. The short turn around time of the high volume GaAs foundry also enables very short design cycles for MCM of this type.

The dies are attached to the package using high conductivity epoxy for optimal thermal performance (fig. 1, 9). The passive elements in the GaAs chips are implemented using spiral inductors, metal-insulator-metal (MIM) capacitors and thin film resistors. An AlN SO8 size package is used for the RF3826 and a copper base package is used for the higher power RF3833. The packaged devices are soldered to the evaluation board and tested. DC blocking capacitors, DC bias chokes, and decoupling capacitors are located on the evaluation board.

4. PERFORMANCE

Fig. 5 shows the measured S-parameters for the RF3826 at 28 V operation. The amplifier obtains 12 dB gain with input return loss <-10dB across the band. The CW output power and efficiency were measured over the frequency range of 0.05–2.0 GHz (Fig. 2–8). The output power is between 9–11 W over the entire band and the drain efficiency is between 54–66%. PAE is between 47–57%.

Similar tests were performed on the RF3833 which is designed for 48V operation (Fig. 10–15). A saturated output power of 22–32 W was obtained with a drain efficiency of 53–69% over the band. PAE is between 48–64%.

5. CONCLUSION

We have demonstrated a small form factor 10 W and 25 W GaN HEMT power amplifiers over 0.05–2 GHz bandwith with greater than 50% efficiency. These amplifiers are targeted for multi-band communication systems covering VHF/UHF/L-bands. The RFMD approach allows for one device to replace multiple amplifiers used in multi-band communication systems.

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Fig. 1. 10W PA in a 5mm x 6mm ceramic SO8 package

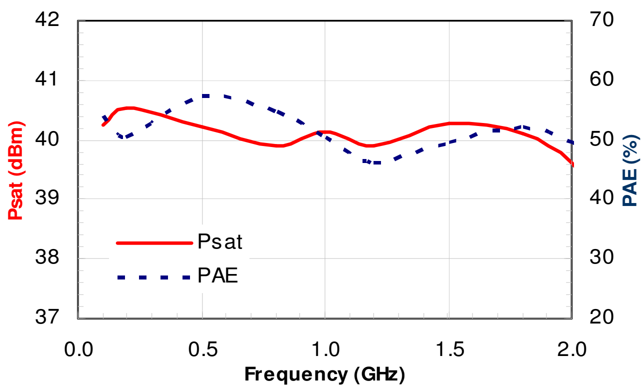

Fig. 2. RF3826: Output power and PAE over frequency

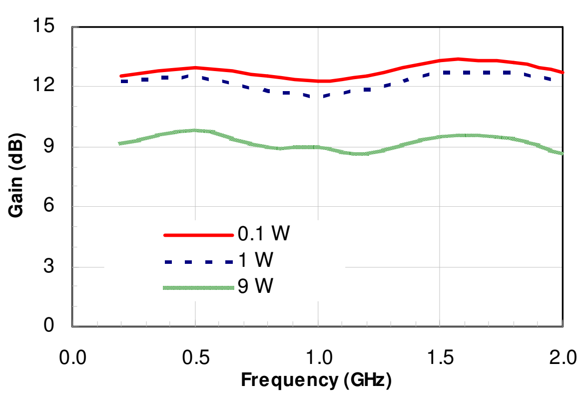

Fig. 3. RF3826: Gain over frequency at various output power

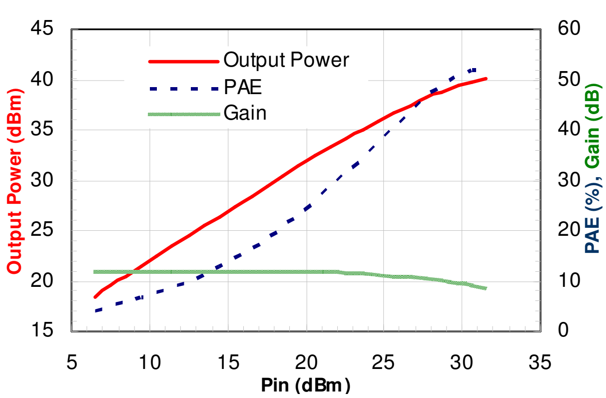

Fig. 4. RF3826: Output Power, PAE and Gain at 1800MHz

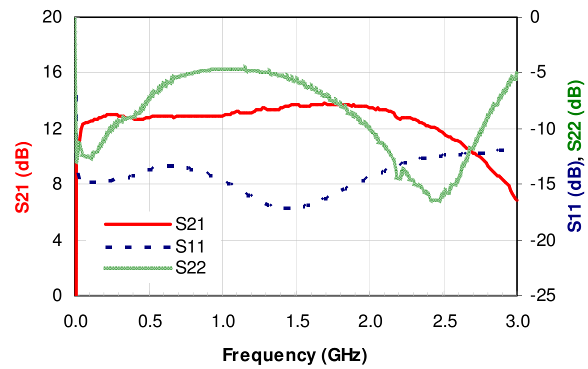

Fig. 5. RF3826: Small signal S-parameters

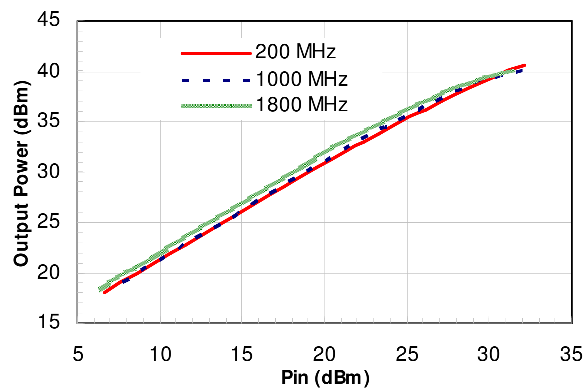

Fig. 6. RF3826: Output power over drive for various frequencies

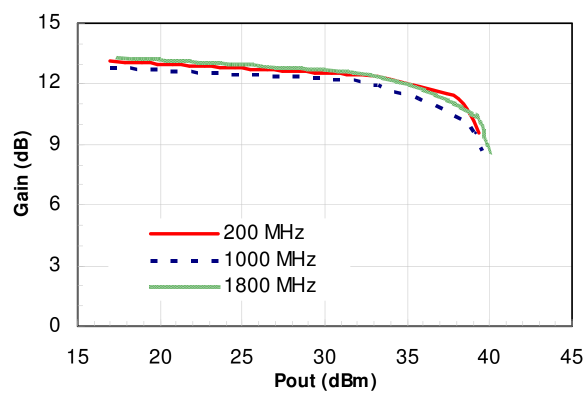

Fig. 7. RF3826: Gain vs. output power at various frequencies

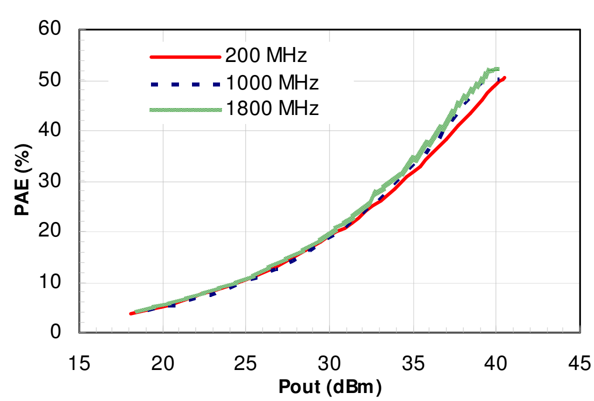

Fig. 8. RF3826: PAE vs. output power at various frequencies

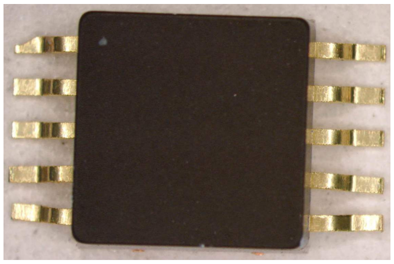

Fig. 9. 25W PA in a 7mm x 7mm Cu package

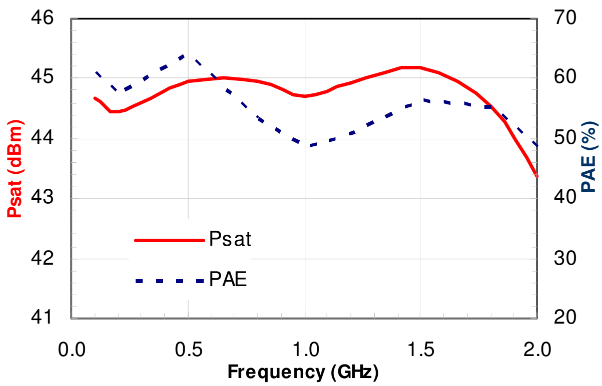

Fig. 10. RF3833: Output power and PAE over frequency

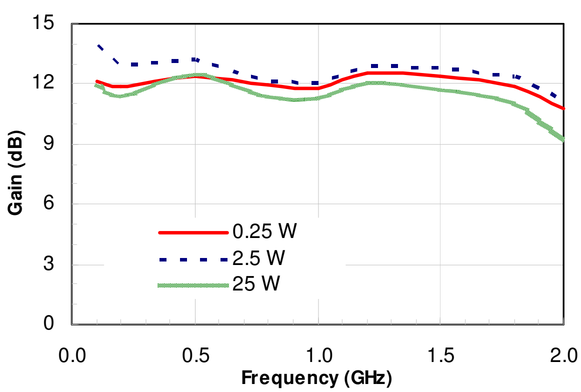

Fig. 11. RF3833: Gain over frequency at various output power

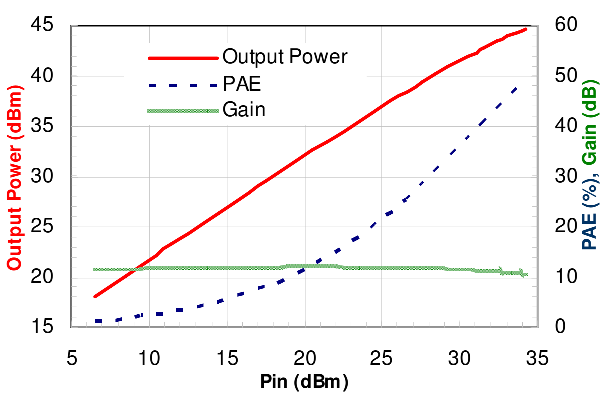

Fig. 12. RF3833: Output Power, PAE and Gain at 1000MHz

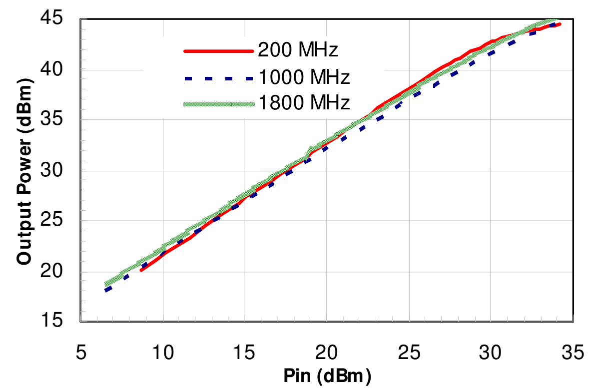

Fig. 13. RF3833: Output power over drive for various frequencies

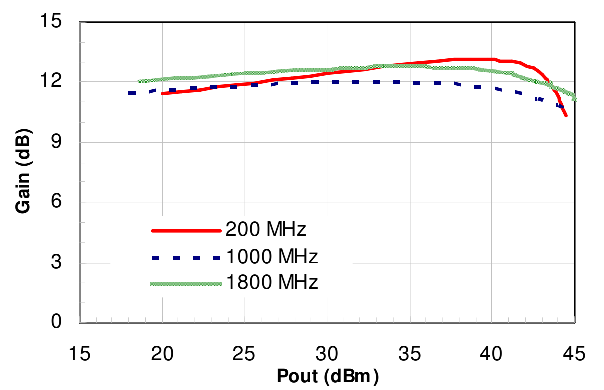

Fig. 14. RF3833: Gain vs. output power at various frequencies

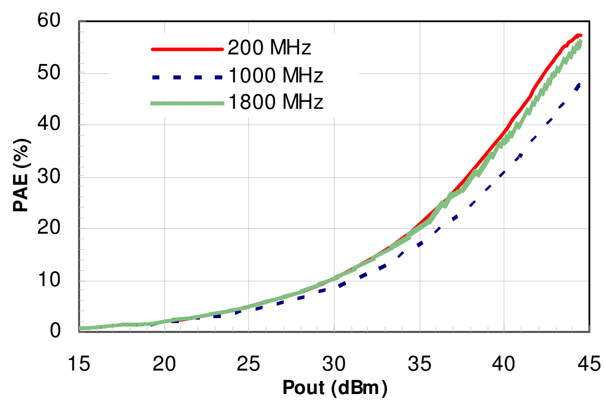

Fig. 15. RF3833: PAE vs. output power at various frequencies