Variable Output, High Efficiency-Low Distortion S-Band Power Amplifiers and Their Performances Under Single Tone and Noise Power Excitations

A. Platzker, S. Bouthillette

Raytheon Advanced Device Center
358 Lowell Street, Andover, Massachusetts 01810

Abstract - A family of one stage, high efficiency-low distortion variable output power MIC amplifiers for narrow band applications at S-band was developed. The amplifiers utilize 0.5µm gatelength PsHEMT devices with 4.8mm to 19.2mm peripheries. High efficiency (>60%) is maintained under CW operation at 2.45GHz over 12dB of input range by varying Vds between 2 and 8V. At 2.45GHz, amplifiers with 19.2mm devices biased at Vds=8V, provide 12W of single tone power at 62% PAE with 13dB gain (1dBc) and 36.5dBm noise power at NPR=17dB (40MHz wide noise with 700KHz notch) with 43% efficiency.

INTRODUCTION

Non distorting power amplifiers which operate at high efficiency over a range of input powers are useful for communication applications in which the conservation of prime power is important. A family of such amplifiers where high efficiency, linear operation is maintained over a 12dB range of input powers has been developed for narrow band (200-300MHz) applications at S band. The amplifiers use 0.5µm long gates PsHEMT devices and the high efficiency is achieved by varying the drain voltages of the devices over the range of 2 - 8 Volts.

The family of amplifiers comprises single stage, single device, hybrid MIC amplifiers with device peripheries in the range of 4.8mm to 19.2mm. Operating at Vds = 8V, the family of amplifiers delivers 3W to 12W of output power with single tone excitation. The amplifiers operate at a minimum of 60% power added efficiency and provide 13 - 15 dB of associated gain with less than 1dB of gain compression.

PsHEMT DEVICES

The characteristics of our PsHEMT devices make them ideal choices for usage as high efficiency, linear power amplifiers with variable output capabilities. The high gain at low drain currents and the sharp pinchoff at large drain voltages enable the devices to operate very efficiently over very large portion of their I-V characteristics. Our amplifiers maintain their linearity, bandwidth and high efficiency when their drain voltages are reduced to as low a value as 2V. This is accomplished without retuning the amplifiers at each drain voltage - the amplifiers are fixed tuned. Amplifiers with comparable performance have not been previously demonstrated with any solid state devices.

The PsHEMT devices have been described in recent publications (1,2). The open channel currents are 500-600mA/mm, the pinch-offs -0.6 to -0.8V and the gate-drain breakdowns 14-20V. The gates are 0.5µm long and have 300µm unit peripheries. The gate to gate spacings are 40µm and the source to drain 3µm. The gates are connected to a bus bar running along the devices. Gate and source pads are interleaved on the input side. The sources are airbridged over the gate bar and each group of four is connected to a pad which is grounded through a via. A bonding pad is provided for each group of eight gates. The drains are connected on the output side to a wide bar suitable for bonding. The devices are 100µm thick.

AMPLIFIERS DESIGN

The amplifiers are designed to provide the devices with 45Ωmm in parallel with -0.3pF/mm on the output and 1Ωmm in series with 3pF/mm on the input. Both input and output matching networks are composed of two parts: (a) 15mil thick l/4 long (ZrSn)Ti Oxide with ε_r=38 transform the device impedances to 20Ω and (b) l/4 long 15mil thick aluminas complete the transformation to 50Ω. A stub is provided for second harmonic short on the output side. Biases are injected through shorted stubs on the aluminas. The 4.8mm amplifiers did not require additional tuning and perform properly as assembled, larger peripheries require additional tuning which was provided by bonding ribbons to experimentally determined positions. A

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second iteration of the design will incorporate these slight modifications.

AMPLIFIERS PERFORMANCE

The performance of the amplifiers under single tone excitations are summarized in Figures 1 and 2. Figure 1 shows a typical small signal response of a 4.8mm amplifier; larger peripheries amplifiers have similar responses. The bandwidth is 300-400MHz and the gain

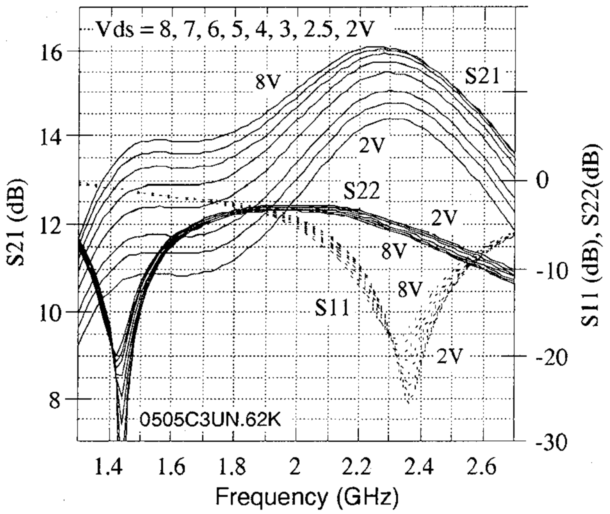

Fig 1. S-parameters of untuned 4.8mm PsHEMT amplifier at Vds=2V to 8V, Vgs=-0.62V. (Ids=49.4mA at Vds=8V, Ids=31.2mA at Vds=2V)

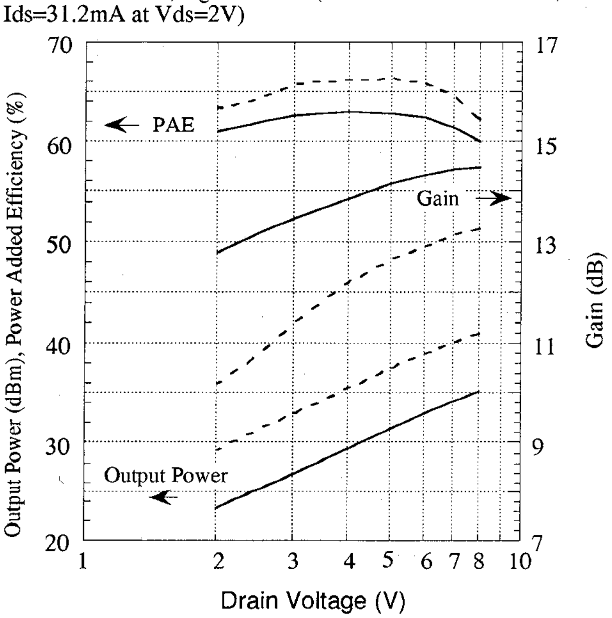

Fig 2. Single tone 2.45GHz power performances of 4.8mm and 19.2mm power amplifiers at 1dB gain compressions as a function of drain voltage (log scale). 4.8mm: Vgs=-0.62V (Small signal Ids=60.3mA at Vds=8V, 32.9mA at Vds=2V) 19.2mm: Vgs=-0.65V (Small signal Ids=237.8mA at Vds=8, 101.2mA at Vds=2V)

decreases by approximately 1.5dB as the drain bias is varied from 8V to 2V. Somewhat larger decreases are observed for larger devices. Over the band of interest, the input match is <-10dB. Figure 2 shows the Output powers, Gains and Power added efficiencies of typical 4.8mm and 19.2mm amplifiers at 2.45GHz. All the attributes are at 1dB of gain compressions and are displayed as a function of Vds in logarithmic scale. Higher than 60% power added efficiencies are achieved at all drain voltages. The output powers are seen to scale with periphery and to vary linearly with log(Vds).

The linearity of the amplifiers was determined by measuring their Noise Power Ratio with an automated measurement setup built around an NPR test set manufactured by Noise/Com of Paramus N.J. The measurement determines the total distortion at the middle of the band of operation due to the intermodulations of all the adjacent channels. Such intermodulations are caused by the nonlinearities of the amplifiers. This measurement is a natural extension of the familiar 2-tone intermodulation measurement to n-tones. The measurement is performed by sending two successive signals to the amplifiers: One signal is white noise of the required bandwidth, the other signal is the same as the first but with a deep notch at the middle of its band. The amount by which the notch is filled as it passes through the amplifier is the Noise Power Ratio of the amplifier. All our measurements were performed with a 40MHz wide signal with a 700KHz notch at 2.45GHz.

The performances of 4.8mm and 19.2mm amplifiers under noise excitation are shown in Figures 3 and 4.

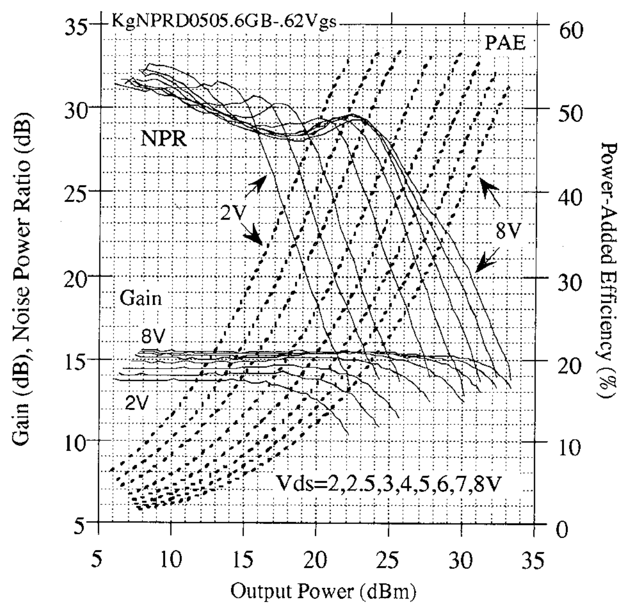

Fig 3. Noise power performance of as assembled 4.8mm PsHEMT power amplifier at Vds=2V to 8V, Vgs=-0.62mA (Small signal Ids=56.7mA at Vds=8V, 31mA at Vds=2V)

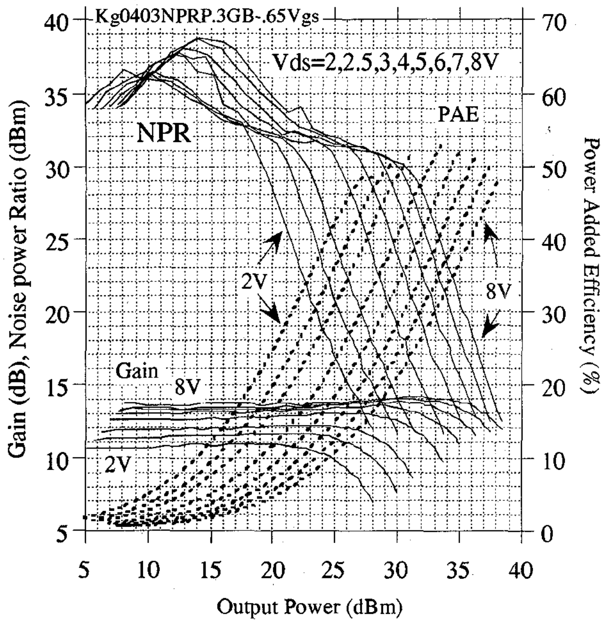

Fig 4. Noise power performance of permanently tuned 19.2mm PsHEMT power amplifier at Vds=2V to 8V, Vgs=-0.65V (Small signal Ids=232mA at Vds=8V, 90.1mA at Vds=2V)

Shown in the figures are the NPRs gains and Power added efficiencies of the amplifiers as the drains varied from 8V to 2V. Excellent performance is obtained over the entire range. Summaries of the salient features of the amplifiers under noise and single tone 2.45GHz excitations are shown in Figures 5 and 6. The figures show that the difference between the 1dB single tone performance and the performance under noise signals varies with device peripheries. The final two figures, 7 and 8, show the effect of varying the gate bias of the 4.8mm amplifier on its noise performance. Under high gate bias (more positive, higher Ids), the noise performance suffers adversly at high drain values while under low gate bias (more negative, less Ids) it suffers adversly at low drain values. Our experiments have shown that optimum noise performance of all our amplifiers can be obtained over a 0.1V range of gate bias.

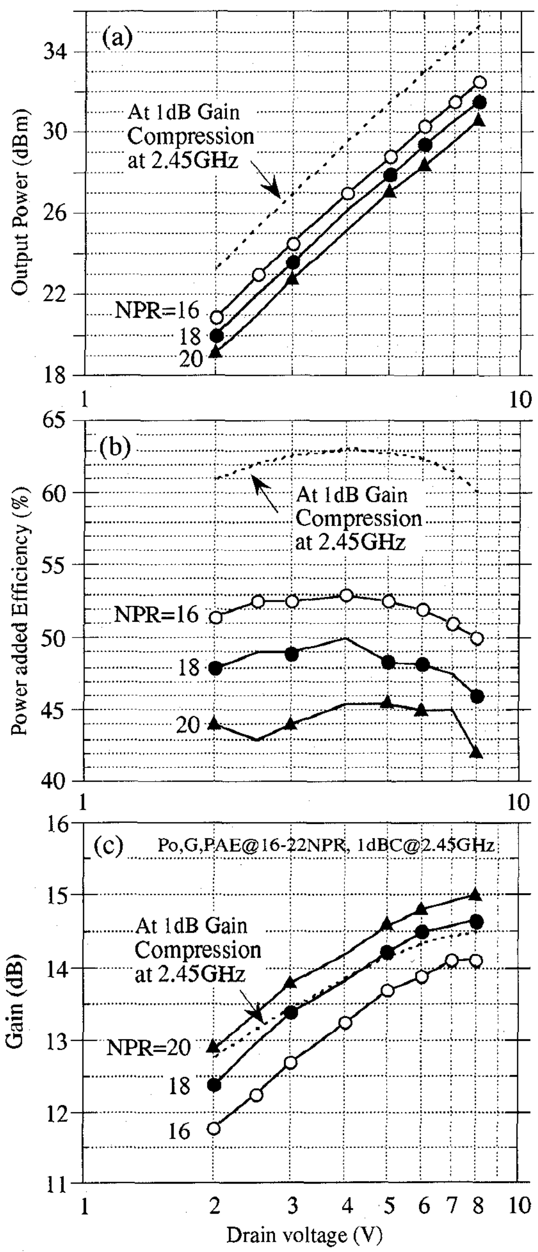

Fig 5. Noise power performance of as assembled 4.8mm PsHEMT power amplifier as a function of drain voltage in log scale. Vgs=-0.62V (Small signal Ids=56.7mA at Vds=8V, 31mA at 2V).

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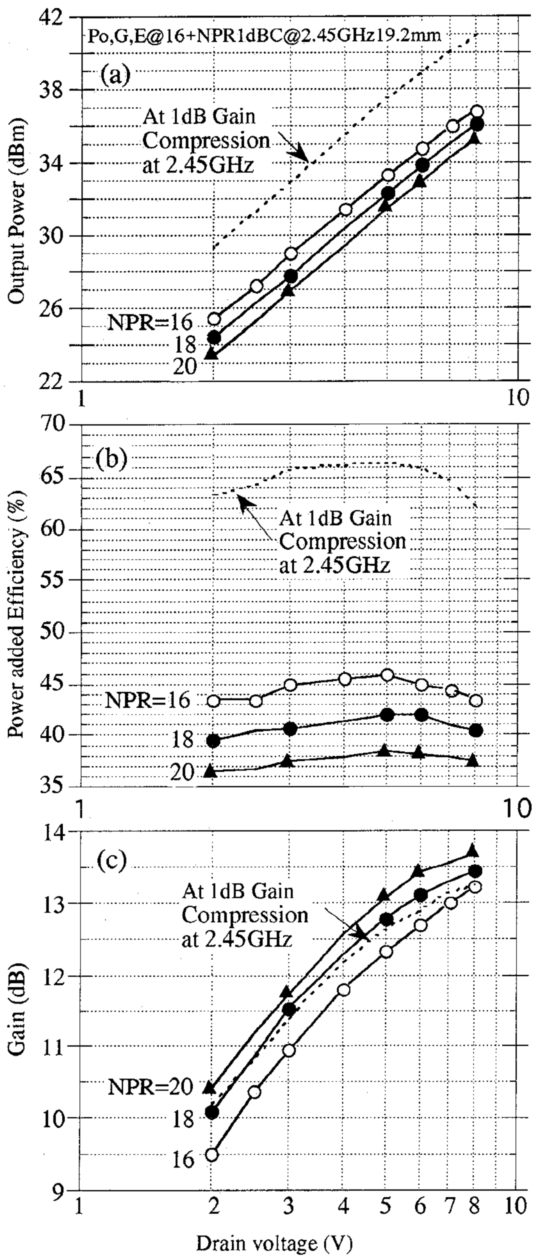

Fig 6. Noise power performance of permanently tuned 19.2mm PsHEMT power amplifier as a function of drain voltage in log scale. Vgs=-0.65V (Small signal Ids=232mA at Vds=8V, 90.1mA at 2V) at .

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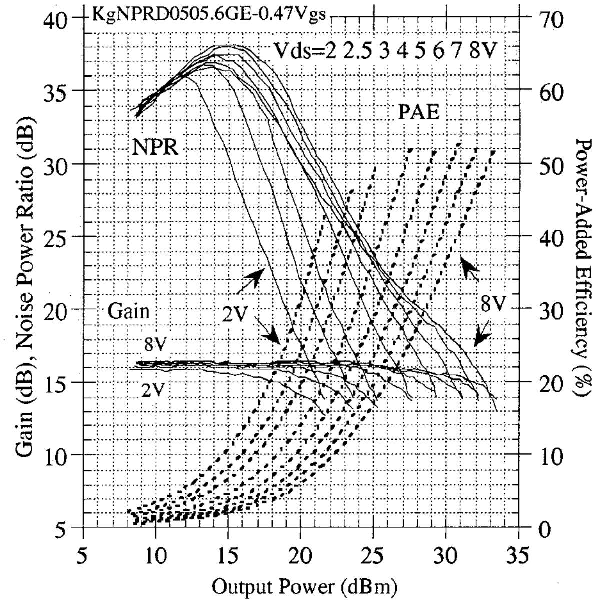

Fig 7. Noise power performance of as assembled 4.8mm PsHEMT power amplifier as a function of drain voltage in log scale. Vgs=-0.47V (Small signal Ids=196.5mA at Vds=8V, 145.7mA at 2V)

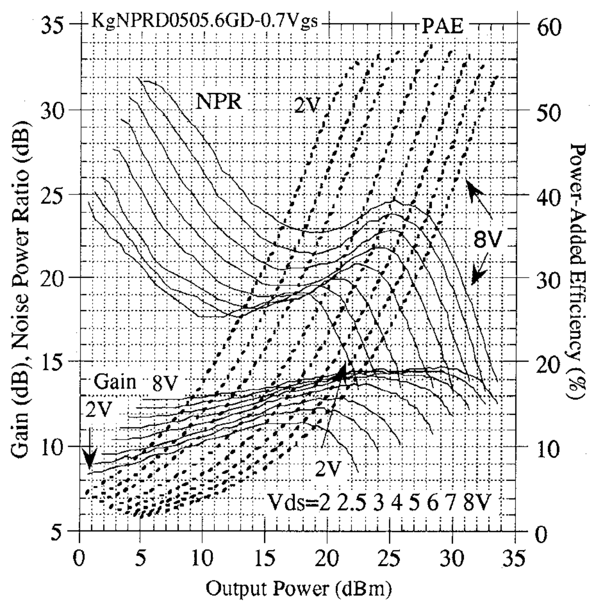

Fig 8: Noise power performance of as assembled 4.8mm PsHEMT power amplifier as a function of drain voltage in log scale. Vgs=-0.7V (Small signal Ids=23.2mA at Vds=8V, 11.1mA at 2V)