High Efficiency Class-E Amplifier Utilizing GaN HEMT Technology

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Abstract

A class-E power amplifier based on a GaN HEMT cell has been designed and tested. Around 2GHz, the amplifier provides 10 watts with associated PAE of 85% and gain of 12dB. Class-E amplifiers have shown high power and PAE at VHF and high efficiency at S-band, but this result is the first demonstration of class-E efficiency with high associated power, greater than 10 watts, at microwave frequencies. The unique combination of high current HEMT operation and high breakdown voltage afforded by wide-bandgap technology, inherent with GaN HEMTs, makes this result possible.

Introduction

The GaN HEMT cell used for this design nominally provides 10 watts at p1dB with associated gain of 17dB at 2 GHz when operated in class-AB mode. The breakdown voltage is typically greater than 100 volts.

Ideal class-E operation produces drain voltages approximately 3 times greater than the bias voltage. Another limitation that has been derived for ideal operation relates bias voltage, peak current, output capacitance and maximum operating frequency is shown in the following expression:

$$fmax := \frac{Imax}{56.5 \cdot 10^{-12} \cdot cs \cdot vcc}$$

Based on this expression, power can only be optimized with high breakdown voltage if the ratio of Imax to output capacitance remains high. Considering all active devices available for use in microwave amplifiers, GaN HEMTs offer the best trade for class-E operation.

Design and Results

A non-linear model of the GaN HEMT has been developed and used to design a class-E hybrid amplifier which operates around 2 GHz. The output match is based on classic class-E theory, integrating the entire drain-source capacitance, Cds, into the output matching network design. The input match is designed to provide a reasonable match at approximately 25% Idss, which is the full power operating point. This should provide peak gain under full RF drive. The amplifier has been constructed using alumina substrates on which the input and output distributed networks are fabricated. The amplifier, as constructed, is shown in Figure 1. The amplifier has been measured for saturated output power and PAE around 2GHz with results shown in Figure 2. The PAE is greater than 82% with output power above 10 watts form 1.9 to 2 GHz. Since the class-E amplifier is modulated through the drain supply, a plot of power and PAE with drain voltage is shown in Figure 3.

Conclusions

A 10 watt class-E amplifier operating at 2GHz with ~84% PAE has been demonstrated using GaN HEMT technology. The high current and breakdown voltage, along with high Ft that are possible using the GaN HEMT make high frequency class-E operation possible.

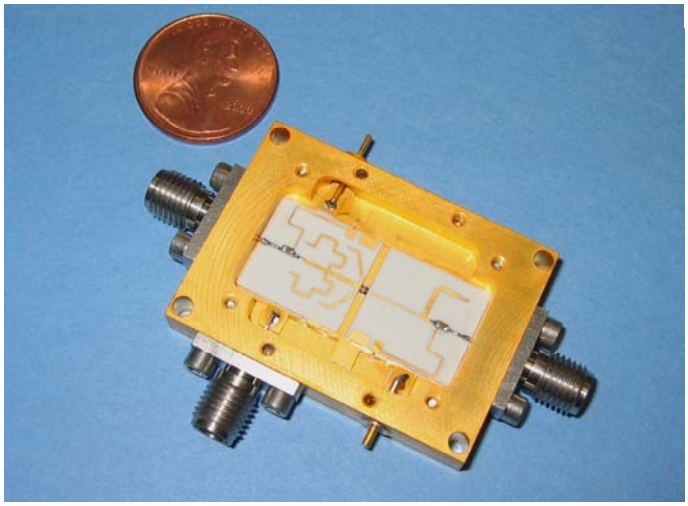

Figure 1 – Class-E Amplifier Module

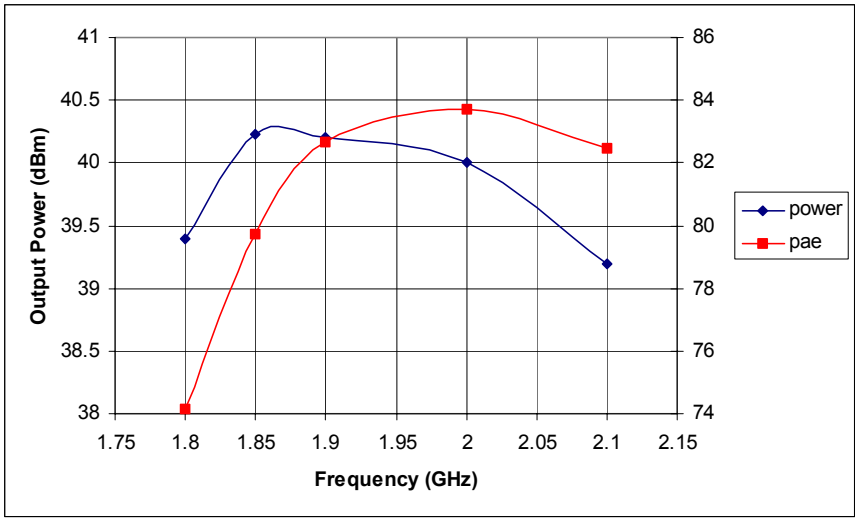

Figure 2 – Class-E Amplifier Measured Performance

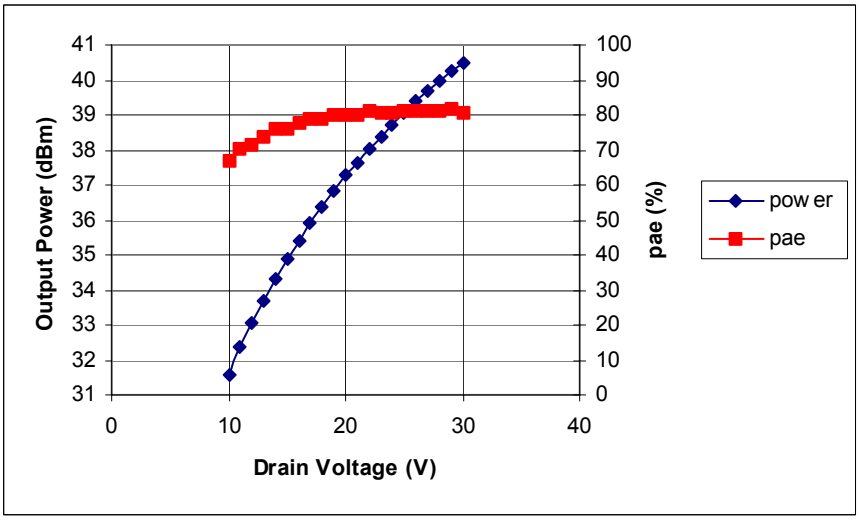

Figure 3 – Class-E Amplifier Drain Modulation