A 3.5 Watt High Efficiency GaAs Fet Amplifier for Digital Telephone Communications.

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Abstract

A high efficiency 3.5 watt power module intended for commercial application in the digital cellular telephone market is described. The demonstration circuit is designed to be coupled with a functional gain control circuit or can be a stand alone power stage. The GaAs FET module operates at 6.2 volts, produces 35.5 dBm of output power, 12.5 DB of gain, and 53 % power added efficiency in the 890 - 920 Mhz frequency range.

Introduction

Servicing the expected growth of personal telephone subscribers will require the advancement of digital communication techniques. With predictions of 150 million subscribers by year 2000, consumer cost is a driving issue. Using GaAs FET devices in a common source configuration, operating class AB, provides the relatively good linearity performance and very high efficiency required for such digital applications. Additionally, GaAs offers the ability to operate at low voltages (down to 3 volts) with the same high efficiencies.

Device Material and D.C Parameters

To achieve the desired power level for the application a single 15 mm gate periphery die was selected for the design. The FET layout consists of 120 fingers, each 125 microns wide and 0.5 microns long. The structure has 12 cells , each cell containing a group of 10 fingers. The channel layer is a grown epitaxial film using MBE technology. Wrap around grounds were used for source grounding. D.C. characteristics include pinchoff voltage: -2.5 to -2.0 volts, IDSS: 3.0 - 4.5 amperes, breakdown voltage (gate to drain) : -22 to -20 volts, and transconductance 1440 - 2160 mS.

Device Modeling

For small signal characterization, standard S-parameter measurements were performed. For large signal characterization, a semi-automatic load pull system using automatic coaxial tuners, switches, and a HP-8510 network analyzer was used. From these measurements, performed on a 1.8 mm die, a simplified broadband equivalent circuit applicable to both the input and output of the device was optimized. The equivalent circuit and impedance values for the 15 mm die were scaled from the 1.8 mm die and are shown in Figure 1. The model was originally established for X and Ku-band applications but was used for the first iteration of this module.

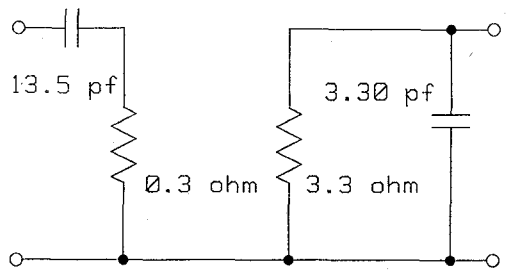

Figure 1. Large signal equivalent 1 port models for 15 mm die.

Design

The module layout is shown in figure 2. The active circuit measures 13 mm x 14 mm. The 50 ohm line can be removed to accommodate a functional gain/driver circuit. The dice is attached directly onto a 0.025 inch thick Beryllium Oxide substrate using AuSn euthetic . The BeO material provides the needed thermal conductivity, has excellent RF loss characteristics, and being a well established material is inherently less risky than other new technology substrates. The carrier is made of Lanxide, an aluminum composite. Sheet epoxy with both high thermal and electric conductivity is used for substrate to carrier attach.

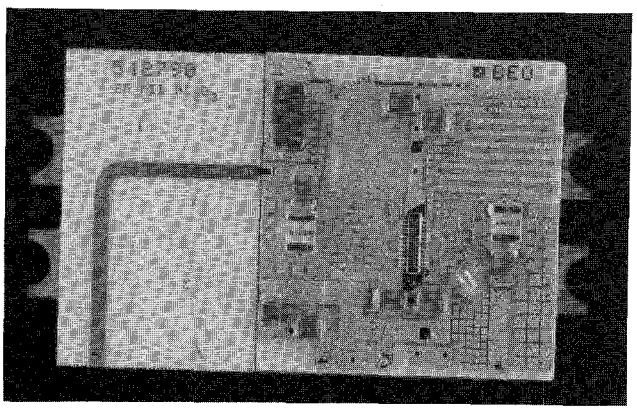

Figure 2: 3.5 Watt GaAs High Efficiency Amplifier.

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The design and layout was optimized using Touchstone and based on the two port unilateral equivalent model shown in Figure 2. At 900 MHz an input Q of 43 was calculated. With a Q this high the bandwidth of the matching topology will be very narrow unless de-Q techniques are employed. One such network employed a series of 12 ohm thin film resistors in series with the gate, however the gain degraded significantly. To help stability, a shunt inductor with 500 ohms of series resistance terminated with an R.F. ground was placed at the gate of the device.

The device input, being a capacitive impedance, is matched to 50 ohms via a classical approach using a 2 element series L - shunt C network. For realization, a printed series line and a shunt 9 picofarad chip capacitor were used. Gate bias is provided through a quarter wave short R.F. circuited stub.

The output , being of much lower Q will be much more forgiving to element variations as compared to the input. From the device output a series printed inductor terminated with a 7 picofarad shunt chip capacitor provides the 50 ohm match. Drain bias is provided through a wide printed line, which is electrically very short, placed as close to the die as possible so as to minimize ohmic losses. A second quarter wavelength stub (@ f= 900 MHz) is also added for harmonic tuning (a second harmonic stub). Both input and output ports are D.C. blocked using 470 picofarad capacitors and R.F. grounding occurs through 6800 picofarad capacitors. A .1 microfarad capacitor in the gate biasing network is provided for stability at frequencies in the MHz range.

Module Tuning

Once the power and gain were optimized the tuning for efficiency started. The goal being primarily to lower the class AB operating current without effecting power or gain. Quarter wavelength harmonic tuning proved successful in significantly reducing the power in the second harmonic and thus raising the efficiency. A hand made air wound coil was placed in the drain bias line for additional efficiency improvement.

Module Performance

The operating voltage (Vds) is 6.2 volts, with a quiescent current of 800 mA and class AB operation pulling up to 1100 mA typical. A negative five volts is required for the gate bias. The typical output power, associated gain and power added efficiency is shown in Table 1. The harmonic data, shown in Figure 3, demonstrates the effectiveness of harmonic tuning.

Freq (MHz)	Gain (dB)	Output Power (dBm)	Power Added Eff. (%)	Drain Eff. (%)
890	12.66	35.66	53.01	56.05
900	12.68	35.68	53.06	56.08
915	12.75	35.75	53.29	56.28

Vdrain = 6.2 volts
Pin = 23 dBm

Table 1: Typical gain, power, and efficiency of 1 stage module.

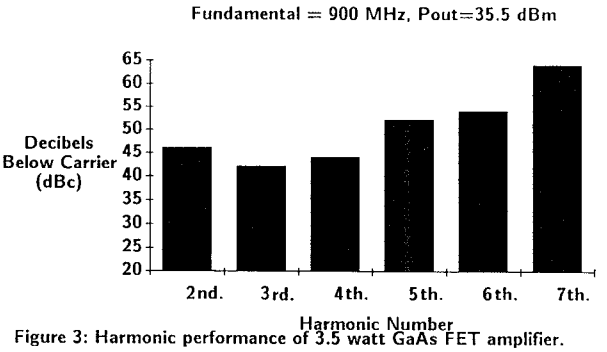

Figure 3: Harmonic performance of 3.5 watt GaAs FET amplifier.

Conclusion

A high efficiency 3.5 watt module destined for use in the digital cellular telephone market has been demonstrated. Work in the area of L band modeling of power GaAs devices, the effect of harmonic tuning and the development of both large signal and high efficiency models is currently being addressed. The cost of the BeO substrate material is expected to reach 1 dollar per square inch, in a high volume application, making this substrate a very cost effective approach. This module can therefore be cost effective for commercial applications.

Acknowledgments

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