HIGH EFFICIENCY BROADBAND POWER AMPLIFIER MMIC

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ABSTRACT

A GaAs broadband, dual-channel high-efficiency power amplifier MMIC is presented in this paper. The average performance for a single channel of the power amplifier is 18.0 dB small-signal gain, 16% power-added efficiency, and 2 dB compressed output power of 29.4 dBm from 6 to 18 GHz at 25°C. The two channels combined off chip achieve 32 dBm average output power. This 0.5 µm ion-implanted MESFET amplifier MMIC has been demonstrated in volume production with 154 wafer starts over 3 months resulting in a 30% total yield through fixtured RF test.

INTRODUCTION

Many multi-purpose systems require high-efficiency wideband power amplifiers. This paper describes the design, fabrication, and performance of a balanced power amplifier developed for the MIMIC program which achieves high gain and efficiency using a single MMIC. A comparison of published 6- to 18-GHz MMIC power amplifier performance with a nominal 1-W output power is summarized as follows: a two-stage design which demonstrated an average 16% power-added efficiency and 10-dB gain in volume production[1] and a four-stage design which demonstrated an average 12% power-added efficiency and 18.5-dB gain for a single device[2]. The three-stage power amplifier presented in this paper demonstrates nominally 1-W output power, an average 16% power-added efficiency and 18-dB gain from 6 to 18 GHz. This performance represents the mean of a random sample of 116 devices from 122 completed wafers. The best device from this random sample demonstrated an average 18% power-added efficiency and 20.5-dB gain from 6 to 18 GHz. This result demonstrates advantages in power-added efficiency and gain level for wideband power amplifier MMICs.

DESIGN

The monolithic GaAs three-stage dual-channel power amplifier shown in Figure 1, employs a 1.2 mm dual-gate FET distributed amplifier driving a two-stage reactive/lossy matched amplifier. The reactive/lossy matched amplifier has a 1.2 mm single-gate FET driving a 1.9 mm single-gate FET. The ratio of the two FETs in the reactive/lossy matched amplifier was optimized to provide maximum efficiency while maintaining an average 1-W output power. A single channel of the power amplifier produces an average 18 dB small-signal gain, 16% power-added efficiency, and 2 dB compressed output power of 29.4 dBm with an input VSWR of better than 2:1 from 6 to 18 GHz at 25°C. The chip measures 4.8 by 6.5 mm. The two channels of the power amplifier may be combined off-chip with either balanced or in-phase combiners to achieve 32 dbm average output power. The amplifier was designed to be interfaced with microstrip media. The amplifier design and layout conform to standard Texas Instruments foundry guidelines to ensure a high yielding device. The Texas Instruments foundry process includes 100% on-wafer probing of each device for RF screening. This device has also been designed for automated assembly techniques such as pick and place, reflow solder processes and automated bonders.

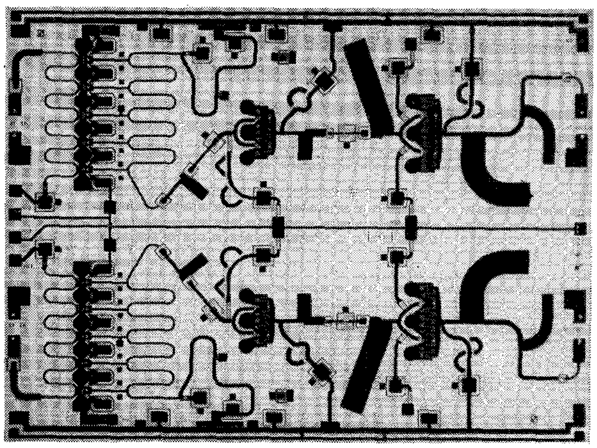

Figure 1. Power Amplifier

FABRICATION

This power amplifier was fabricated using Texas Instruments standard 0.5 µm gate-length ion-implanted GaAs MESFET MMIC process. The design uses MIM

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(metal-insulator-metal) capacitors and is processed on a 3 inch substrate that is thinned to 100 µm prior to process completion. The backside of the wafer is plated with plated-through via holes. The foundry processed 154 wafers with 122 completing processing for a 79% wafer yield. DC final functional probe yield was 75%. After back-side processing was completed, thin wafer RF probe was performed on dc functional devices, yielding 83%. Final visual inspection was 63% and fixtured yield was 98% resulting in a total yield of 30%.

PERFORMANCE

A total of 116 power amplifiers were fixtured and measured for small-signal gain, input return loss, output power and power-added efficiency on a single channel of the device. Bias conditions for the fixtured measurements were Vd=8.0V and Id=650mA for a single channel.

The statistical analysis of the small-signal gain measurements is shown in Figure 2. Average gain from

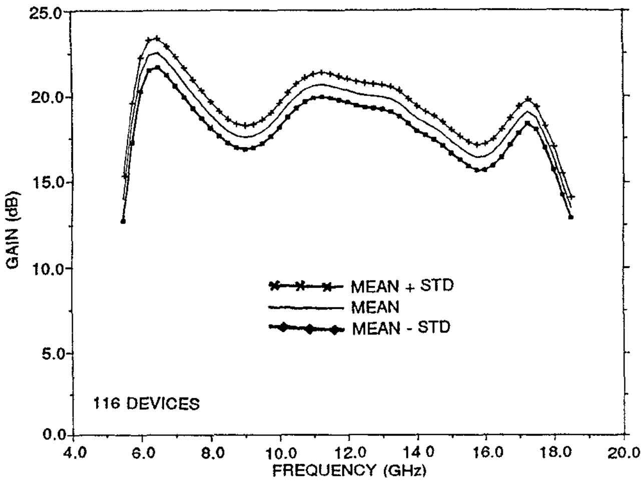

Figure 2. Small-Signal Gain

6 to 18 GHz is 18 dB, with an average gain at X-band of 19 dB and 16.5 dB at Ku-band. RF wafer probe measurements of small-signal gain for 8,100 devices are shown in Figure 3. Correlation between RF wafer probed measurements and fixtured measurements is excellent.

The statistical analysis for output power of a single channel of the power amplifier at 2 dB compression and room temperature is shown in Figure 4. The average output power from 6 to 18 GHz is 29.4 dBm. The maximum average output power, 30.8 dBm, occurs at mid X-band while mid Ku-band performance is 28.7 dBm. The output power at 2 dB compression at -55°C and +90°C relative to the output power at 25°C is shown in Figure 5. The degradation in power from 25°C to 90°C averages 0.3 dBm from 6 to 18 GHz.

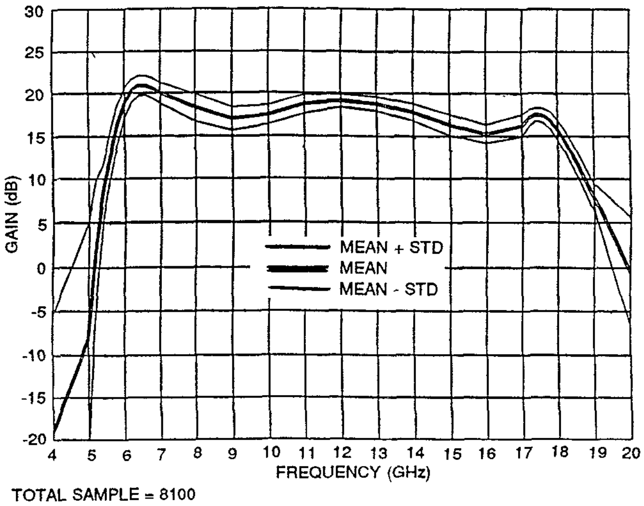

Figure 3. On-Wafer Probe Gain Distribution

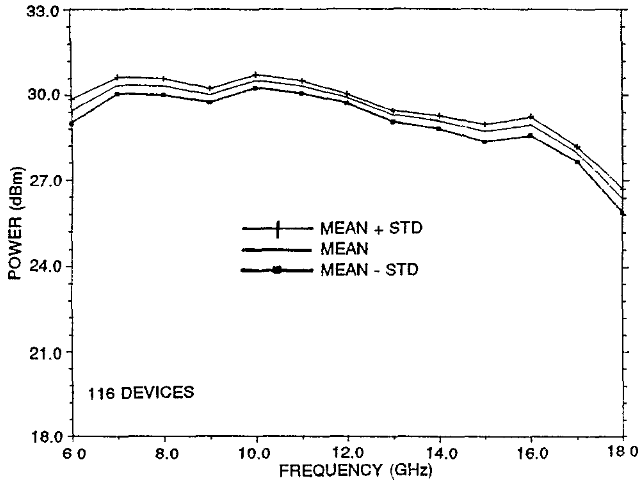

Figure 4. Single-Channel Output Power

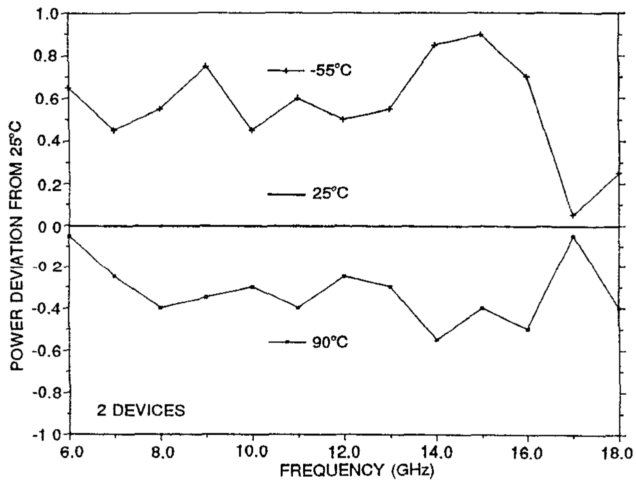

Figure 5. Single-Channel Power Relative to Power at 25°C

The statistical analysis of the power-added efficiency at 2 dB compression is shown in Figure 6. The average power-added efficiency at 2 dB compression from 6 to 18 GHz is 16.0%. The maximum, 21.9%, is mid X-band while mid Ku-band performance is 13%.

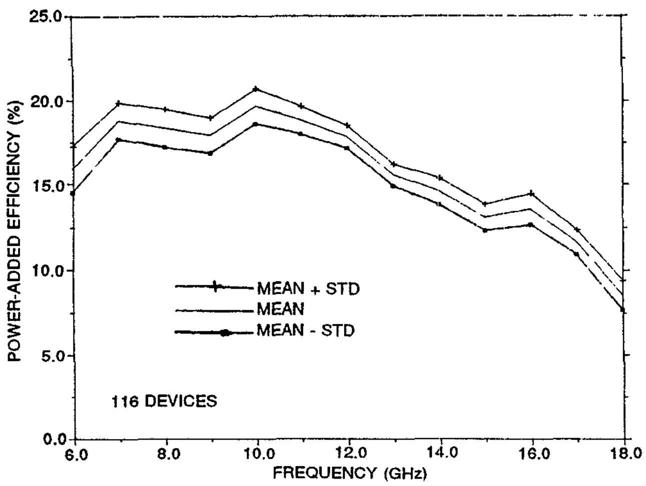

Figure 6. Power-Added Efficiency at 2-dB Compression

CONCLUSION

A broadband high efficiency MMIC power amplifier has been designed. While maintaining a nominal 1-W output power, this power amplifier has demonstrated significant improvements in gain and efficiency over 6 to 18 GHz and is suitable for insertion into broadband EW applications.

ACKNOWLEDGEMENTS

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