A 15-WATT DUAL BAND HBT MMIC POWER AMPLIFIER

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Abstract

A monolithic HBT power amplifier is presented for S and C band applications. The amplifier provides greater than 15 watts of peak output power at S and C-bands with approximately 18 dB of gain. The amplifier also provides a minimum of 10 watts output power across the entire frequency range that encloses both bands.

Introduction

As a further level of integration in microwave systems, a MMIC power amplifier was designed for operation in both S and C bands. The amplifier was fabricated using Texas Instruments' power HBT process [1]. A photograph of the MMIC is shown in Figure 1. The overall chip size is 6.6 x 9.1 mm. By designing for two distinct bands, excellent performance has been achieved in two bands by one MMIC. To our knowledge, this is the best reported performance to date for such an amplifier.

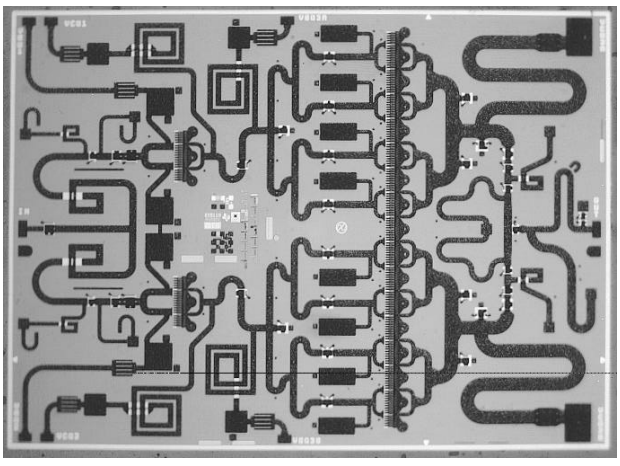

Figure 1: 15-Watt Dual Band HBT MMIC Power Amplifier

Design

The amplifier was specifically designed for two band operation. First, numerous matching network topologies were designed to cover the full bandwidth. Next, computer simulations were performed to see which topologies were best suited for optimization to two distinct bands. The topologies were then downselected and used in the amplifier. This procedure led to relatively complex higher order networks. Nonetheless, it was found at these relatively low frequencies that the networks could accurately be modeled.

To reduce RF and DC losses, the transmission lines were plated twice for a total plating thickness of approximately 11 um of gold. This also reduced resistive losses in the bias lines, in particular the output stage.

Another design challenge was the layout of this chip. Because the active area required for such a high power, the resulting chip size was very large. Reducing this chip size to 6.6 to 9.1 mm to improve yield was accomplished by compacting the matching networks.

The amplifier consists of arrays of 500 um unit cells. Unit cell models were created from 400 um devices and then scaled appropriately. The bias condition at which the 400 um devices were characterized included a collector voltage of 10 volts and a quiescent collector current of 100 mA.

The amplifier was designed using TI custom linear models and load-pull data. The measured broadband large-signal load did not fit a standard model well. In place of a standard model the real and imaginary parts of the large-signal load were fit to equations over frequency and used in the simulator. This empirical model seems to fit very well as tuning the output of the finished amplifier results in only a few tenths of a dB improvement in output power in either band under large signal conditions.

The small-signal HBT linear model used in the design of the power amplifier is shown below in Figure 2.

0-7803-4603-6/97/$5.00 (c) IEEE

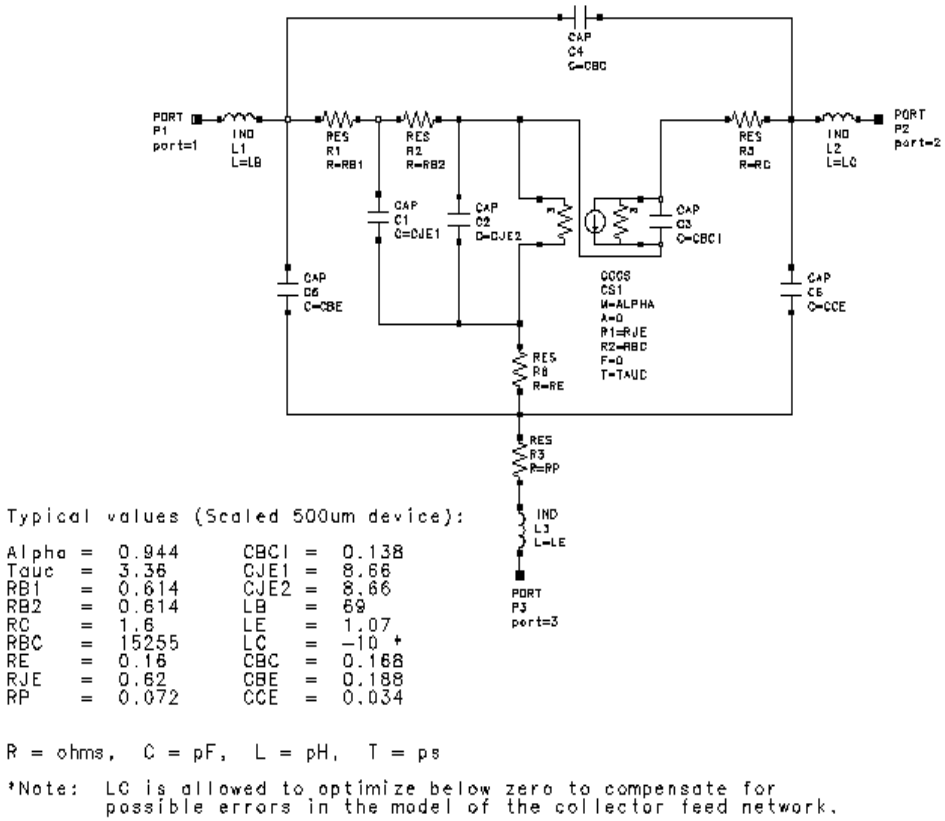

Figure 2: Intrinsic Linear HBT Model Topology and Typical ECPs.

As illustrated, LB, LC and LE are the parasitic inductances associated with metallization, and CBE, CCE, and CBC are the parasitic capacitances across the respective ports. The intrinsic parameters are self-explanatory other than the resistance, RP. Located in series with the parasitic emitter inductance, RP helped greatly in the fitting of S12. Also, in an effort to improve the overall accuracy of the model, the base resistance and the base-emitter junction capacitance were split into two R-C networks to better model the base transit time.

RF Performance

Small Signal:

Figure 3 shows the on-wafer small signal gain of the amplifiers at a collector bias of 9 volts. The modeled vs. measured performance agrees well across both bands with 18-22 dB small signal gain. In a fixture with a proper heat sink and optimized bias, the gain was found to be approximately 2-3 dB higher. The low end performance of the amplifier was further improved with tuning. The overall DC/small signal RF yield of this device is about 55% on a 3 inch wafer.

Large Signal:

Figure 4 shows the pulsed performance of an amplifier after tuning at a collector bias of 8.5 volts. The amplifiers were tested with a pulse period of 100 us, 10% duty cycle and an incident power of 24 dBm. In S-band, the amplifier provides between 15.5 and 19.5 watts output power with 32 to 42% power added efficiency. In C-band, the amplifier provides between 15 and 17.4 watts output power with 31 to 41% power added efficiency.

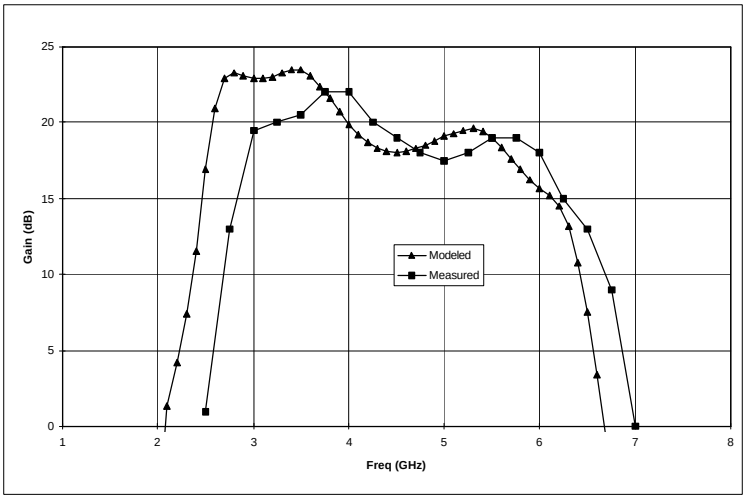

Figure 3: Modeled vs. Measured Small Signal Gain (Vce=9v)

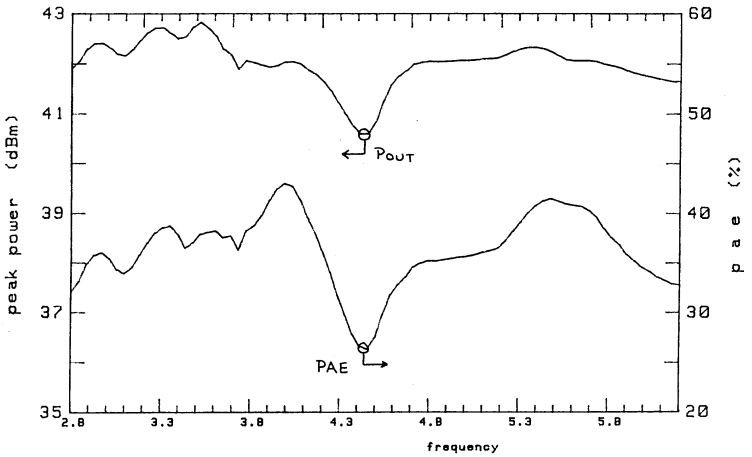

Figure 4: Large Signal Performance Under Pulsed Conditions

Summary

A monolithic HBT power amplifier has been presented. The amplifier can provide greater than 15 watts of output power with approximately 18 dB of gain in two distinct frequency bands in S and C band. A novel device modeling technique was used to achieve excellent broadband large signal amplifier performance.

Acknowledgments

The authors would like to thank Ray Dermott and Alice Hernandez of Texas Instruments, and Dr. James Komiak of Lockheed Martin for their assistance in testing and evaluation.

The authors would also like to thank Jim Adams of Texas Instruments for his design of a concurrent layout tool which was used in the design of this amplifier.

References

[1] Steve Evans, et. al., “Manufacturability and Applications of HBT MMIC Technology”, 1993 Conference on GaAs Manufacturing Technology.