FULLY-MATCHED, HIGH-EFFICIENCY Q-BAND 1 WATT MMIC SOLID STATE POWER AMPLIFIER

Y. Hwang, P. D. Chow, J. Lester, J. Chi, D. Garske,
M. Biedenbender, and R. Lai

TRW Electronic Systems and Technology Division
M5/1017, One Space Park, Redondo Beach, CA 90278

ABSTRACT

A fully-matched, high-efficiency Q-band 1 watt MMIC power amplifier has been developed. This chip utilized 2 mil-thick GaAs substrate to improve amplifier gain, power added efficiency and heat dissipation. 1 watt output power and 30% efficiency was achieved at 44 GHz.

INTRODUCTION

A number of HEMT power amplifiers at millimeter wave have been reported [1]-[8]. A high power, high efficiency power amplifier is a critical component in the Q-band transmitter for Milsatcom terminal applications. Due to the additional size, weight and insertion loss of the combining network at this frequency, it is desirable to achieve high output power and efficiency from a single MMIC chip. To address this requirement, a fully-matched, high-efficiency Q-band 1 watt MMIC power amplifier has been developed as shown in Figure 1. The chip size is 4.5 mm x 2.6 mm. This chip utilized 2 mil-thick GaAs substrate to improve amplifier gain, power added efficiency and heat dissipation. It consists of a two-stage amplifier with 0.9 mm HEMT as driver and 2.24 mm HEMT as output stage. 1 watt output power and 30% efficiency was achieved at 44 GHz.

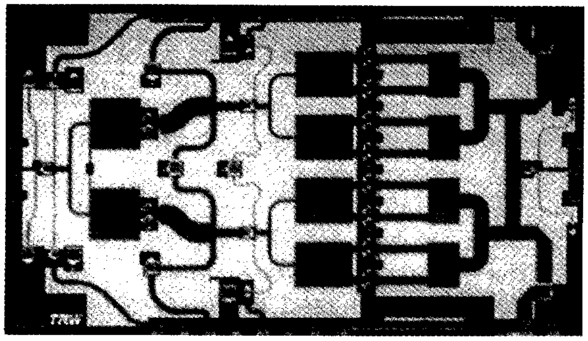

Figure 1 A Q-band 1 watt high-efficiency MMIC chip photo

Q-BAND 1 WATT MMIC CHIP DESIGN

TRW's baseline 0.15 μm GaAs HEMT MMIC power process was used to fabricate the wafers in this work and has been reported [9]-[12]. The MMIC power amplifier reported here is a single-ended two-stage design with the driver stage using a 0.9 mm HEMT, followed by a 2.24 mm HEMT in the output stage. It receives 21 dBm Q-band signals from a pre amplifier and provides 1.0 watt output power. Figure 2 shows the schematic diagram of this fully matched two-stage amplifier. The chip is designed for high output power application based on reactive matching technique. Thin substrate (2 mil) is selected to reduce via-hole inductance, amplifier gain, efficiency and lower thermal resistance. The matching networks includes microstrip lines of different line width. MIM capacitors are used for dc block and RF bypass. EM simulation of matching structure has been performed to achieve good agreement between simulation and measurement results.

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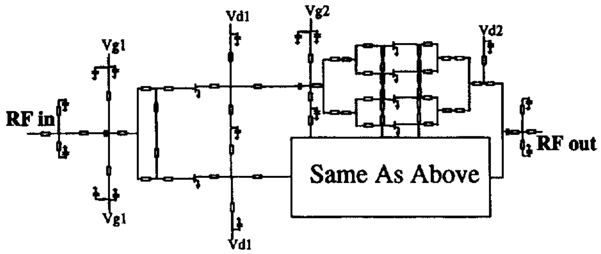

Figure 2 Q-Band high-efficiency MMIC SSPA schematic

PREMATCH STRUCTURE MEASURED DATA VS. SIMULATION

To verify our linear and nonlinear device models, small signal s-parameters of several prematch structure were tested on-wafer. They show good repeatability from chip to chip. Figure 3 shows the prematch structure layout and measured performance vs. simulation. This prematch structure uses 2 of 280 μm device. Amplifier gain and input return loss show good agreement between measurement and simulation. Output return loss shows 0.5 to 1 GHz discrepancy between measurement and simulation. It was biased at Vd=2V and Id= 50% of the drain current at Gm peak.

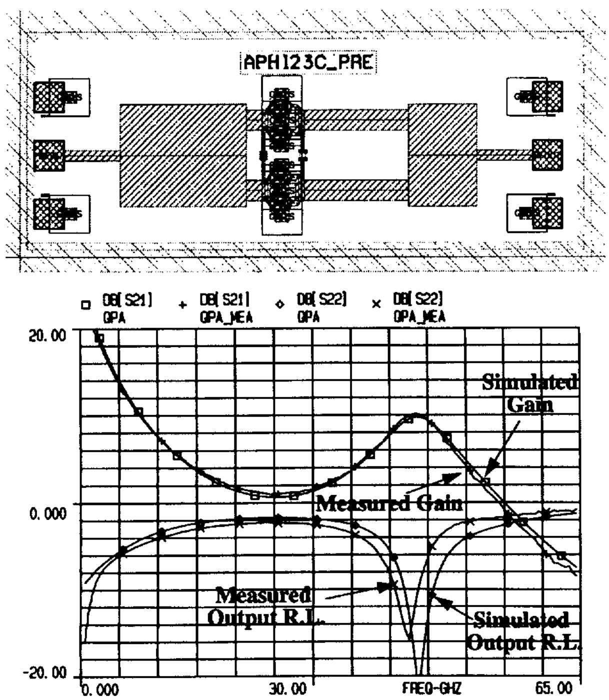

Figure 3(a) Prematch structure layout and measured data vs. simulation

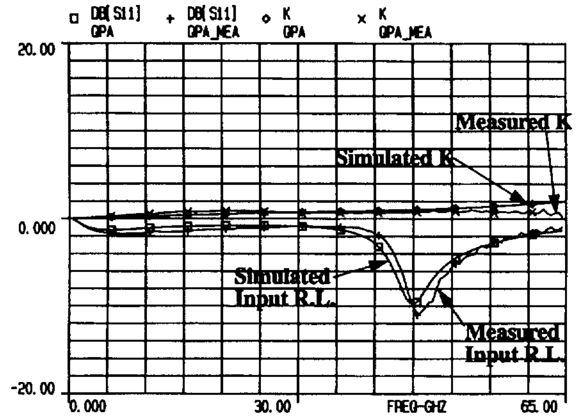

Figure 3(b) Prematch structure measured data vs. simulation

OUTPUT STAGE MEASURED DATA VS. SIMULATION

Small signal s-parameters of several output stage were tested on-wafer. Figure 4 shows the output stage layout and measured performance vs. simulation. They show good repeatability from chip to chip. The output stage consists of a 2240 μm device. Simulated gain shows 2 dB higher, and shifts 1 GHz higher in frequency. Simulated input return loss shifts 1 GHz higher in frequency. Output return loss shows good agreement between measurement and simulation from 40 to 46 GHz. It was biased at Vd=2V and Id=166 mA (50% of the drain current at Gm peak).

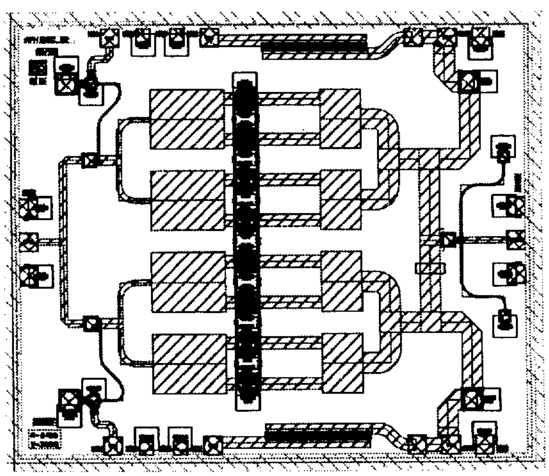

Figure 4(a) Output stage layout

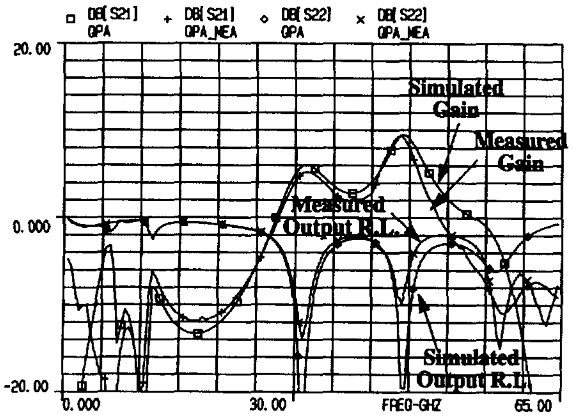

Figure 4(b) Output stage measured data vs. simulation

Q-BAND 1 WATT MMIC LARGE SIGNAL TEST DATA

Table 1 and figure 5 show the measured data of this fully-matched, high-efficiency Q-band 1 watt MMIC power amplifier from 42 to 46 GHz with 21 dBm input power. Both stages were biased at 5V. DC power consumption is about 3 watt (5V, 602 mA). Figure 6 shows output power and efficiency at 44 GHz with input power varying from 0 to 21 dBm. At 44 GHz, it provides 11.5 dB small signal gain. Under large signal operation, it provides 9.2 dB gain, 30.2 dBm output power and 30.6% efficiency with 21 dBm input power. A bandwidth of 2 GHz (output power greater than 950 mW) is achieved from 42.5 to 44.5 GHz. The output power (1.1 watt) and efficiency (32.3%) peak at 43.5 GHz with 21 dBm input power.

Table 1 Measured data from 42 to 46 GHz with 21 dBm input power

F (GHz)	Pout (dBm)	Pout (mW)	Gain (dB)	Eff (%)
46.0	27.33	541	6.33	17.1
45.5	28.10	646	7.10	20.3
45.0	29.08	809	8.08	25.0
44.5	29.90	977	8.90	28.6
44.0	30.20	1047	9.20	30.6
43.5	30.39	1094	9.39	32.3
43.0	30.17	1040	9.17	29.7
42.5	29.87	971	8.87	27.6
42.0	28.73	746	7.73	20.2

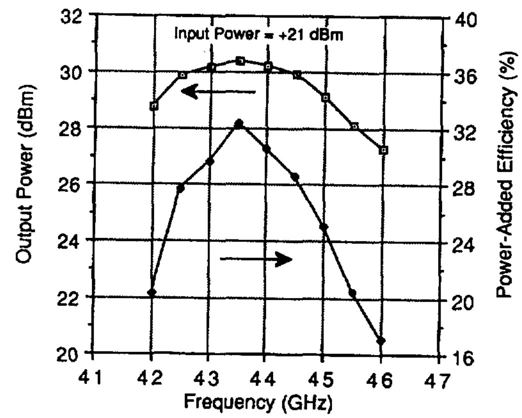

Figure 5 Measured data from 42 to 46 GHz with 21 dBm input power

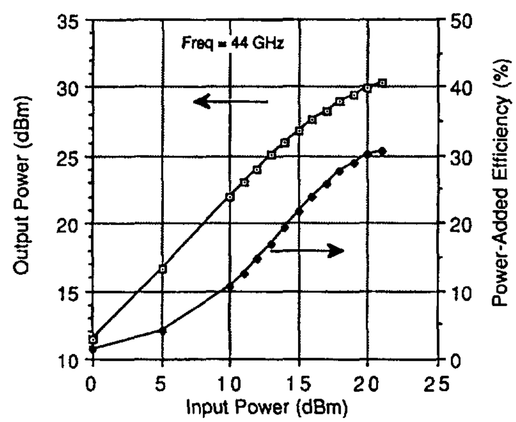

Figure 6 Measured output power and efficiency vs. input power at 44 GHz

SUMMARY

We have presented a Q-band two-stage power amplifier using T-gate power HEMT MMIC process. Measured results show that small signal gain of 11.5 dB, output power of 1 watt and efficiency of 30% have been achieved at 44 GHz, which represent state-of-the-art performance of the monolithic power amplifier at this frequency. Insertion of this chip into Q-band transmitter will enhance system reliability, reduce size and weight due to its high power, high efficiency performance and low thermal resistance.

ACKNOWLEDGMENTS

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