K THROUGH KA-BAND DRIVER AND POWER AMPLIFIERS*

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ABSTRACT

First pass low, medium, and high power MMIC amplifiers operating over the 17 to 40 GHz band have been demonstrated. The low power driver amplifier delivers 8 dBm output power with 8 dB associated gain and the medium power driver amplifier delivers a minimum of 13 dBm with 8 dB associated gain across the band. The high power amplifier delivers 24 dBm output power from 17 to 35 GHz and greater than 22 dBm from 35 to 40 GHz with a minimum of 17.5 dB associated gain. The low power driver amplifier and the high power amplifier were combined to demonstrate a minimum of 22.5 dBm output power with greater than 24.5 dB associated gain across the 17 to 40 GHz band.

INTRODUCTION

There is a need for broadband, high gain, moderate power level MMIC amplifiers in the K-Ka band regime for both military and commercial application. The military desires a compact, light weight TWT driver for electronic warfare systems, while the emerging commercial mm-wave market requires amplifiers at 23, 27, 30, and 38 GHz. The commercial market is caught between the desirability of MMIC technology for ease of high frequency assembly/tuning, and the cost of developing a successful custom design for relatively low volumes. One solution to this dilemma is to use amplifiers that cover multiple bands, thus allowing a higher overall MMIC production quantity which reduces the unit cost.

This paper describes three amplifiers that were developed specifically for 18 to 40 GHz TWT driver applications, but that are also suitable for commercial mm-wave use. The amplifiers were designed to provide low, medium, and high power across the 18 to 40 GHz band. The amplifiers utilize an individual source via PHEMT structure to achieve high gain and power performance over the broad, high frequency band.

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DESIGN

A two stage low power driver amplifier was designed using a distributed topology. The distributed topology yields a compact, wideband amplifier. A single stage distributed amplifier was designed in a 50 ohm system. The second stage design was a slight modification from the first stage.

Each stage of the low power design is composed of four 0.100 mm devices with 0.05 mm unit gate width. The device model used in the design was scaled from a 0.60 mm device. Figure 1 shows a photo of the two stage low power driver amplifier. The amplifier measures 1.7 x 1.9 mm.

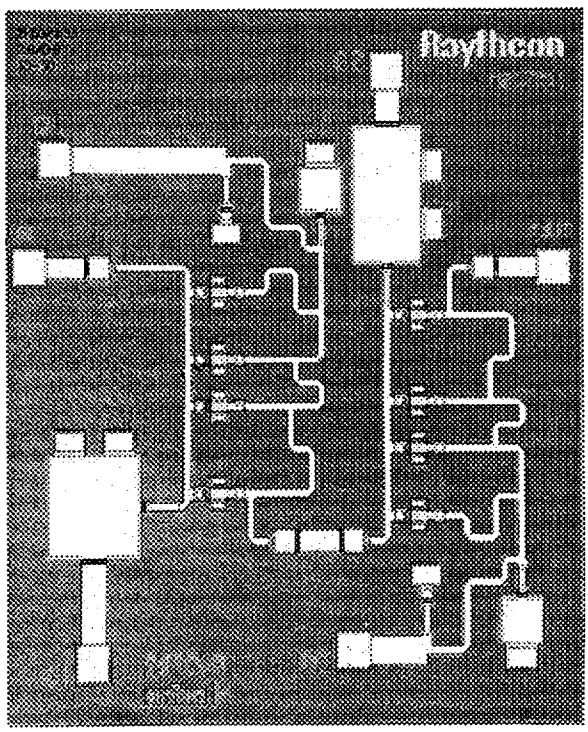

Figure 1. Two Stage Low Power Driver Amplifier.

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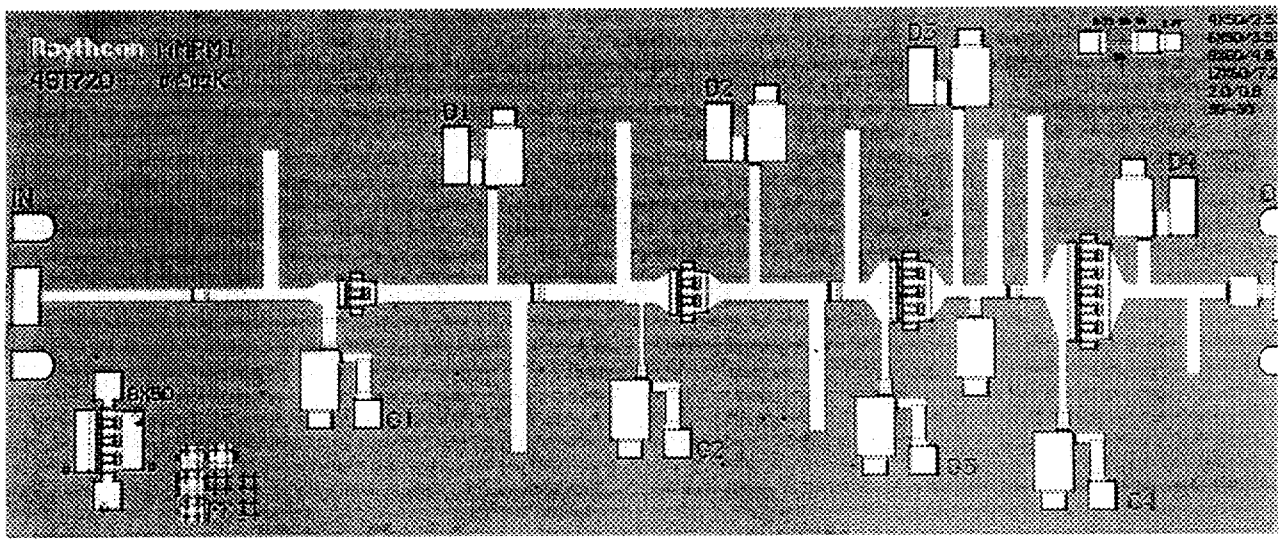

Figure 2. Four Stage Reactive Match Power Amplifier.

The two stage medium power driver amplifier design approach was similar to the low power design. In order to achieve higher power, four 0.20 mm devices with 0.05 mm unit gate width were used per stage. The larger periphery devices necessitated the use of series gate capacitors. The series gate capacitors reduce the effective shunt capacitance of the gate artificial transmission lines [1].

In order to achieve high output power across the 17 to 40 GHz band, a four stage single channel reactive match amplifier was designed. The four stage reactive match amplifier, which measures 4.7 x 1.9 mm, is shown in Figure 2.

The power budget for the amplifier was based on tuned power performance of a 0.60 mm PHEMT device. At 44 GHz, the 0.60 mm device demonstrated 23 dBm output power with 5 dB associated gain. This device performance was achieved at Vds = 5 V and Ids ~ 35% of Imax.

The total device periphery of the amplifier is 1.7 mm in a 0.2 mm driving 0.3 mm driving 0.48 mm driving 0.72 mm configuration.

The optimum power load of the devices was determined from previous Q-band amplifier designs [2]. The devices in the last three stages of the amplifier were matched for power. The input and first interstage circuits were used to tailor the gain response.

In order to synthesize the necessary device power match, reactive matching circuitry typically requires low value (< 0.3 pF) shunt capacitors. At high frequencies, the capacitor to via hole structure is difficult to accurately model. In an effort to minimize modeling uncertainty, the power amplifier was designed without using shunt capacitors as matching elements. Instead, shunt capacitance was realized using open circuited stubs. Lumped capacitors were used for series matching and bypass.

MEASURED PERFORMANCE

The measured performance of the two stage low power driver amplifier is shown in Figure 3. At Vds = 5V and total drain current of 101 mA, the amplifier delivers between 8 and 10.5 dBm output power from 17 to 40 GHz with 0 dBm input drive.

The power performance of the medium power amplifier is shown in Figure 4. Over the 18 to 40 GHz band greater than 13.5 dBm output power with a minimum of 8.5 dB associated gain is achieved.

The connector to connector power performance of the high power amplifier is shown in Figure 5. From 18 to 35 GHz, the amplifier delivers greater than 23.5 dBm output power with greater than 17 dB associated gain and minimum power added efficiency (PAE) of 11%. From 35 to 40 GHz, the output power is greater than 22 dBm with greater than 18 dB associated gain and minimum PAE of 8%. This performance is obtained with all four stages commonly biased at Vds = 5.5 V and total drain current of 380 mA.

The low power distributed amplifier and high power reactive match amplifier were combined to demonstrate high power and gain across the 17 to 40 GHz band. Figure 6 shows the connector to connector measured power performance of the combined

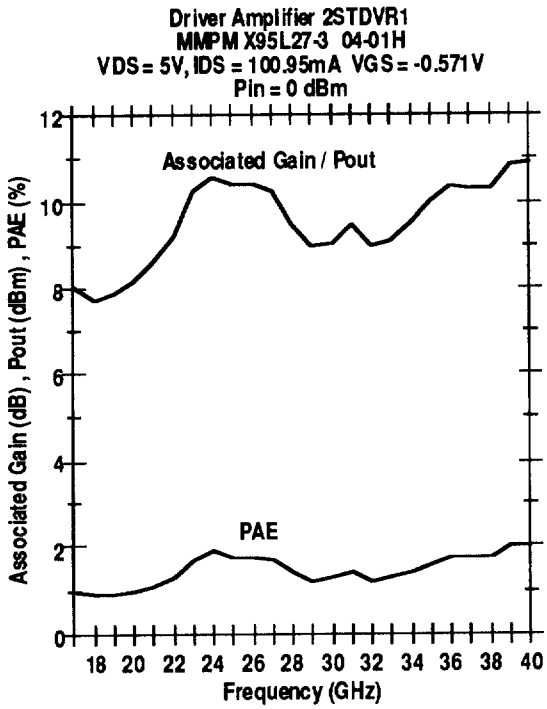

Figure 3. Low Power Driver Amplifier Measured Performance.

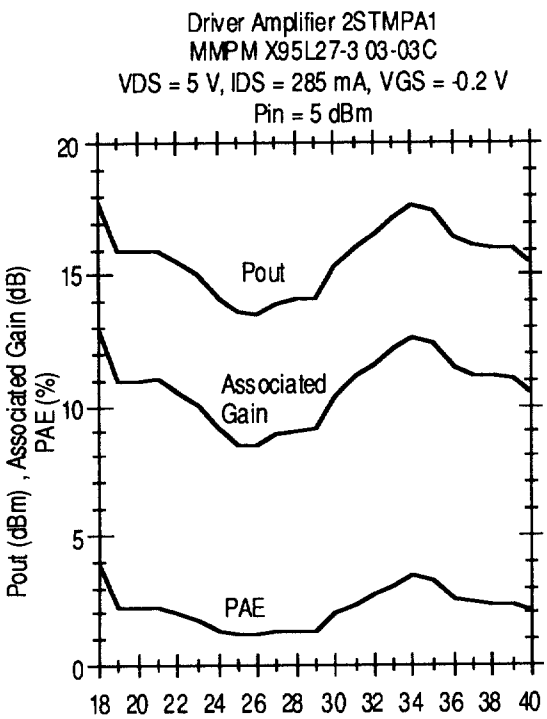

Figure 4. Medium Power Amplifier Measured Performance.

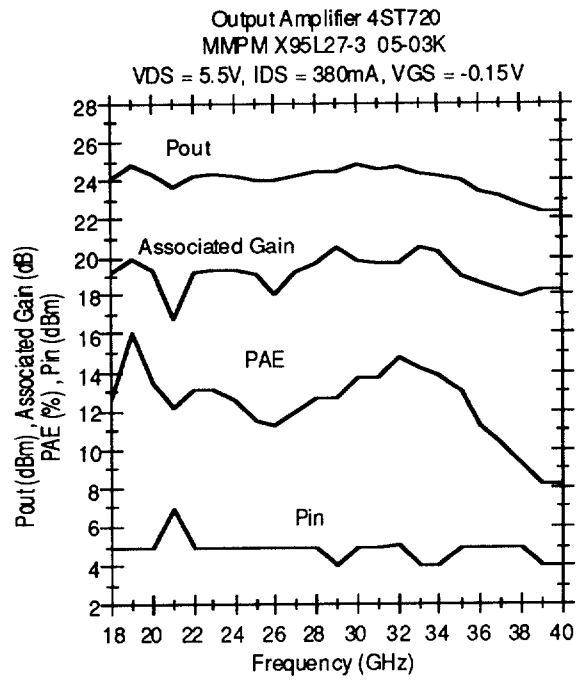

Figure 5. High Power Amplifier Measured Performance.

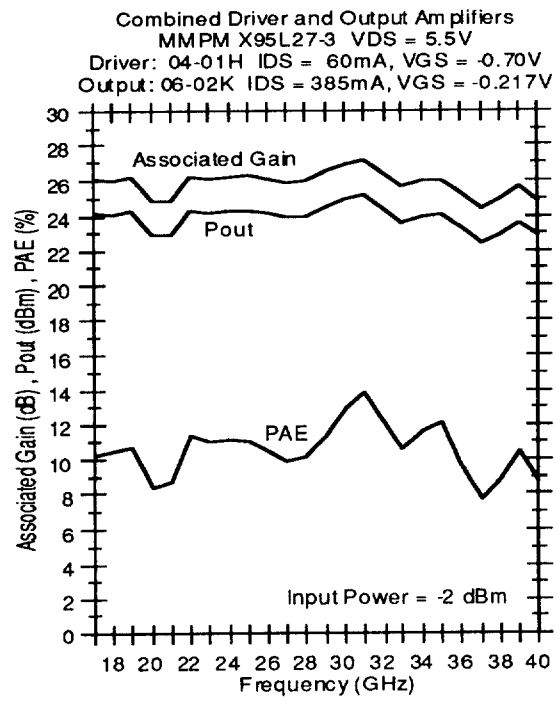

Figure 6. Combined Two Stage Low Power Distributed Driver Amplifier and Four Stage High Power Reactive Match Amplifier Measured Performance.

amplifiers. The amplifiers were biased at Vds = 5.5 V and total drain current was 445 mA. The six stage amplifier delivers greater than 23 dBm output power from 17 to 36 GHz and greater than 22.5 dBm from 36 to 40 GHz at -2 dBm input drive. This results in a minimum associated gain of 24.5 dB across the 17 to 40 GHz band. PAE ranged from 8% to 14% across the 17 to 40 GHz band.

SUMMARY

First pass driver and power amplifiers have been demonstrated over the 17 to 40 GHz band. The driver amplifiers utilized distributed topologies to achieve compact, high gain performance at low to moderate power levels. The high power amplifier utilized a reactive topology to obtain high output power. Reactive matching structures without shunt capacitors were employed to minimize high frequency modeling uncertainties. These three amplifiers were developed specifically for 18 to 40 GHz TWT driver applications, but they are also suitable for commercial mm-wave use.

REFERENCES

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