A Tunable 125 mW K-Band MMIC Power Amplifiers for Point to Point Radio Application

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ABSTRACT

A three stages GaAs MMIC power amplifier in MESFET Technology for point to point radio application that delivers an output power greater than 125 mW, with associated gain higher than 19 dB has been developed. The use of bias feed bonding wires as tuning element has been exploited to shorten the design cycle time and to optimize the circuit performance in the desired frequency bandwidth. The device has a power added efficiency greater than 15% at 1 dB of compression in the frequency bandwidth from 21.2 to 23.6 GHz. A pilot test for production has demonstrated the repetitivity of the good performance and the device has been accepted for large volume production after the first design cycle.

INTRODUCTION

Lately the point to point radio links have been offering to the millimeterwave MMIC devices an unprecedent opportunity of large volume market. The excellent performance achieved in the last years by the GaAs or InP PHEMT [1] [2], and the increasing maturity of the MBE make realistic, in the near future, the development of very high power and power added efficiency MMICs for millimeter frequency. Low cost and large volume production are key elements. However, in the application of the point to point radio where the key parameter is not the efficiency but the maximum power necessary to achieve the required linearity and naturally the low cost, MESFET process has still some good opportunity. MESFET device has better linearity compared to PHEMT and is a well established technology, hence lower cost. Finally, the higher breackdown voltage provides a better reliability.

Fujitsu in the last two years has improved its 0.25µm gate length MESFET process in order to achieve higher gain performance up to the K-Band and has developed a 21.2-23.6 GHz 125mW and a 24.5-26.5 GHz 125mW MMIC to assess the potentiality of such a process. An approach based on in-chip tunability by means of bond wire has been adopted to maximize the chip performance and to reduce the cycle time.

PROCESS TECHNOLOGY

The epilayer of the MESFET process adopted for the design and realization of the power amplifier has been optimized to achieve high gain performance in the K-Band. The saturation current density Idss is of the order of 150mA/mm and the Imax is of the order of 250mA/mm, the gate-drain breakdown voltage Vgdo is equal to 15V at 0.5mA/mm. The power density is of the order of 300 mW/mm with gain at 1 dB of compression point of 7 dB at 18 GHz. The GaAs substrate is made very thin (28µm) to achieve a low thermal path to backside ground which is a 35 µm plated gold.

For frequency above 18 GHz the power contours of the active device become very narrow due to the strong reactive behavior of the load line and the design of necessary output load impedance to obtain the required power performance become much more difficult. Indeed, small variations of the load impedance due to parasitic effects can strongly degrade the power performance and sometime more than two design cycles are necessary to improve and optimize the performance.

DESIGN REALIZATION

The design goal for the 21.3-23.6 GHz MMIC are a linear gain higher than 15 dB and an output power at 1 dB of compression point of 21 dBm. To achieve these targets a three stage amplifier configuration with an output stage gate width of 800μm has been chosen. The optimum load for maximum output power has been measured by means of on-wafer active load/pull measurements [3] and each stage of the MMIC has been loaded for the maximum power condition. The presence of more stages increases the complexity of the problem and particular attention was paid to avoid the saturation of the previous stages.

To give flexibility to the design a tunable approach, often exploited at lower frequency bandwidth, has been used. During the design, the DC pads have not been isolated in the RF bandwidth by means of on-chip shunt capacitors but they have been designed as integral part of the matching open stubs. Indeed, as shown in the layout in Figure 1, at the drain side of each stage an open stub has been used as a matching element. At the end of each open stub a DC bond pad has been located to feed the drain bias through bond wire. A 700 um length bond wire has been used in the simulation to provide an inductance value of the order of 1nH, necessary to decrease the sensitivity of the circuit to such bond wires and achieve at the same time a certain tuning capability. The bond wires are connected to off-chip capacitors inside the package in order to cut off the RF signal. This approach allowed us to have a certain control on the load impedance of each stage. This tuning capability gives the possibility to correct shift of the load impedance and maximize the performance of the MMIC when used in the packaged form. In fact several users do not have microelectronics capability and prefer to use packaged MMICs and, in this case, package effects need to be compensated. The final overall size of the three stage amplifier is equal to 1.5 x 2 mm.

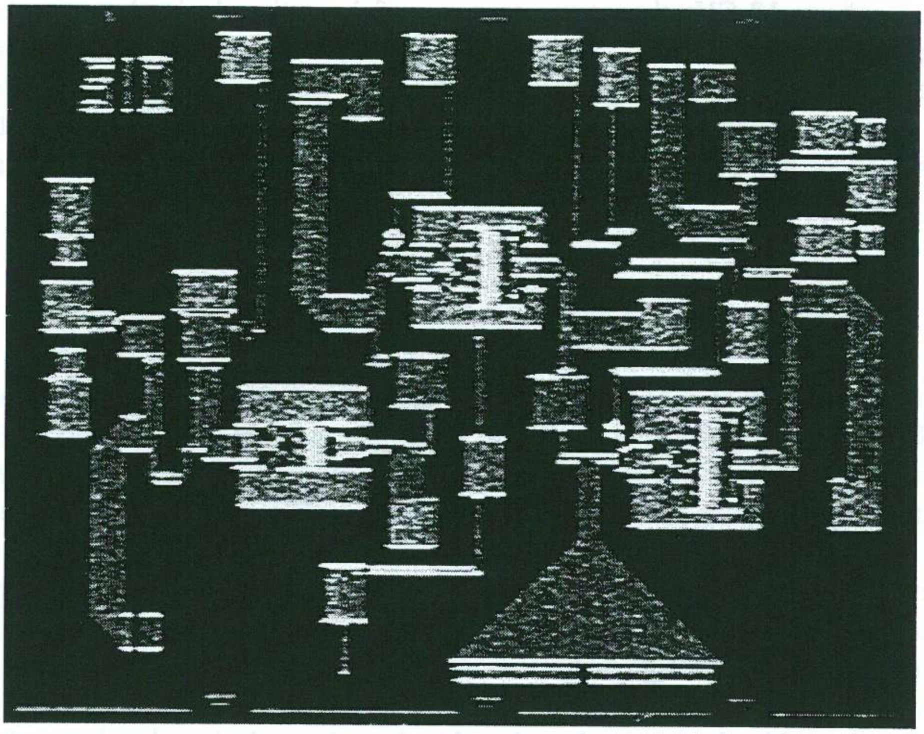

Figure 1 - 21.3-23.6 GHz MMIC, photograph of the layout.

TEST RESULTS

The chip, first, has been tested on-wafer without any tuning and, in a second time, in package applying a tuning of both bias feed bond wires. In Figure 2 the power and gain performance at the two different steps, on wafer measurements without tuning and in package measurements after tuning, are reported. As can be noticed, the overall performance of the circuit have been optimized and the effect of the package compensated by adjusting the output load of the three stages. The device, including the package effects, delivers, at the bias Vds=5V and Ids=180mA, an output power greater than 21 dBm with a gain at 1 dB of compression point of 19 dB covering the frequency bandwidth from 21.2 to 23.6 GHz. This frequency bandwidth is able to cover two European point to point application (i.e., 21.2-22.4 GHz and 22.4-23.6GHz bands).

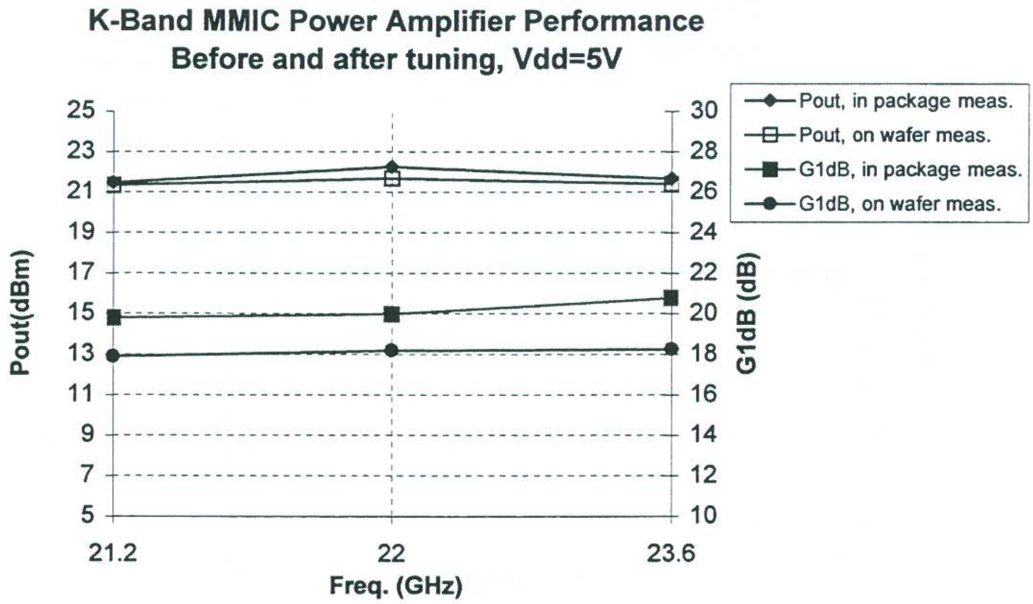

Figure 2: Power and Gain Performance (before and after tuning)

The measured power added efficiency in the overall frequency bandwidth is higher than 15%. In Figures 4 and 5 and 6 it is shown the good repetitivity of the performance of five different devices, tuned following the same procedure.

This technique is useful to adjust the variance of wafer to wafer and is successful for large volume production. A more accurate pilot test for production has demonstrated the repetitivity of the good performance at the first cycle.

A MMIC covering the frequency 24.5-25 Ghz has bees also successfully realized obtaining similar performance, with a linear gain of 18dB and an output power of 21 dBm. Above 25 Ghz the power density of the MESFET process starts to decrease degrading the performance of the MMIC.

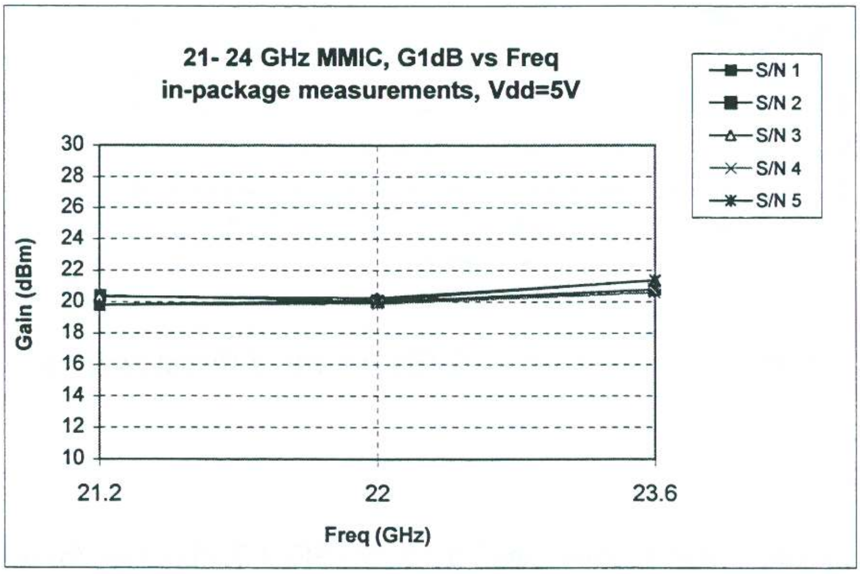

Figure 3: Power at 1 dB of compression point for 5 different samples

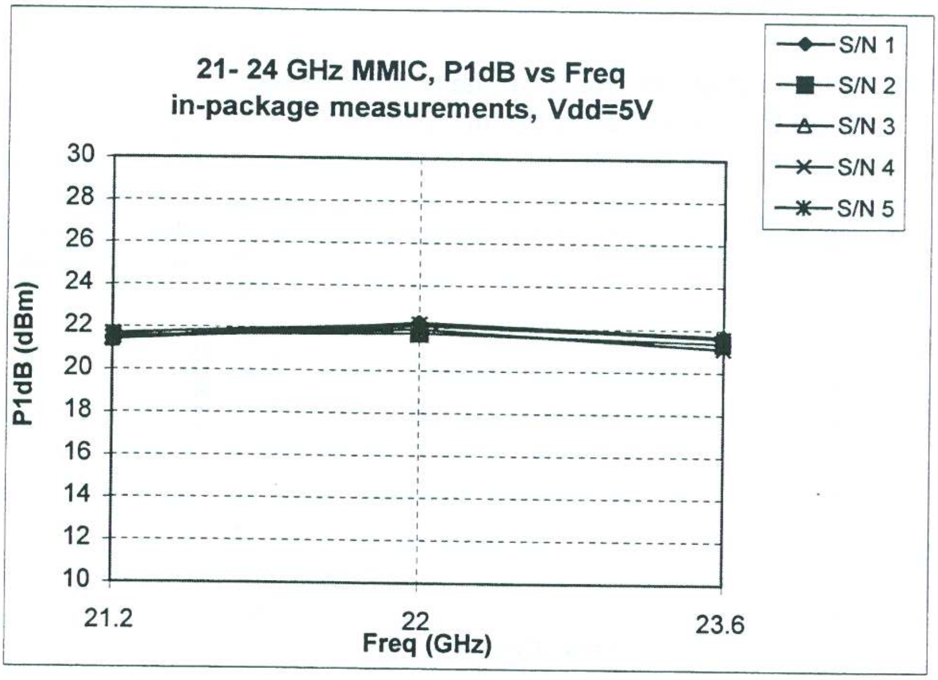

Figure 4: Gain at 1 dB of compression point for 5 different samples

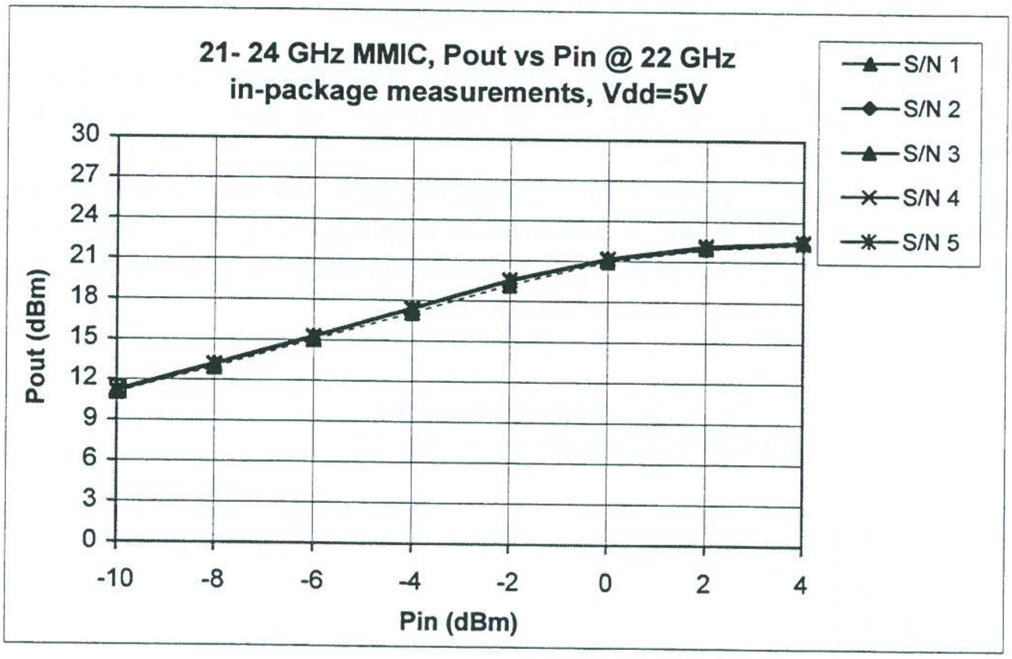

Figure 5: Pout vs Pin at F=22 GHz for five different samples.

CONCLUSIONS

A three stage GaAs MMIC power amplifier in MESFET Technology for point to point radio application that delivers an output power greater than 125 mW, with associated gain higher than 19 dB has been developed. The use of bias feed bond wires as tuning element has been exploited to shorten the design cycle time, to optimize the circuit performance and to compensate the package parasitics in the desired frequency bandwidth. Pilot test for production has demonstrated the repetitivity of the good performance and the device has been accepted for large volume production after the first design cycle.

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