A HIGH POWER AND HIGH EFFICIENCY POWER AMPLIFIER FOR LOCAL MULTIPOINT DISTRIBUTION SERVICE

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ABSTRACT

This paper presents a high power and high efficiency MIC power amplifier using 0.2 μm InGaAs/AlGaAs/GaAs pseudomorphic HEMT (PHEMT) devices. The average performance of the power amplifier is 8.75 dB small signal gain, 39.6% power-added-efficiency, and 37 dBm (5.0 W) from 27.5 to 29.5 GHz. At these power levels, the output power density was 780 mw/mm including output circuit losses. This represents the highest output power and efficiency ever reported at Ka-band using MIC amplifiers.

INTRODUCTION

Future communication services such as television, video-on-demand, distance learning, interactive games as well as a host of other services to homes will be distributed using local multipoint distribution service (LDMS) system using 27.5 to 29.5 GHz band. In a typical system architecture, a cellular network consisting of low power transmitters, operating in 1 GHz bandwidth, provide transmission to the subscribers, as shown in Fig. 1. The interference due to frequency reuse between adjacent channels is minimized by providing orthogonally polarized signals between adjacent channels, and using frequency interleaving in diagonally proximate cells and spatial separation [1].

This need has created considerable interest in high power pseudomorphic HEMTs operating at millimeter wave frequencies. This application requires components that have small size and low weight at a lower cost. The hybrid MIC power amplifiers can provide excellent reliability for moderate volume applications at a lower cost. The assembly, tune and test is minimal and can be used to achieve the optimum required performance within this prescribed band.

Amplifiers with 4.7 watts with 38% power-added efficiency over 18.0 to 21.2 GHz frequency range [2], 3.2 watts with 10 dB gain and 35% power-added-efficiency at 3 dB compression at 20 GHz [3], and 1 watt with 25% power-added-efficiency have been demonstrated at 35 GHz [4] by combining one or several devices.

In this paper we present a high power, high efficiency and highly manufacturable hybrid power amplifier. This power amplifier achieved 8.75 dB small signal gain, 39.6% power-added-efficiency, and 37 dBm (5.0 W) from 27.5 to 29.5 GHz. The results represent the best performance attained by pseudomorphic HEMT at these frequencies.

DEVICE AND PROCESS TECHNOLOGY

The pseudomorphic InGaAs/AlGaAs/GaAs HEMT devices has been engineered to provide high breakdown voltage and high current densities. It also provides high gain and power-added efficiency at millimeter wave frequencies. To improve the breakdown voltage, the AlGaAs layer is left undoped and the Schottky gate is recessed to this undoped region. Furthermore, to increase the current density, an additional planar doping is employed to increase the amount of charge in the 2-dimensional electron gas. The device optimization was performed to ensure high aspect ratio which is defined as the ratio of gate length to the gate to channel separation. This enables the device to provide high gain, high efficiency as well as high cut-off frequency for millimeter wave operation. Typically, for a 0.2 μm gate length devices, gate to drain voltage of greater than 12 volts (measured at 0.1 ma/mm), maximum channel current of 500 ma/mm, transconductance of 550 mS/mm, and ft of 55 GHz is obtained. This process is capable of providing better than 0.6 W/mm

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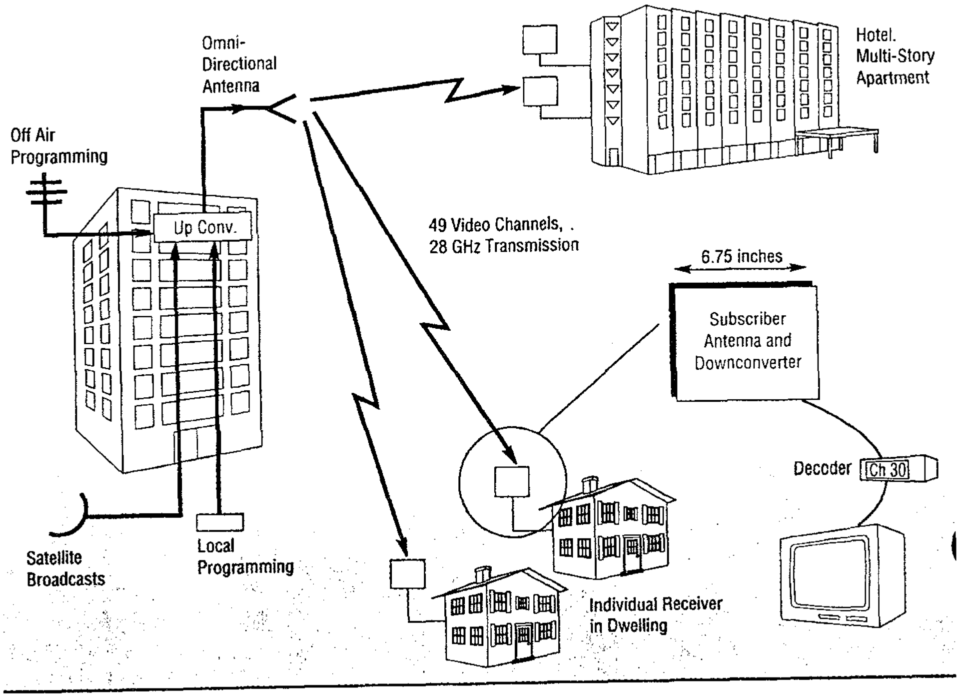

Fig. 1 Local multipoint distribution Service (LMDS) System.

with better than 5 dB compressed gain and better than 28% power-added-efficiency at 60 GHz [5].

The amplifier uses 0.2x1600 μm device as a basic cell for use in in-phase multi-cell matching. As shown in Fig. 2, the basic power cell consists of 1.6 mm gate periphery. Each finger is 0.2 μm in length and 100 μm in width. The device dimensions are 0.675 μm x 0.300 μm.

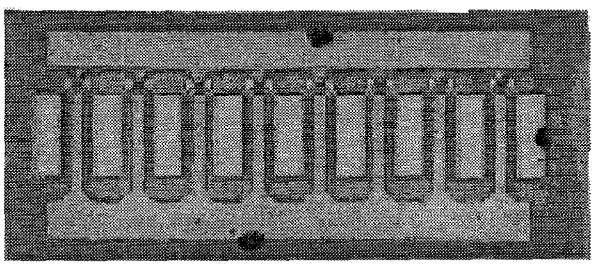

Fig. 2 Layout of baseline 1.6 mm power HEMT device.

POWER AMPLIFIER DESIGN

Figure 3 shows the layout of the amplifier. It consists of four 1600 μm cells with input and output matching circuits. The low pass input network achieves matching and combining in two steps [6]. To obtain the maximum capacitance per unit area, the first stage of the input from the device match employed 2 mil GaAs followed by 10 mil Quartz. This network provides appropriate input match to the devices. A complex load impedance which was modelled as a parallel combination of capacitance and resistance is used for the output. The input is conjugately matched to measured S-parameters. The output network consists of two cascaded sections of quarter-wave transmission lines. It presents a power match to the devices as well as serving as a power combiner. Isolation resistors are included to suppress the odd mode oscillations that may be caused due to imbalances in the devices. The gate and drain biases are brought in by $\lambda/4$ lines configured in an open-short-open scheme. Additional bypass of 20 pf and a 0.01 μf capacitor provide low frequency stability.

The devices on a 4 mil GaAs have a typical thermal resistance of 41.2 degree C -mm/W, and that on a 1.2 mil it is 28.7 degree C -mm/W. Therefore, in order to reduce the thermal resistance of the basic cell, the active area below the device is thinned to about 30 μm for improved thermal resistance.

The amplifier provides unconditional stability under all load conditions. Several amplifiers were assembled and they all achieved similar performance. These amplifiers can be tuned to better

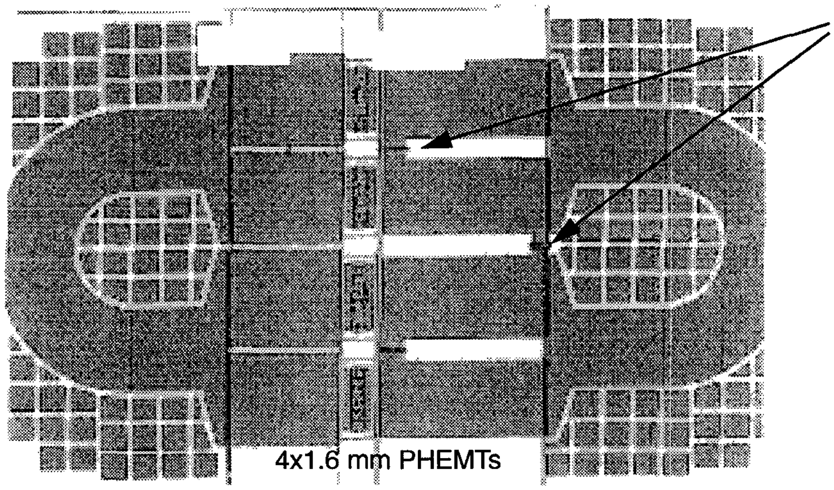

Fig. 3 Layout of the hybrid power amplifier

than 1.2 GHz bandwidth within 27.5 to 28.5 GHz band.

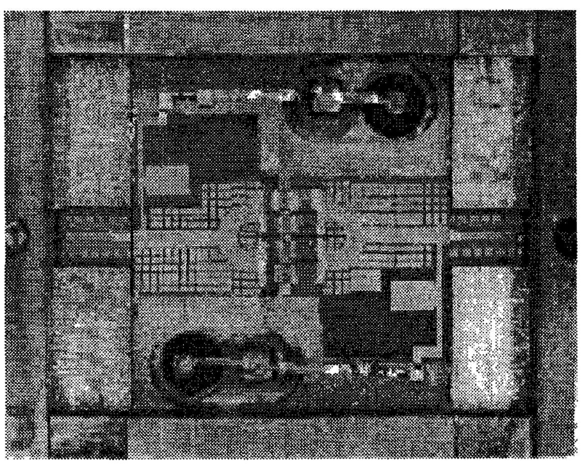

Fig. 4 Photograph of the 28 GHz amplifier

POWER AMPLIFIER PERFORMANCE

We fabricated several power amplifiers utilizing the 1.60 mm power HEMT devices. Figure 4 shows a photograph of the power amplifier. All of them performed fairly consistently. A typical performance is shown in Fig. 5. It shows output power, and power-added efficiency performances of the amplifier at 28 GHz. The average small signal gain was 8.75 dB. It attained a power gain of 5 dB and output power of 37 dBm (5.0 W) with 39.6% power-added-efficiency from 27.5 to 29.5 GHz. This translates to greater than 780 mw/mm.

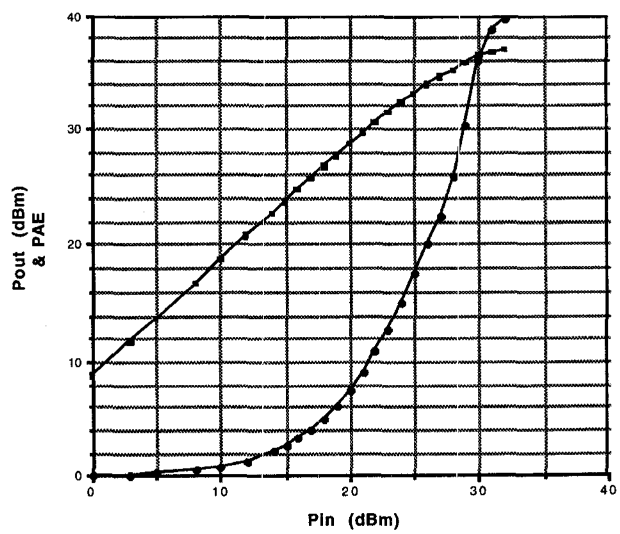

Fig. 5 Measured performance of the amplifier at 28 GHz

A typical frequency response of the amplifier with 20 dBm input power is shown in Fig. 6. Better than 1.2 GHz bandwidth can be tuned within this band. The advantage of this feature is that the same circuit also can be used in 26.5 to 28.5 GHz to meet Canadian LMDS system requirements.

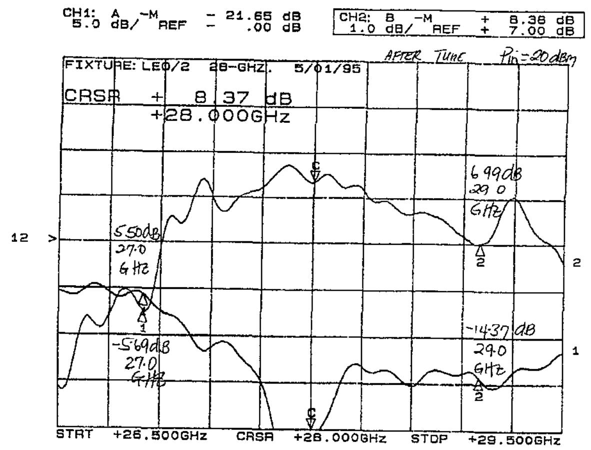

Fig. 6 Measured output power and return loss of the amplifier as a function of frequency.

CONCLUSIONS

In this paper, we have demonstrated high power and high efficiency power amplifier using pseudomorphic InGaAs HEMT at 28 GHz. The average performance of the power amplifier is 8.75 dB small signal gain, 39.6% power-added-efficiency, and 37 dBm (5.0 W) from 27.5 to 29.5 GHz. At these power levels, the output power density was 780 mw/mm including output circuit losses. This leads us to conclude that the device power density is greater that 780 mw/mm. This definitely represents the highest output power, power density and efficiency ever reported at Ka-band from a single amplifier.

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