KU-BAND POWER AMPLIFIER USING PSEUDOMORPHIC HEMT DEVICES FOR IMPROVED EFFICIENCY

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ABSTRACT

A two-stage Ku-band power amplifier demonstrating state-of-the-art power-gain and efficiency has been developed using 0.25μm gate-length, 1600μm gate-width double-heterojunction pseudomorphic HEMT devices. At 12 GHz, output power of 2.2 and 2.7 watts has been achieved, with power-added efficiency of 39% and 36% respectively. Associated gain of 14 dB has been demonstrated.

INTRODUCTION

Highly efficient power amplifiers are essential for achieving maximum reliability plus minimum size and weight in phased array systems. In particular, for active phased arrays poor efficiency causes high thermal loading which often results in excessively high junction temperatures. Poor efficiency results in heavier modules, power supplies, and in effect heavier arrays. The efficiency requirement fuels continued HEMT device development and experimentation.

In the past, pseudomorphic high electron mobility transistors (PHEMTs) have been designed to provide improved power, gain, and efficiency at millimeter-wave frequencies, but have not been extensively evaluated at the lower frequencies such as Ku-band. However, the increased doping level and carrier confinement in pseudomorphic material structures over that of conventional HEMTs results in an increase in F_t, and output power, yielding an overall improvement in Ku-band performance. A two-stage power amplifier based on PHEMT devices has demonstrated state-of-the-art performance at Ku-band.

DEVICE DESCRIPTION

PHEMTs possess physical characteristics that make them well suited to high frequency power amplification. This is due to enhanced electron mobility and velocity resulting from the separation of the electrons from their donor ions and excellent confinement of carriers to the InGaAs channel afforded by the quantum well structure. Figure 1 illustrates the cross section and doping of the pseudomorphic HEMT.[1]

At frequencies below 20 GHz there has been little power development of PHEMT devices, while GaAs power MESFETs have been predominantly used. PHEMT devices are now competitive with MESFETs due high transconductances (600 mS/mm) of device periphery and high power densities (1W/mm at 60 GHz).[2]

A LO/HI/LO resist system was used to produce 0.25μm T-shaped cross-section metal gate lines using electron-beam lithography. The resist system provides T-shaped resist cavities with "guaranteed" undercut profiles. Measured end-to-end 0.25μm gate resistance is 60Ω/mm gate width.[3]

This amplifier is based on a device with a 0.25μm gate length. The gate width is 1600μm, and contains sixteen 100μm fingers, as shown in Figure 2. Source inductance is minimized by using small reactive ion-etched via holes under each source contact.

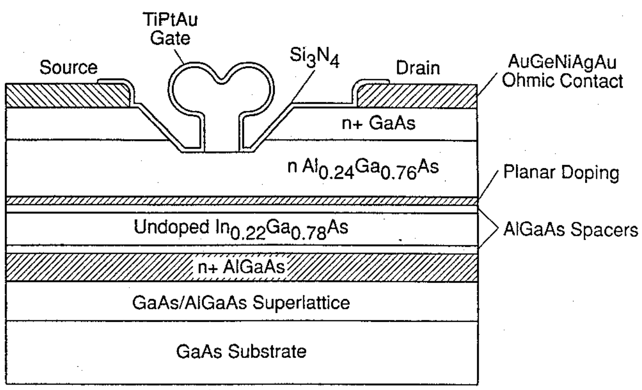

Figure 1. Cross-Section of Pseudomorphic HEMT

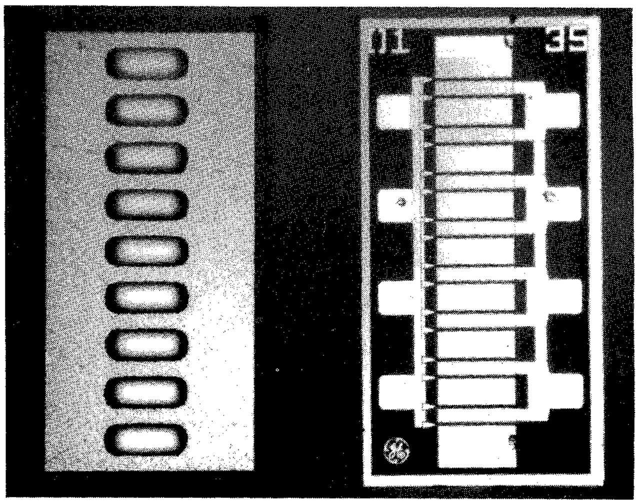

Figure 2. Back and Front Views of 1600μm Gate-Width Power HEMT

The device demonstrates 51% power-added efficiency at 15 GHz with 10.8 dB associated power gain and 600mw output power. Gate to source/drain breakdown, defined conservatively at 1ma/mm of gate current, is 7.2 volts.

AMPLIFIER DESIGN

To achieve maximum efficiency, the amplifier was designed with a 1:4 device periphery ratio between the driver and final stage. To achieve adequate interstage margin, reactive splitters and combiners were used for interstage matching. The use of high-dielectric substrates allowed realization of very low impedance transmission structures, as shown in the amplifier photo in Figure 3.[4,5]

The transistor's output load impedance was determined through load pull techniques. The design was then verified by a simple large-signal model.

Achieving adequate stability margin in PHEMT amplifiers requires non-traditional design techniques. PHEMTs have 600mS/mm transconductance as compared with a typical FET's 100mS/mm and will tend to be significantly less stable. Certain conditions can induce such oscillations: for example, when the device is matched for power conditions, yet operating with small signal drive, during bias application, or during pulse rise or fall time. This tendency can be prevented by incorporating small amounts of drain-gate feedback. Such feedback in MESFET amplifiers typically reduces the output power, because the feedback network splits part of the output power from the load and directs it to the gate. The HEMT amplifier, on the other hand, when fed back was stable and increased the output power by 0.1dB. This is probably due to suppression of the oscillation.

PERFORMANCE

The two-stage amplifier was tuned for maximum power and efficiency at a single frequency of 12 GHz. The output power is 2.2 watts, with 39.2% power-added efficiency and an associated gain of 14dB. When tuned for maximum power, 2.75 watts is achieved with 36.3% efficiency and 14dB gain. Tuning for efficiency only results in a 3% efficiency improvement, as seen in Figure 4. This also results in a 20% loss in output power, as seen in Figure 5.

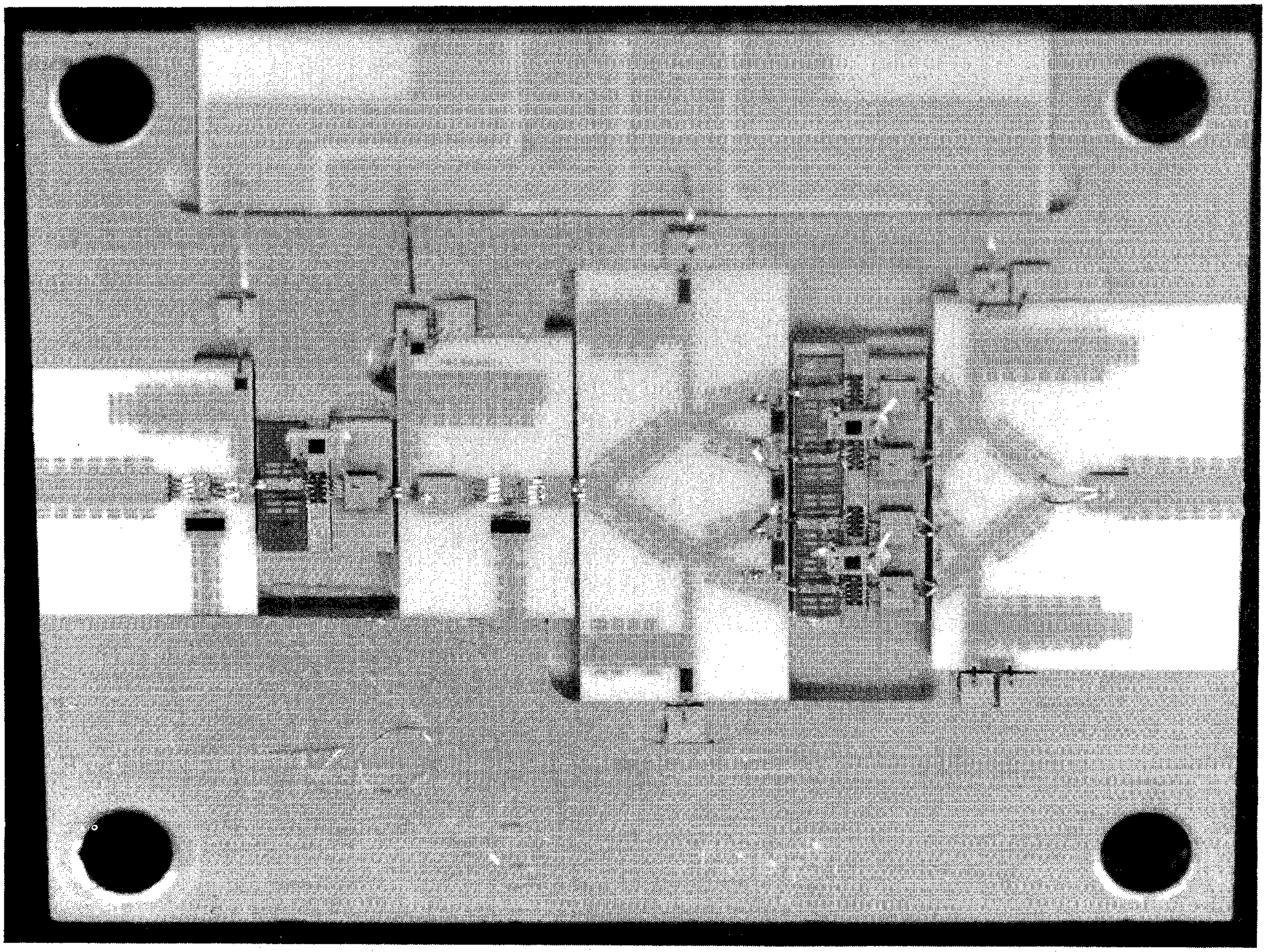

Figure 3. Two-stage Ku-Band Pseudomorphic HEMT Power Amplifier

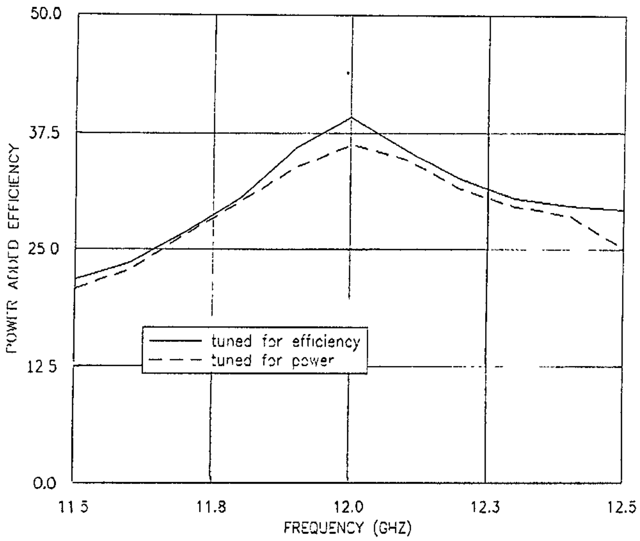

Figure 4. Amplifier Efficiency Tuned for Maximum Efficiency and for Maximum Power.

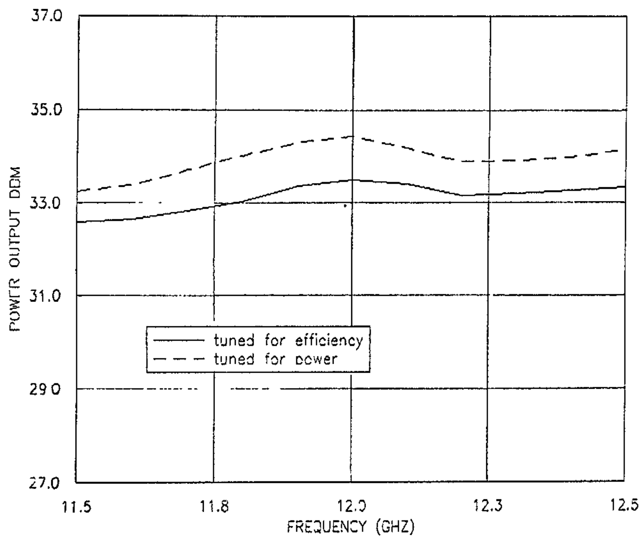

Figure 5. Amplifier Output Power Tuned for Maximum Efficiency and for Maximum Power.

CONCLUSION

Although the traditional domain of HEMT amplifiers has primarily been millimeter waves, we have demonstrated that amplifiers using PHEMT devices exhibit significant performance benefits in efficiency and power gain at microwave frequencies as well.

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