60 GHz Power Amplifier Using PHEMT

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ABSTRACT

A Millimeter wave power amplifier has been developed using 0.15 μm, T-gate pseudomorphic HEMT. It utilizes a novel low loss planar combiner. The performance obtained was 715 mWatt output power with more than 13 dB linear gain at 60 Ghz, which are highest reported in the literature to date. These state-of-the-art results are attributed to the excellent device and combiner performance

Introduction

60 Ghz. is the frequency of choice for crosslink and covert communications. Transmitter components were usually based on Impatts or TWTAs, and suffered from poor reliabilities. Recent technical developments using super-lattice HEMTs have resulted in devices which exhibit greater than 220 mW output power at greater than 25 % power added efficiencies. Using low-loss, high efficiency combiners, it is possible to realize units up-to 10 Watts in near future at this frequency. This paper reports on a 715 mW output power module, which can serve as a building block for higher power SSAs. This power level is the highest reported in the literature at this frequency. The basic components as well as details about the power module are described in this article.

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Device Technology

The devices used for this application are pseudomorphic HEMTs (InGaAs/GaAs). These HEMTs offer the advantage of higher breakdown voltage and higher current density to produce more power than the conventional (GaAlAs/GaAs) HEMTs. These devices fabricated by using MBE material and E-beam lithography, also offer higher efficiencies and gain at millimeter wave frequencies. Although higher power has been demonstrated at device level, the chips selected for this application, have a 400μm gate width, with a 0.15μm "T"-gate structure. This smaller device was selected on the basis of impedance and does not compromise gain or bandwidth while maintaining power output and efficiency. Figure 1 shows the picture of the device used for this application, and Figure 2 shows the power characteristics.

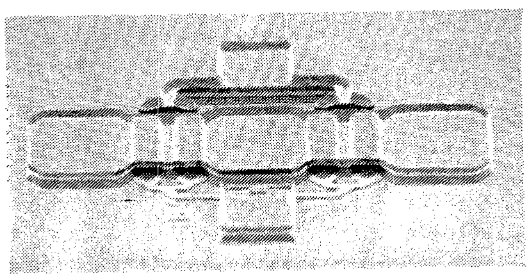

Figure 1. 60 GHz Pseudomorphic HEMT

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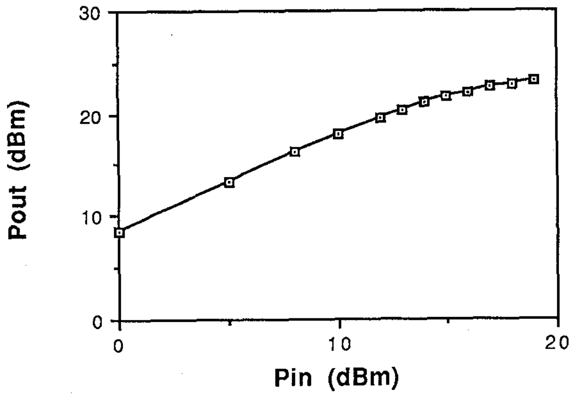

Figure 2. Power Characteristics of
400 Micron Device

Power Amplifier

The power module design was chosen to achieve maximum power output, while allowing wide bandwidth. Thus, the devices were characterized using harmonic balance techniques, and matched to optimum load impedance. Two of these devices were combined in parallel to achieve the required power, and mounted in a carrier. Figure 3.0 shows such a unit in the carrier and it's power characteristics. At this level 320 milli-Watts was achieved with 5.0 dB power gain and 16.4% power added efficiency.

Planar Combiner

Millimeterwave planar power combiners have been developed at 44 Ghz. and at 60 Ghz. These combiners are 3-way and 5-way, and use a tapered line construction. Tapered line combiners are MMIC compatible and do not suffer the parasitics usually associated with Wilkinson and Nagai type combiners. Figure 4.0 shows the back-to-back realization of a 3-way planar combiner. The photograph also shows the impedance taper required to convert to 150 Ω and back again to 50 Ω. Two deposited thin film resistors are used to give the planar combiner good port - to - port isolation and VSWR. Figure 5.0 shows the measured performance characteristic, including 0.55 dB insertion loss, less than 1.0 dB transmission unbalance, and greater than

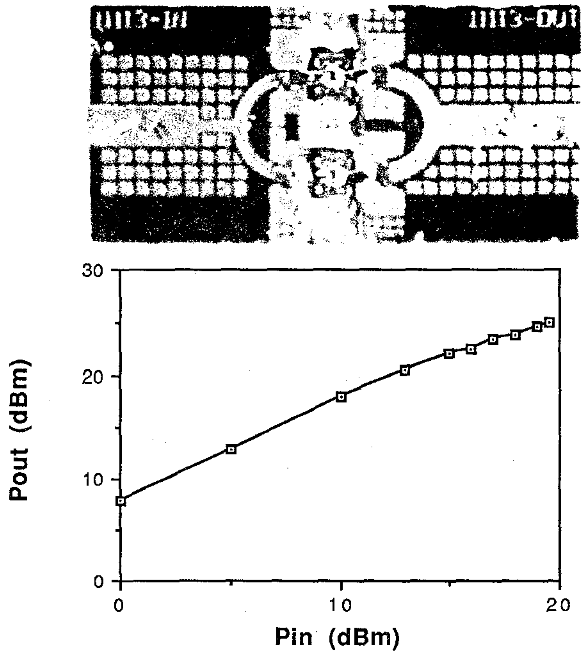

Figure 3 Module photograph and its power characteristics

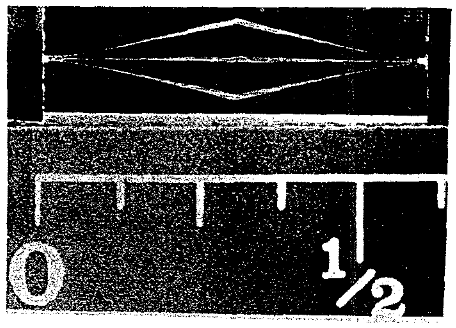

Figure 4. Back to Back 3-Way Planar Combiner

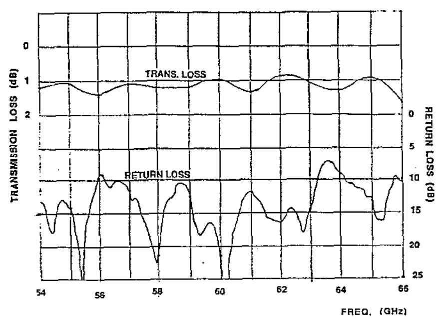

Figure 5. Combiner Transmission and
Return Loss

16 dB port isolation. The phase imbalance between the center port and the outer ports was about 8 degrees, which can be easily compensated for by selecting the amplifier modules with proper phase.

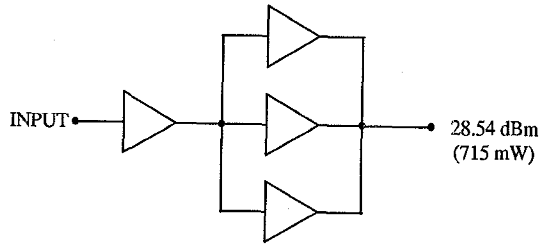

Figure 6 UNIT BLOCK DIAGRAM

Unit Design

Three power amplifiers are combined in a planar combiner circuit to achieve 715mW output power. The unit was constructed in a breadboard fixture, and is a two stage amplifier. The driver stage, connects to the three-way planar power splitter (described above). This feeds the 3 amplifier modules, whose output is combined again using the planar power combiner. Figure 6.0 shows the unit drawing. The circuits are on 5 mil quartz, and the devices and substrates are epoxied to the module floor.

The driver stage is identical to the power amplifier stages. The integrated circuit has greater than 13dB linear gain, with 715 mW output power. The entire unit photograph is shown in Figure 7.0, and the output power characteristics are shown in figure 8.0. The data does not include contributions from the waveguide transitions.

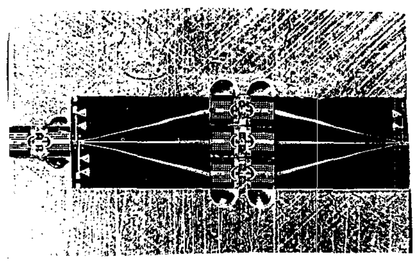

Figure 7. Photograph of the Unit Amplifier

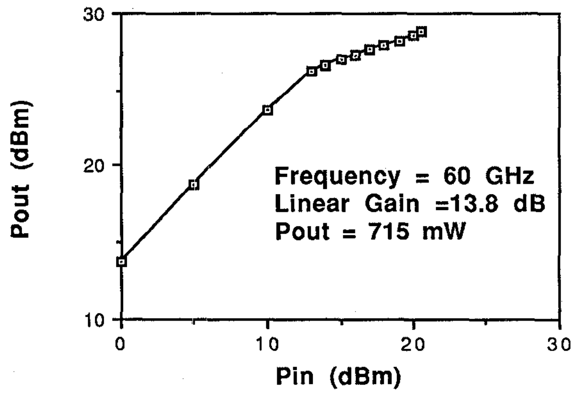

Figure 8. Output Characteristics of the Unit Amplifier

Conclusions.

State of the art results have been demonstrated at 60 Ghz in a extremely compact amplifier module. The design techniques used are very flexible, and lend themselves to rapid prototyping, and design optimization. This approach can provide high output power while preserving bandwidth, unit gain and efficiency. These modules can now be used with higher order waveguide combiners to achieve power levels up to 10 Watts in the near future.

Acknowledgments

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