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K- AND Ka-BAND HIGH EFFICIENCY AMPLIFIER MODULES USING GaAs POWER FETs

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SUMMARY

Sub-half-micrometer GaAs power FETs fabricated with a side-etched-gate technology (1-3) have been developed that exhibit low junction temperatures suitable for space application (4). With these devices high efficiency amplifier modules have been developed and will be reported on. At 20 GHz, using these devices, a high gain module was assembled that had an output power of 775 ± 75 mW from 18- to 20-GHz with 6.9 ± 0.2 dB gain, and a maximum efficiency of 20.3%. At 35 GHz, an output power of 210 mW with 3 dB gain and 22% efficiency has been obtained with one 0.6 mm width cell, and two cells were combined to obtain 300 mW with 3 dB gain and 18.8% efficiency. The power and efficiency results obtained at 35 GHz are some of the highest reported to date and indicate that Ka-band solid state power amplifiers are feasible.

DEVICE TECHNOLOGY

The GaAs FETs are fabricated using epitaxially grown (VPE) or ion-implanted (I^2) active layers and have thick T-shaped submicrometer refractory metal gates. The short gate length is obtained by defining 0.75 µm Ti/Pt/Au lines with deep UV (300 nm) contact lithography and then chemically side etching the thin titanium layer to form a final gate length of 0.4 µm. The devices have thick air-bridged sources that are flip-chip mounted (using a flux-less soldering technique) to a high conductivity copper heatsink. Both low device-to-carrier source inductance (< 30 pH) and thermal resistance (< 33°C/W for 1.2 mm device) are realized with electrically small (<λ/16) transverse cell dimensions which result in improved high frequency performance. Table 1 summarizes measured device performance at 20 GHz.

K-BAND AMPLIFIERS

With these devices, a 20 GHz amplifier module was developed using an alumina-based hybrid technology. The module uses a balanced configuration with a two-stage 7 dB gain, 0.5 W amplifier in each arm of a Lange quadrature hybrid. The performance of the complete two-stage module is shown in Fig. 1. The amplifiers use distributed matching circuits printed on 0.25 mm thick alumina substrates that are designed by a large signal modeling technique (5). The amplifier carriers are Thermkon 83 which has a high thermal conductivity (two-thirds that of copper), and a thermal expansion coefficient close to that of alumina. The hybrids have Ti/Pt/Au interdigitated lines formed by ion-beam milling and alternate lines are joined with plated air-bridges. The isolated port of the hybrid is terminated in a thin film cermet resistor with a wrap-around ground.

Ka-BAND AMPLIFIERS

At 35 GHz, single stage and multi-stage amplifiers with integral waveguide-to-microstrip transitions have been developed. A unique feature is that all amplifier matching networks are readily accessible for tuning since the E-probe transition is through the top waveguide wall. With single stages, a peak output power of 210 mW with 3 dB gain and a power-added efficiency of 22% has been obtained. The amplifier frequency response at 90 mW input power is shown in Fig. 2a. A three-stage amplifier consisting of a 300 µm input device followed by a 600 µm device and two Wilkinson-combined 600 µm devices was tested. The frequency response of the three stage amplifier, illustrated in Fig. 2b has a peak output power of 300 mW with 10 dB gain and a power added efficiency of 17.7%. These reported results are not adjusted for the 0.4 dB back-to-back fixture loss.

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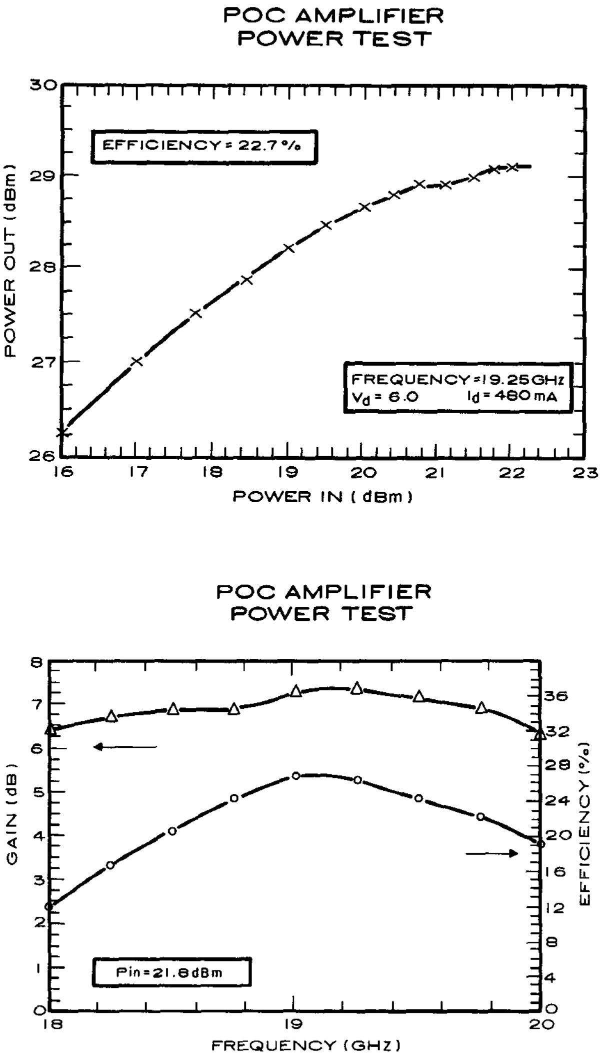

Figure 1. a) Power performance of a 1 W module. b) Gain and efficiency across a 2 GHz bandwidth.

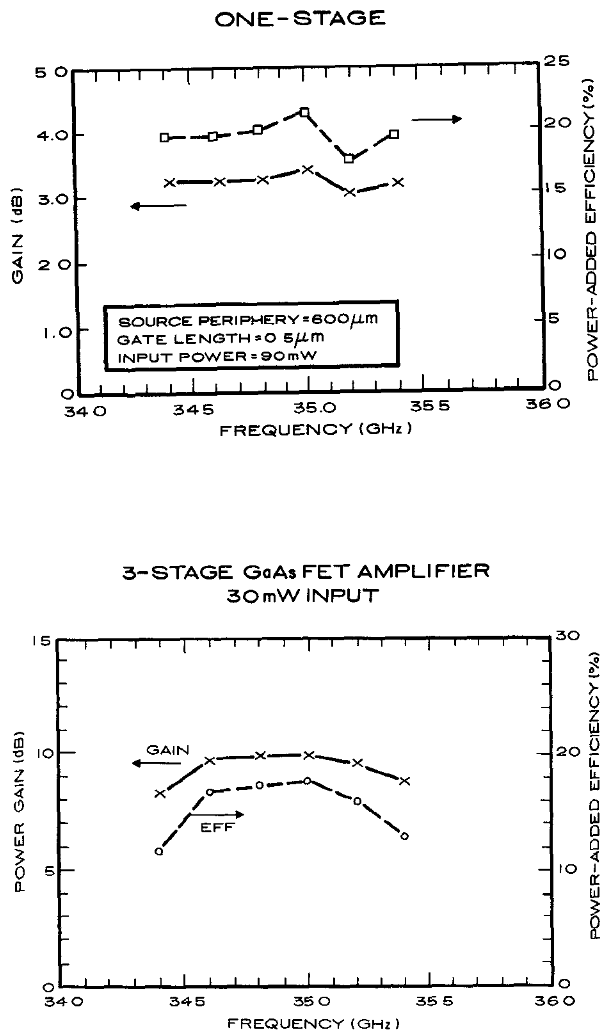

Figure 2. a) Gain and power-added efficiency of a single stage amplifier at 35 GHz. b) Three-stage amplifier performance at the same frequency.

TABLE 1. K-BAND POWER AND EFFICIENCY PERFORMANCE.

Device Number	Freq. (GHz)	Output Out (mW)	Gain (dB)	Eff. (%)	Total Width (mm)
E68A	18.0	197	4.5	26.0	0.6
	18.5	287	3.7	20.0	0.6
B2627	12.5	225	6.7	40.5	0.6
	18.0	407	4.4	26.0	1.2
	21.0	206	5.1	27.0	0.6
B2705	12.0	165	8.4	53.0	0.6
	19.0	477	4.3	26.0	1.2
	19.0	505	4.7	24.5	1.2
	35.0	205	3.1	23.0	0.6
	35.0	300	3.0	19.0	2x0.6
B2691	12.5	546	6.1	40.0	1.2
	18.0	498	4.5	31.0	1.2
B2720	12.0	310	9.1	49.0	1.2
B2765	20.0	210	4.7	33.5	0.6
	38.0	120	3.0	12.0	0.6
B2698	20.0	300	4.3	31.0	0.6
R258	19.0	433	4.1	24.0	1.2
	21.0	494	4.7	27.0	1.2
G11B	12.0	1040	6.8	41.0	2x1.2
	20.0	220	4.1	31.0	0.6