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Broadband MMIC Power Amplifier for C-X-Ku-Band Applications*

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Abstract: A three-stage MMIC power amplifier operating from 6 to 18GHz is fabricated using 0.25μm AlGaAs/InGaAs/GaAs pseudomorphic high electron mobility transistor (PHEMT). The amplifier is fully monolithic, with all matching, biasing, and DC block circuitry included on the chip. The power amplifier has an average power gain of 19dB over 6～18GHz. At operation frequencies from 6 to 18GHz, the output power is above 33.3dBm, and the maximum output power of the MMIC is 34.7dBm at 10GHz. The input return loss is less than −10dB and the output return is less than −6dB over operating frequency. This power amplifier has, to our knowledge, the best power gain flatness reported at C-X-Ku-band applications.

Key words: GaAs; PHEMT; MMIC; power amplifier; C-X-Ku broadband
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1 Introduction

Wideband microwave MMIC power amplifiers are of interest to electronic warfare and countermeasures due to their small size, low cost, and reliability. In many applications the system requires individual amplifiers to be combined into power modules which may then be deployed in phased arrays. The most common approach to achieve broadband gain is the negative feedback[1], distributed[2,3], lossy matching[4] or balanced scheme[5]. The negative feedback topology has a drawback of the degradation of the gain. Generally, the chip size of the distributed and balanced amplifier is large, and the operating bandwidth of the distributed and balanced amplifier is limited by the bandwidth of the transmission line and the coupler[6].

In this paper, we described the design and characteristics of a wideband three-stage MMIC power amplifier for C-X-Ku-band applications using an advanced GaAs PHEMT foundry progress.

2 Power amplifier design

The amplifier used 85μm × 10 devices as a basic cell. Figure 1 shows the schematic diagram of the GaAs PHEMT structure. The device model was de-embedded from the two-port S-parameters of the 0.85mm PHEMT measured by a HP8510C vector network analyzer. The extraction of the parasitic parameters using cold-FET method and the intrinsic parameters using hot-FET method in small signal model for the 0.85mm PHEMT is based on Ref.[7]. Figure 2 shows the small signal model for 0.85mm PHEMT. After optimizing these extracted parameters, the simulated S-parameters from the equivalent model are fit into the measured data. Table 1 lists the extrinsic and intrinsic parameters of the small signal model for 0.85mm PHEMT. The model for 1.7mm PHEMT

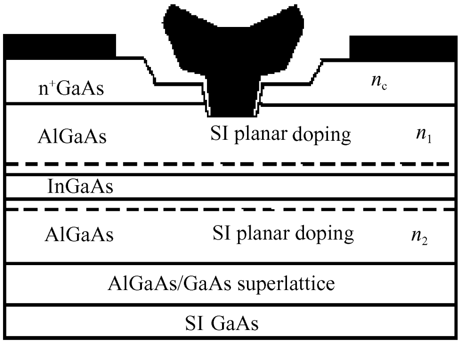

Fig.1　Schematic diagram of the GaAs PHEMT structure

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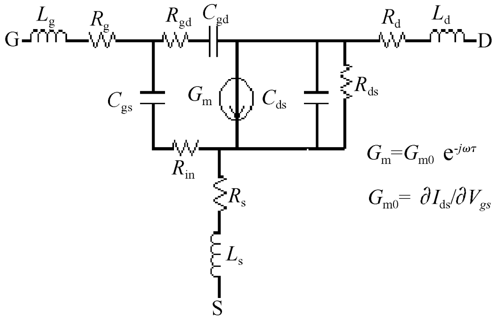

Fig.2 Small-signal model of 0.85mm PHMET

was scaled up from the 0.85mm PHEMT model for circuit simulation and optimization. Figure 3 shows that a three-stage topology design was adopted to meet the 20dB gain target. The first stage used a distributed amplifier topology to achieve a good input match over the design band and to provide positive gain slope compensation. The second stage used two 1700μm gate width transistors to drive an output stage consisting of four 1700μm transistors.

The first matching network for a power amplifier is the output matching network which is designed to transfer maximum output power from the FET to a 50Ω system. Lossy matching techniques in the interstage network were used to provide additional gain slope compensation and to provide the optimum impedance level for power matching.

The photograph of the fabricated MMIC power amplifier is shown in Fig. 4. The chip size of the MMIC power amplifier is 5.7mm × 3.6mm.

3 Power amplifier performance

Three wafers containing the power amplifier MMIC were manufactured. Each circuit was tested for DC functionality. All the measurements were performed at the fixed DC biases of $V_{ds}=7.0$V and $V_{gs}=-0.4$V. The small-signal and return loss

Table 1 Extracted HEMT/PHEMT electrical parameter in experiment

Extrinsic parameter	R_d/Ω	R_s/Ω	R_g/Ω	L_g/nH	L_s/nH	L_d/nH	C_{pg}/pF	C_{pd}/pF
	0.711	0.684	0.333	0.02	0.003	0.03	0.038	0.071
Intrinsic parameter	C_{gd}/pF	C_{ds}/pF	C_{gs}/pF	G_m/mS	τ/ps	R_i/Ω	R_{ds}/Ω	
	0.0737	0.157	3.349	42.5	0.31	1.5	9.5	

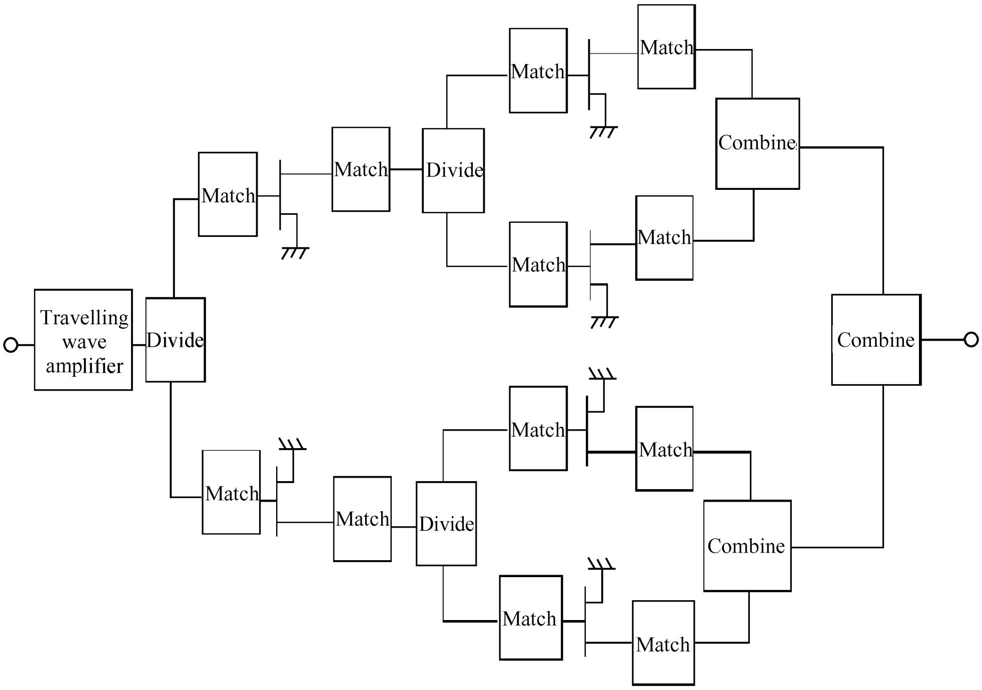

Fig.3 Topology of three-stage MMIC power amplifier

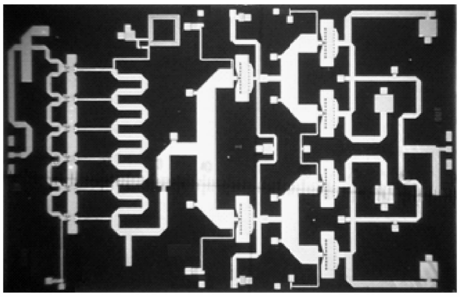

Fig.4 Photograph of MMIC power amplifier

measurements for the MMIC power amplifier were tested under CW conditions. The gain and return-loss performances of the three-stage MMIC power amplifier are shown in Fig. 5. The amplifier has about 25dB of small gain with good flatness over 5～19GHz and maximum gain of 26.5dB at 13GHz. The input (S_{11}) return losses is less than −10dB, and the output (S_{22}) return losses is less than −6dB over 6～18GHz.

Figure 6 shows the measured output power and PAE performances as a function of input power for various frequencies. The output power of over 33.3dBm is obtained. The maximum output power of the MMIC was 34.7dBm at 10GHz. The power-add efficiency is between 18% and 20% over 6～18GHz. The results show the power amplifier has better power gain flatness as compared to Ref. [8]. For power measurements the chip was soldered onto a silver carrier and mounted into a coaxial test jig. These measurements are corrected for test jig losses.

4 Conclusions

We have reported the design and performance of a fully monolithic wideband power amplifier operating from 6 to 18GHz for C-X-Ku-band applications. Using 0.25μm AlGaAs/InGaAs/GaAs PHEMT technology, the three-stage MMIC power amplifier achieved a small-signal gain (S_{21}) of 25dB. The input return loss is less than −10dB, and the output return loss is less than −6dB over 6～18GHz. The output power of over 33.2dBm and the maximum P_o of 34.7dBm are obtained at 10GHz. The PAE is achieved to be 18%～20% in these frequency bands.

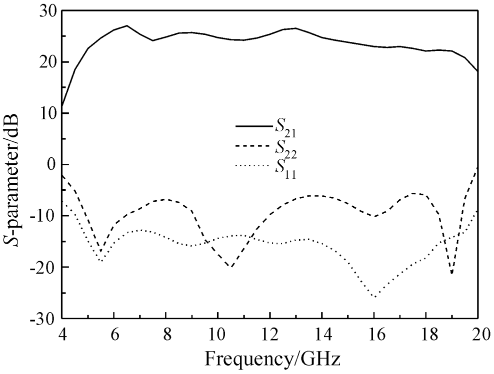

Fig.5 Measured small signal S-parameters of MMIC power amplifier

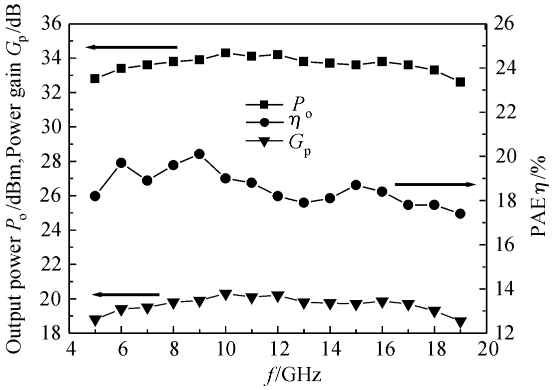

Fig.6 Measured P_o, G_p, and PAE for MMIC power amplifier

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应用于 C-X-Ku 波段的宽带功率放大器*

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摘要： 采用 0.25μm AlGaAs/InGaAs/GaAs PHEMT 工艺技术，研制出了 6～18GHz 三级 MMIC 全匹配宽带功率放大器单片.在 6～18GHz 的工作频率下，放大器的平均功率增益为 19dB，输出功率大于 33.3dBm，在 10GHz 处有最大输出功率 34.7dBm，输入回波损耗 S_{11} 低于 − 10dB，输出回波损耗 S_{22} 低于 − 6dB.与报道的 C-X-Ku 频段宽带功率放大器相比，有较好的功率平坦度.

关键词： 砷化镓；赝配高电子迁移率晶体管；微波单片集成电路；功率放大器；C-X-Ku 波段
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