A FULLY INTEGRATED BROADBAND AMPLIFIER WITH 161% 3-dB BANDWIDTH

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A broadband, low voltage supply, fully integrated monolithic amplifier using GaAs high electron mobility transistor was described. At 2V power supply, it has 14.5 ± 0.4 dB of gain from 1 through 6 GHz. The 3-dB bandwidth is from 800 MHz to 7.4 GHz. The bandwidth is 161%. More than 15 dB gain is attainable if the supply voltage is increased to 3 V.

1 Introduction

Broadband amplifiers using GaAs covering several octaves have been reported by a number of researchers in the literature [1–5]. Most of them professed from dc to tens of GHz using distributed circuit topology [1-2]. For distributed amplifiers, circuit construction is complicated, power consumption is high, and the die area is large, which will increase the cost of production. Resistive feedback topology is suitable for multi-stage amplifiers [3-4]. For this single-stage broadband amplifier, it is difficult to have a source resistor that is large enough to broadening the bandwidth of the amplifier and small enough to get a small voltage difference between gate and source of the HEMT device. Thus, lossy matched amplifier is a better way to solve this problem [5]. The lossy matched amplifier is attractive for its simplicity, compact size and low cost. At this time and the near future, different communication equipment use different frequencies ranging from 900 MHz to 5.7 GHz. A broadband amplifier which provides very smooth gain from 900 MHz to 6 GHz working under single battery power supply voltage with simple circuit construction on small chip area will be a practical and useful circuit for multi-band portable wireless system.

2 Circuit Design

The amplifier is designed for 50Ω systems. Fig. 1 shows a schematic circuit diagram of the amplifier. The dotted line shows the chip boundary. The 0.2 μm GaAs PHEMT process is provided by Philips in France. In order to provide enough gain at higher frequency, a 6 x 50 μm transistor was chosen. This transistor provides G_{max} = 17 dB at 7.4 GHz. Lossy matched method is used to design this broadband amplifier in stead of feedback design. As shown in Fig. 1, while parallel connecting lossy matched resistor R_l at input port of the transistor, S_{11} was effectively pulled into Smith chart center. A quite good input impedance matching will be obtained at bandwidth from 1 to 6 GHz after connecting an inductor L_i at input port. At output port, series inductance L_o is the only matching element. Drain port

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voltage source comes through shunt-connected RF choke inductor L_d = 9.9 nH. Because the lowest frequency of this circuit is 900 MHz, inductor L_d value can not be lowered any more. Simulated results show that 9.9 nH inductor will resonate at frequencies higher than 5.6 GHz and the inductor changes to be capacitive. To avoid the resonance, L_d is divided into three 3.3 nH inductors and series connected, since the resonant frequency of 3.3 nH inductor is 14 GHz, which is high enough for the operating frequency of this amplifier. In the bias network, C_g and C_d are used for RF bypass capacitors. Resistor R_g is used to enforce the isolation between RF and DC power supply. Series connected capacitors C_i and C_o were used for circuit matching as well as dc block. Large C_i value and small C_o value are aimed to have a more smooth gain on the broadband range. Fig. 2 shows a photograph of the amplifier with chip size of 1.5×1 mm^2.

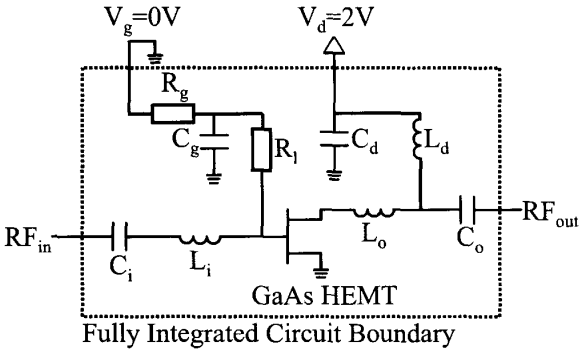

Figure 1. Schematic of the broadband amplifier.

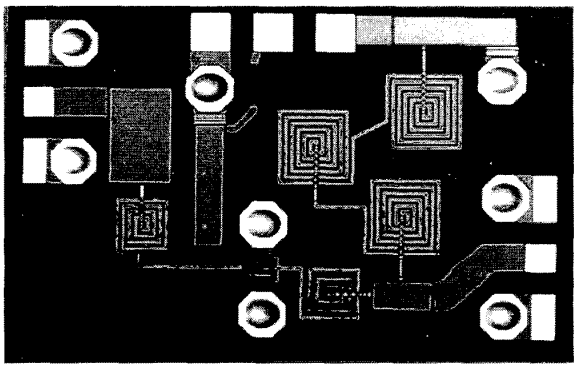

Figure 2. Photograph of the broadband amplifier.

3 Simulation Results and Measurement

Fig. 3 shows simulated and measured results for small signal gain and return losses of the amplifier. When power supply voltage is 2 V, simulated amplifier gain S_{21} is between 14 ± 0.5 dB at frequency ranging from 1 GHz to 6 GHz as dashed line in Fig. 3. Both input and output return losses are better than 10 dB.

The chip was measured on wafer using 50Ω coplanar ground-signal-ground (GSG) probes. Under 2V-power supply, measured small signal gain is between 14.5 ± 0.4 dB while frequency ranging from 1 to 6 GHz as solid line shown in Fig. 3. The 3-dB bandwidth is from 800 MHz to 7.4 GHz. The bandwidth is 161%. The return losses of input and output are almost higher than 10 dB. Measured results agree well with simulated ones as shown in Fig. 3. If the power supply is increased to 3 V, amplifier gain can reach up to 15.2 dB.

Fig. 4 shows the gain and output power vs. input power. When the power supply is 2 V and operation

frequency is 3.5 GHz, output 1-dB compression point is P_{1dB} = 18.1 dBm, and the third order intercepted point IP3 is 25.8 dBm. Measured noise figure is shown in Fig. 5, which is 4.7 dB at 1 GHz and increase to 5.5 dB at 6 GHz. In general, the noise figure of a lossy matched amplifier is worse than that of other approaches because of the resistor R_l. There is a tradeoff between gain bandwidth and noise figure. The circuit is stable under all bias conditions.

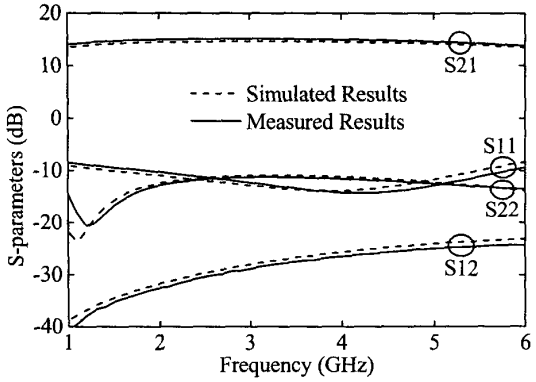

Figure 3. Simulated and measured results of S-parameters under 2V-power supply.

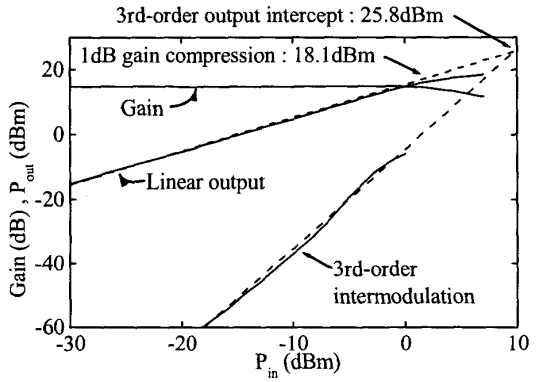

Figure 4. Intermodulation characteristics of the broadband amplifier for a two-tone signal at 3.5 GHz (Δf = 100MHz)

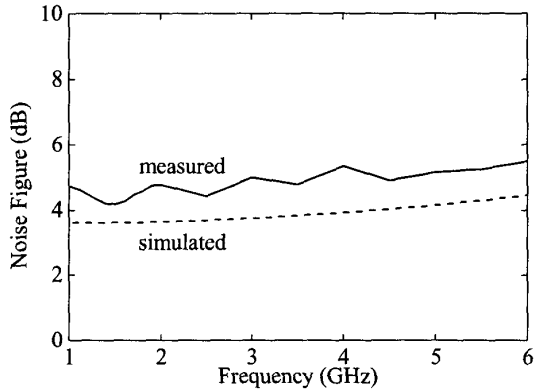

Figure 5. Simulated and measured noise figure of the amplifier.

4 Summary

A fully integrated lossy matched broadband amplifier with 0.2 μm gate length GaAs HEMT has been designed, fabricated and tested. Under 2V-power supply, small signal gain S_{21} is between 14.5 ± 0.4 dB and 3-dB bandwidth is from 800 MHz to 7.4 GHz. The bandwidth is 161%. Increase the power supply to 3 V, amplifier gain can reach up to 15.2 dB. Noise figure is better than 5.5 dB at 6 GHz. The output 1-dB compression point P_{1dB} is 18.1 dBm and the third order intercepted point IP3 is 25.8 dBm. Comparing the simulated and measured results, good agreement is observed.

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