28 dB Gain DC-6 GHz GaInP/GaAs HBT Wideband Amplifiers with and without Emitter Capacitive Peaking

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High gain shunt-series shunt-shunt wideband amplifiers with and without capacitive peaking are demonstrated by using GaInP/GaAs HBT technology. Experimental results show that power gain is 28 dB and input/output return loss is better than 12 dB from DC to 6 GHz for the wideband amplifier without emitter capacitive gain peaking. On the other hand, the wideband amplifier with emitter capacitive gain peaking has the same gain but the power gain bandwidth increases up to 8 GHz at the cost of lower input/output return loss. Power and noise performance are very similar for both types of wideband amplifiers. Both circuits have 8 dBm OP_{1dB} and 20 dBm OIP_3 at 2.4 GHz Noise figure of both designs are below 2.8 dB from 1GHz to 6GHz. Total current consumption is 67 mA at 5 V supply voltage for both wideband amplifiers.

INTRODUCTION

Wideband amplifiers [1] [2] [3] play an important role in modern RF communication systems. The essential design approach of a wideband amplifier is a dual feedback technology. A dual feedback configuration (shunt-series shunt-shunt) is used to achieve terminal impedance matching and wide bandwidth simultaneously in this paper. The circuit schematic of the designed shunt-series shunt-shunt GaInP/GaAs HBT wideband amplifier is illustrated in figure 1. The resistors R_{f1} and R_{f2} as illustrated in figure 1 are the feedback resistors. A Darlington pair is used in the second stage to improve the frequency response. A shunt-series shunt-shunt amplifier has intrinsic over-damped characteristics in gain response and thus an emitter capacitive gain peaking technique is used to extend the power gain bandwidth by remedying the intrinsic over-damped frequency response of power gain [4]. An emitter capacitive gain peaking technique can extend the power gain bandwidth at the cost of lower input/output return loss. In this paper, two identical wideband amplifiers except one with peaking capacitors and the other without peaking capacitors are fabricated to compare the performance. C_{e1} and C_{e2} in figure 1 are emitter peaking capacitors.

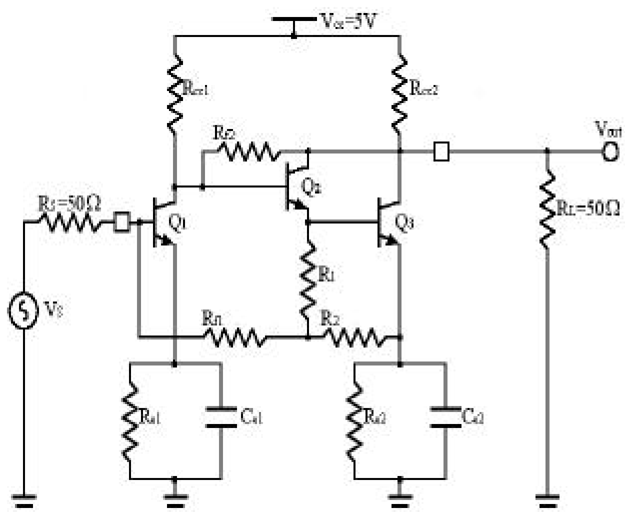

Figure 1.Circuit Schematic of a shunt-series shunt-shunt wideband amplifier.

CIRCUIT DESIGN

The photo of the fabricated HBT wideband amplifiers is shown in figure 2. There are two designs in the die. Wideband amplifiers in figure 2 were implemented with 1.4 um emitter width GaInP/GaAs HBT technology. The top one is a wideband amplifier with emitter gain peaking capacitors and the bottom one is a wideband amplifier without emitter gain peaking capacitors. The bottom device layout has been rotated 180 degree with respect to the top one to facilitate on-wafer probing. Both designs have identical transistor sizes for comparison purpose. The size of transistor Q_1 is 1.4 μm x 9μm x 2, the size of transistor Q_2 is 1.4μm x 6μm x 1 and the size of transistor Q_3 is 1.4μm x 9μm x 5. The die size is 1 mm x 1 mm. Most of the die area is not fully utilized in order to facilitate the on-wafer measurement and fit the minimum die size requirement of the foundry service. The die size of each amplifier can be easily compacted into 0.4 mm x 0.4 mm.

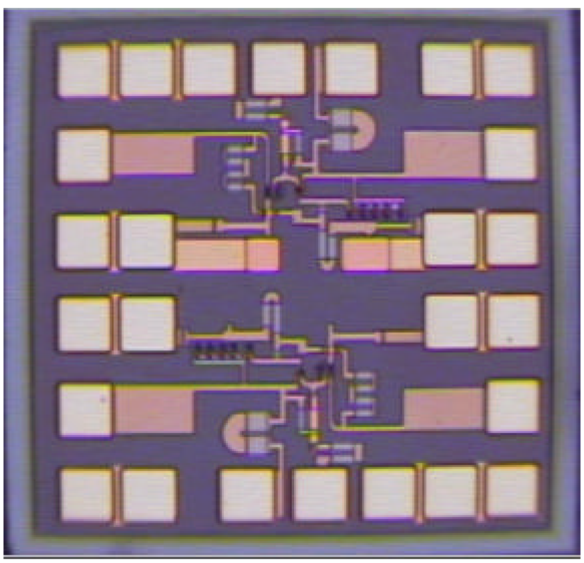

Figure 2.Die Photo of shunt-series shunt-shunt wideband amplifiers with and without emitter capacitive gain peaking.

RESULTS AND DISCUSSIONS

Total current consumption is 67 mA at 5 V supply voltage for both wideband amplifiers during on-wafer measurement. The first stage consumes 17 mA while the second stage consumes 50 mA. Forward transmission gain and input return loss are illustrated in figure 3 while reverse transmission gain and output return loss are illustrated in figure 4. The circuit without gain peaking capacitors has 6 GHz 3dB power gain bandwidth, S_{11} is below –15 dB and S_{22} is below –12 dB for the measurement range from DC to 18 GHz as revealed in figure 3 and figure 4.

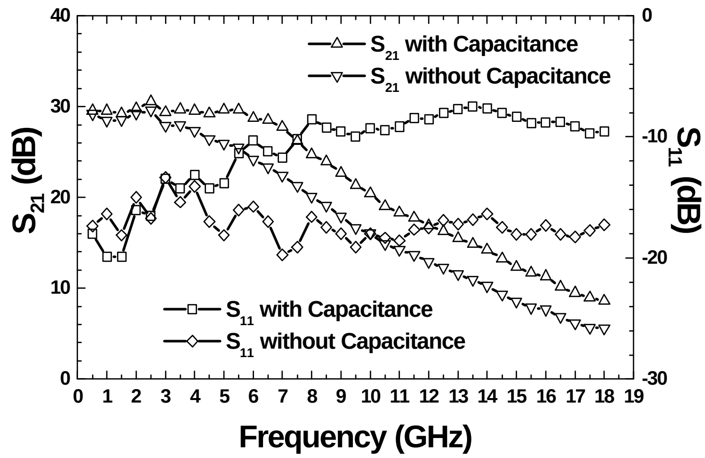

Figure 3. Forward transmission gain and input return loss measurement results of wideband amplifiers with and without emitter capacitive gain peaking.

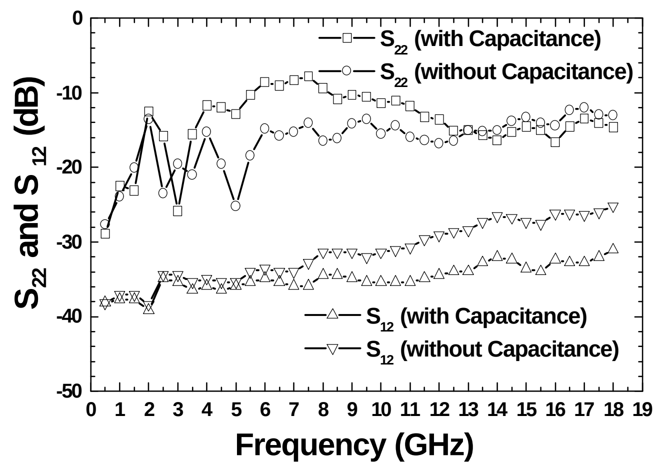

Figure 4. Reverse transmission gain and output return loss measurement results of wideband amplifiers with and without emitter capacitive gain peaking.

The circuit with emitter gain peaking capacitors has higher 3dB power gain bandwidth but suffers lower input/output return loss for frequencies above 4 GHz when gain peaking starts to show up. Thus, S_{11} reaches –8dB while S_{22} reaches –9 dB at 8 GHz for the circuit with emitter gain peaking capacitors. In other words, there exist some trade-offs between power gain bandwidth and matching bandwidth when emitter gain peaking capacitors are introduced.

Figure 5 illustrates the Z_T (50 Ω load transimpedance) and Z_{21} (open load transimpedance) of both two designs calculated from measured S parameters. The Z_T is defined as the transimpedance gain with 50Ω load and is calculated according to the following widely used formula

$$Z_T = \frac{S_{21}}{1 - S_{11}} \cdot 50$$

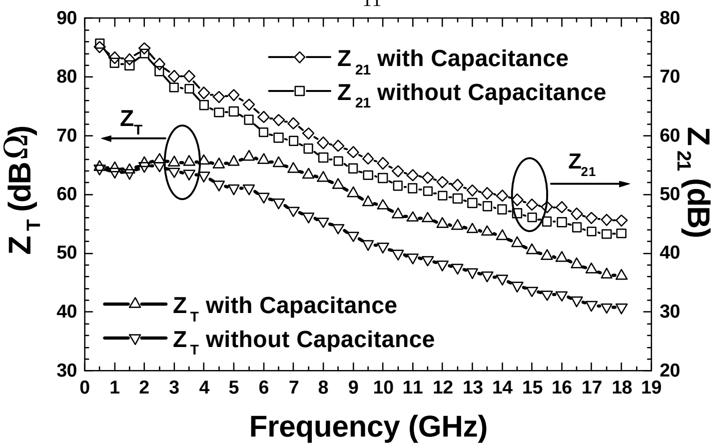

Figure 5.Measured Z_T & Z_{21} of wideband amplifiers with and without emitter capacitive peaking.

The circuit using emitter gain peaking capacitors has 65 dBΩ gain and 8 GHz 3 dB bandwidth for Z_T, but the circuit without emitter gain peaking capacitors has the same gain with 4 GHz 3 dB bandwidth for Z_T. The Z_{21} data in figure 5 also shows that the emitter gain peaking capacitors has influence on Z_{21} response.

Figure 6 illustrates the noise performance of both circuits. Noise figures of the two designs are below 2.8 dB for frequencies from 1 GHz to 6 GHz. Both designs have similar noise figures for frequencies up to 12 GHz and the wideband amplifier without emitter gain peaking capacitor shows slightly higher noise figures for higher frequencies.

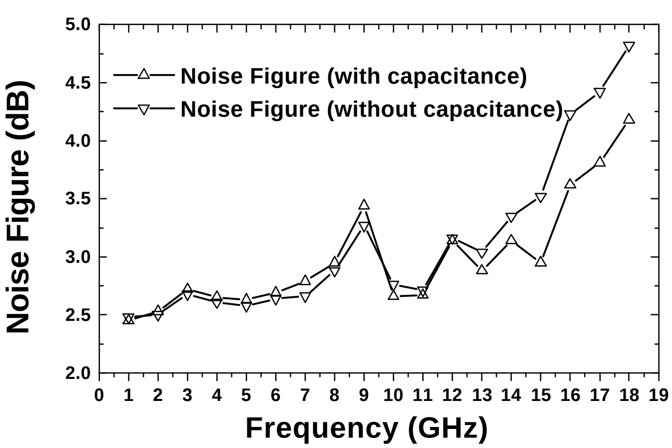

Figure 6. Measured noise figures of wideband amplifiers with and without emitter capacitive gain peaking.

Power performance is also measured. Both circuit have very similar power performance. 8 dBm OP_{1dB} and 20 dBm OIP_3 at 2.4GHz are obtained for the circuit with emitter capacitive gain peaking as illustrated in figure 7. OP_{1dB} and OIP_3 of both circuits as a function of frequency are illustrated in figure 8. There is no apparent power performance difference between two designs.

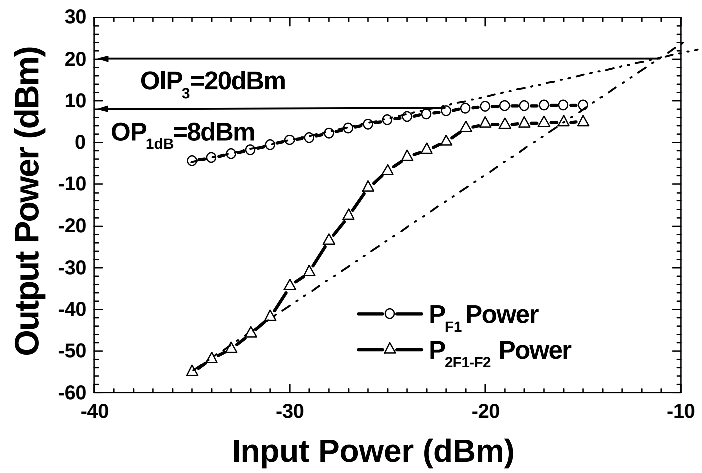

Figure 7. Power performance at 2.4GH for the wideband amplifier with emitter gain peaking capacitor z

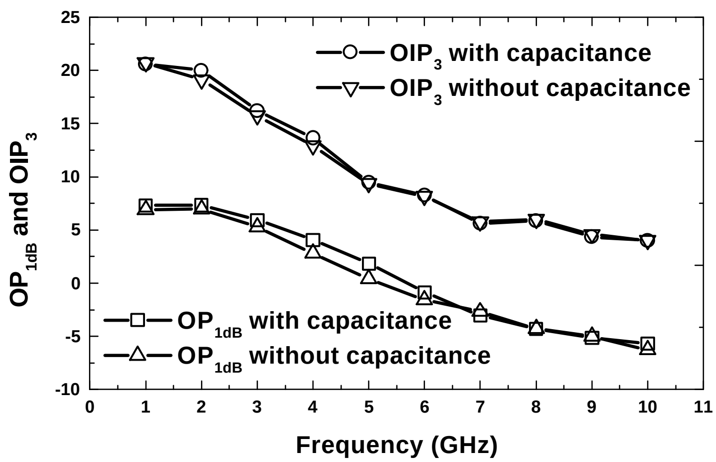

Figure 8. Power performance of wideband amplifiesr as a function of frequency

CONCLUSION

28 dB gain DC-6GHz GaInP/GaAs shunt-series shunt-shunt feedback wideband amplifiers are demonstrated in this paper. The experimental results show that power gain is 28 dB and input/output return loss is below 12 dB from DC to 6 GHz for the wideband amplifier without emitter capacitive

gain peaking. An emitter capacitive gain peaking technique can extend the 3dB power gain bandwidth at the cost of lower input/output return loss. The circuit using peaking capacitors has 8 GHz 3dB power gain bandwidth while S_{11} reaches –8dB and S_{22} reaches –9 dB at 8 GHz. Both circuits have similar noise and power performance. 8 dBm OP_{1dB} and 20 dBm OIP_3 at 2.4 GHz for both circuit are obtained**.** Noise figures of both circuits are below 2.8dB for frequencies from 1 GHz to 6 GHz.

ACKNOWLEDGEMENT

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