A Ka-band GaInP/GaAs HBT Four-stage LNA

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ABSTRACT

A Ka-band GaInP/GaAs HBT four-stage LNA has been designed and fabricated. This circuit is to be used in a multifunction T/R module for local multipoint distribution systems (LMDS) which include both analog and digital transmission. An average noise figure of 6 dB from 27 GHz to 30 GHz, and a gain of greater than 15 dB were measured. These results are the best reported at Ka-band for a LNA using transistors from digital HBT library.

INTRODUCTION

Recently, there has been much interest in providing broadband wireless access to fixed networks via millimeter wave radio transmission in the frequency band between 27.5-29.5 GHz. Local Multipoint Distribution Service (LMDS) could be used to provide wireless access to services ranging from one-way view distribution and telephony to fully-interactive switched broadband multimedia applications. GaInP/GaAs heterojunction bipolar transistors (HBTs) are prime candidates for such applications due to their high peak power density and their usefulness for a variety of circuit types. To demonstrate the HBT's potential for low noise applications, a Ka-band HBT transistor and a four-stage LNA have been developed using the same material and fabrication process as used for other digital HBT components [1].

LOW NOISE AMPLIFIER DESIGN

A preliminary noise model was used based on a modified Van der Ziel model [2]. In this model, there are two shot noise sources and thermal noise due to R_b. One source associates with the base-emitter circuit (i_b) and one with the collector circuit (i_c). It was shown that the high frequency noise can be reduced by lowering the base resistance [3]. This is done by using an array of transistors. Since gain is premium at Ka-band for HBT devices, the circuits were designed for minimum noise measure (NM) instead of minimum noise figure. This provides a good compromise between low noise and high gain[4]. The chosen design source match network was chosen to minimize NM which compromises between maximum gain and F_{min} as suggested in[4].

MMIC FABRICATION

The Nortel self-aligned HBT process [1] has standard transistors, 2x2 μm^2, 3x3 μm^2 and 3x6.5 μm^2, that are primarily used for digital applications. Using an array of 2x10 transistors of size 2x2 μm^2, the transistor was laid out for a common emitter configuration to have a coplanar input (base) and a coplanar output (collector) with the emitter coming off the two sides of the transistor as shown in Fig. 1a). This allows for a low emitter parasitic inductance and has potential use in a coplanar system with no through vias. The 2x2 μm^2 transistors were used to provide the largest peripheral access to the base to minimize R_b [3]. Fig. 1b) shows the layout of the four-stage LNA. The substrate thickness was four mils and the substrate vias were available in the process. Test devices demonstrate typical dc current gains of 70 at a collector current density of 0.5 mA/μm^2.

MEASURED LNA PERFORMANCE

Measured and simulated S-parameters for the transistor are shown in Fig. 2 biased at Vce = 3V, Ic = 12 mA. Fig. 3 compares the measured and the originally predicted noise figure of the four-stage LNA, while Fig. 4 compares the gain response of the amplifier. The input and output match are shown in Fig. 5. Measured noise figure is less than 5 dB at 28 GHz. Measured S_{11} is -15 dB at 28 GHz.

CONCLUSION

In conclusion, a Ka-band HBT transistor and a four-stage LNA utilizing GaInP/GaAs HBTs have been developed. An average noise figure of 6 dB from 27 GHz to 30 GHz, and a gain of greater than 15 dB were measured. This circuit is process-compatible with the other functional components in the HBT T/R module. The noise performance, while not best reported at Ka-band compared to PHEMTs is best reported for a HBT process using transistors available from digital library. The success of this work has paved way for the development of future LMDS circuits.

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REFERENCES

[1] Q.M. Zhang et al., "A New Large Signal HBT model," 1994 IEEE MTT-S International Microwave Symposium, pp. 1253-1256.

[2] A. Van der Ziel, et al. "Accurate Expression for the Noise Temperature of Common Emitter Microwave Transistors," IEEE Transactions on Electron Devices, Sept. 1984, pp 1280-1283.

[3] T. Jenkens et al., "Low-noise High-Power Heterojunction Bipolar Transistor for Mixed-Mode Applications," 1995 IEEE MTT-S International Microwave Symposium, pp. 1129-1132.

[4] S.L.G. Chu et al., "A Ka-band HBT Two-Stage LNA," 1994 IEEE MTT-S International Microwave Symposium, pp. 307-310.

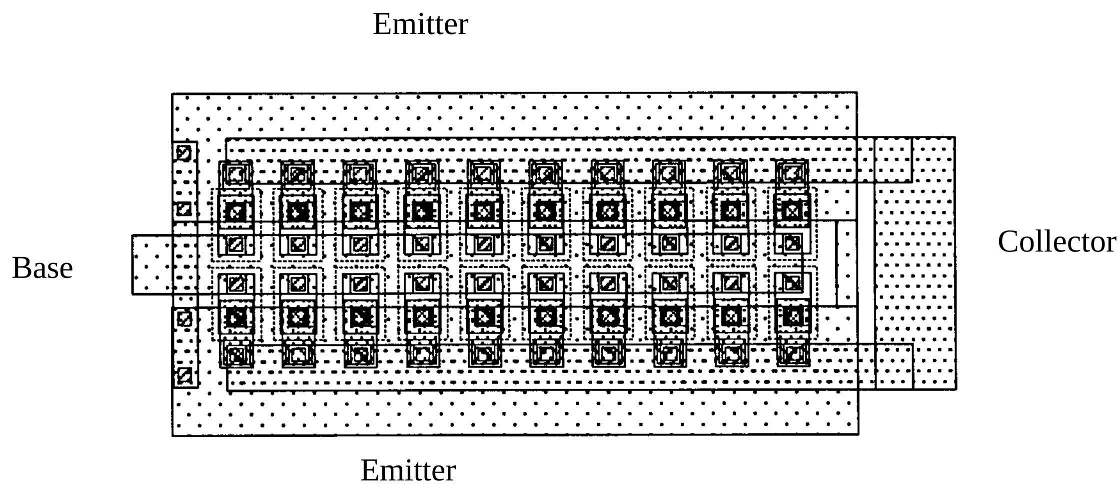

Fig. 1a) A 2 x 10 transistor array of 2 x 2 μm^2 HBTs used in the four stage LNA

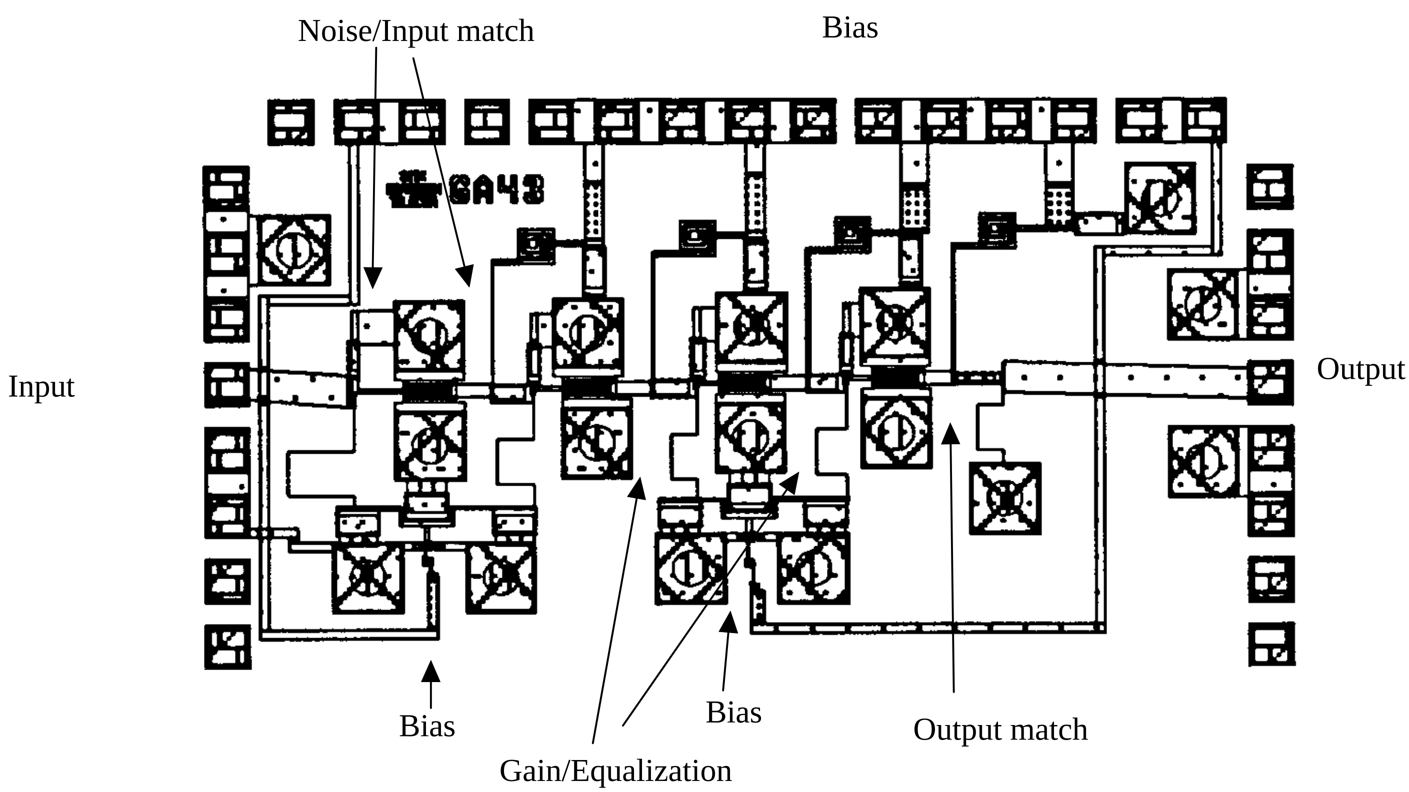

Fig. 1b) Layout of four stage Ka-band LNA

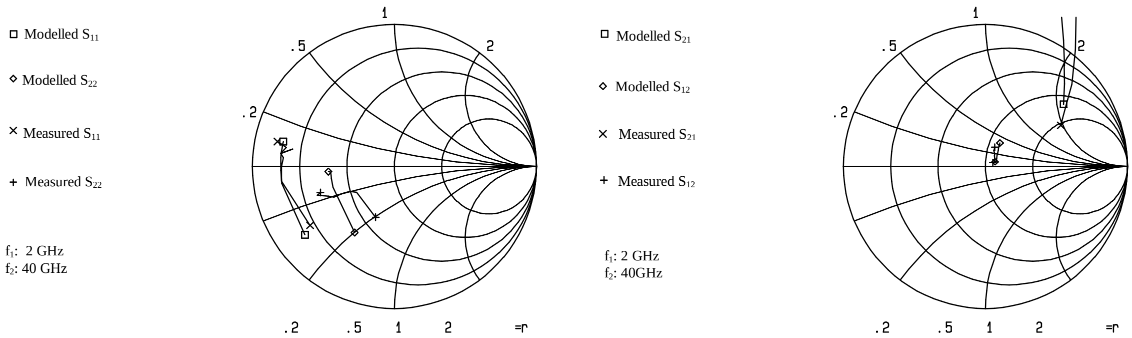

Fig. 2 Measured and modelled S-parameters of the transistor array in Fig. 1a)

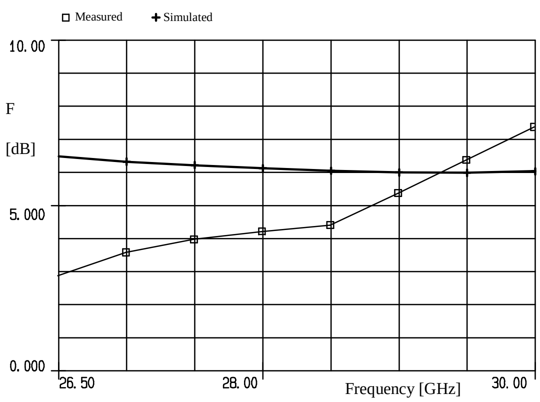

Fig. 3 Simulated and measured Noise Figure of LNA

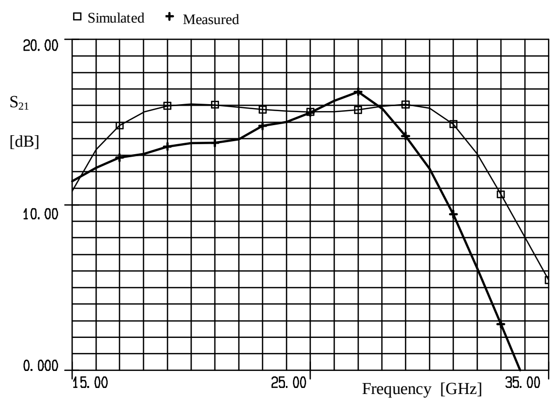

Fig. 4 Simulated and measured Gain of LNA

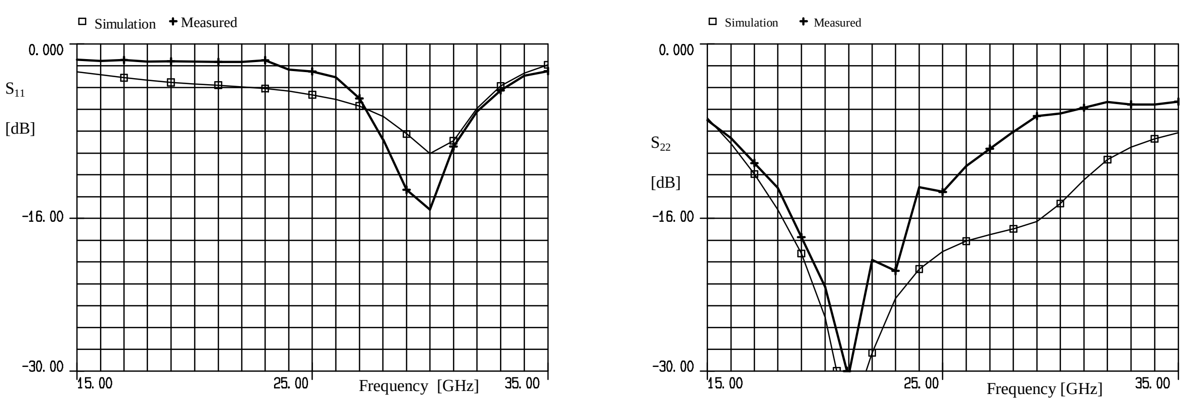

Fig. 5 Simulated and measured input and output reflection coefficient