

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.

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].

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

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

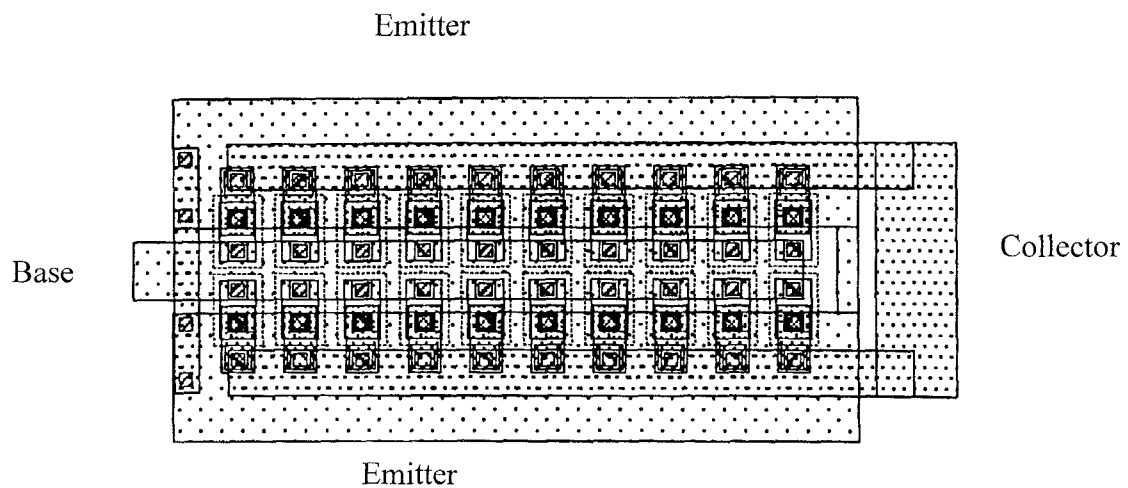


Fig. 1a) A 2 x 10 transistor array of $2 \times 2 \mu\text{m}^2$ HBTs used in the four stage LNA

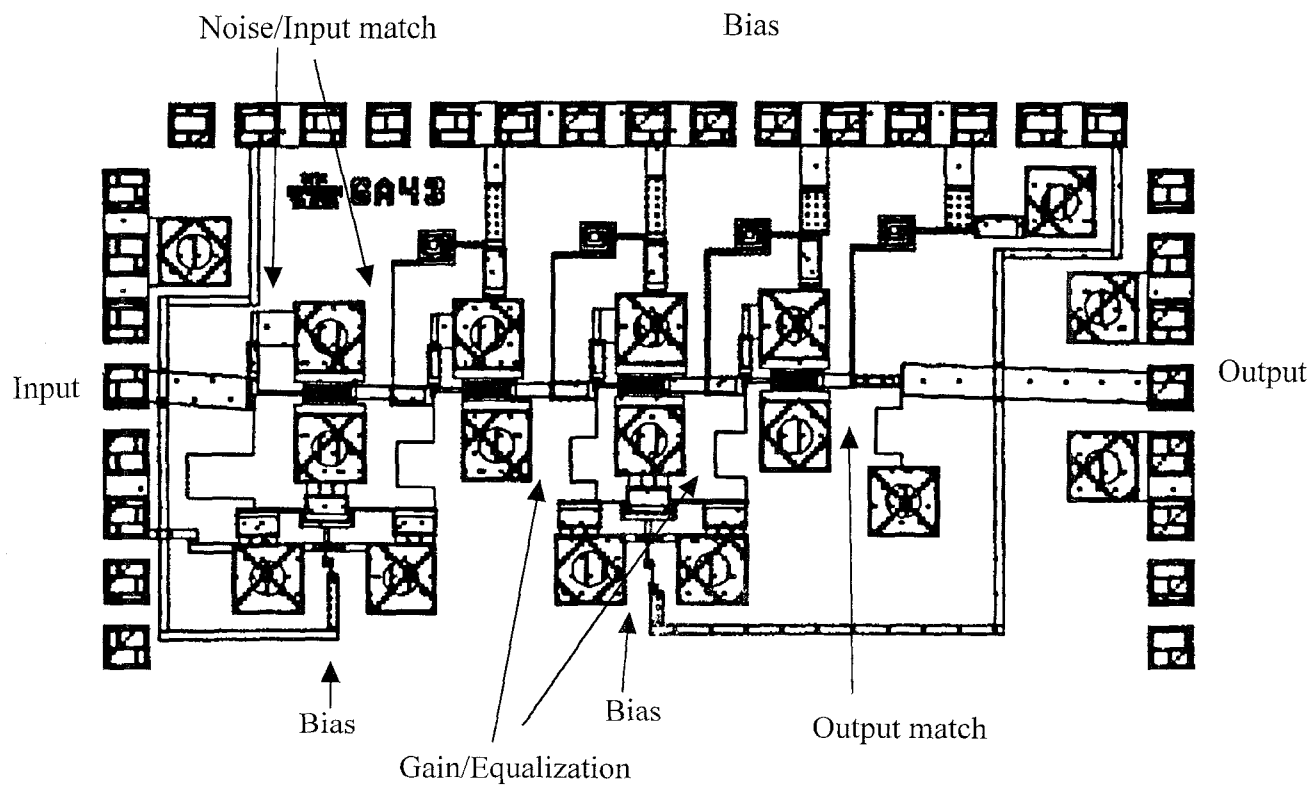


Fig. 1b) Layout of four stage Ka-band LNA

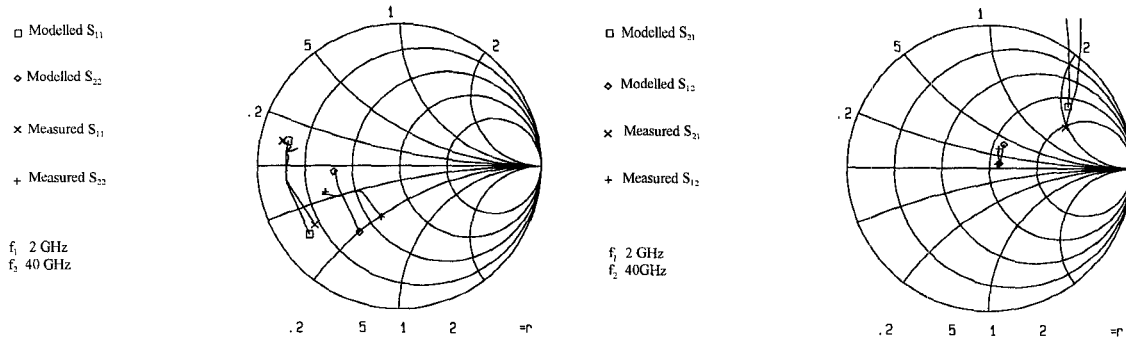


Fig. 2 Measured and modelled S-parameters of the transistor array in Fig. 1a)

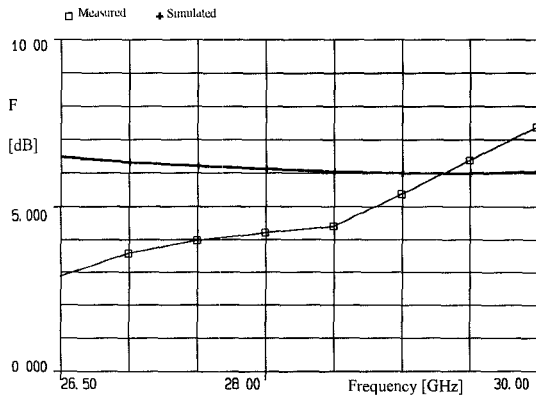


Fig. 3 Simulated and measured Noise Figure of LNA

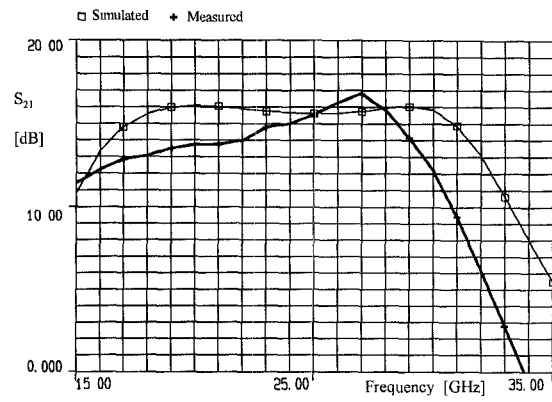


Fig. 4 Simulated and measured Gain of LNA

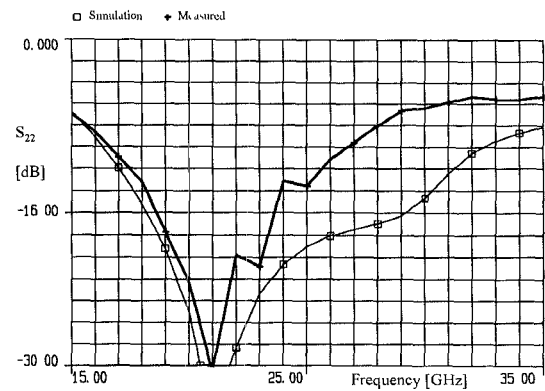
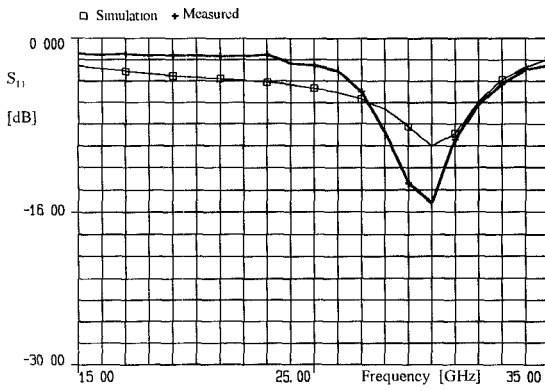


Fig. 5 Simulated and measured input and output reflection coefficient

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, $2 \times 2 \mu\text{m}^2$, $3 \times 3 \mu\text{m}^2$ and $3 \times 6.5 \mu\text{m}^2$, that are primarily used for digital applications. Using an array of 2×10 transistors of size $2 \times 2 \mu\text{m}^2$, 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 $2 \times 2 \mu\text{m}^2$ 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 $0.5 \text{ mA}/\mu\text{m}^2$.

MEASURED LNA PERFORMANCE

Measured and simulated S-parameters for the transistor are shown in Fig. 2 biased at $V_{ce} = 3 \text{ V}$, $I_c = 12 \text{ mA}$. 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. Jenkins 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.