On the Angular Dependence of Cryogenic InP HEMTs in a Magnetic Field

I. Harrysson Rodrigues[1]*, D. Niepce[1], G. Moschetti[2], A. Pourkabirian[2], J. Schleeh[2], T. Bauch[1], J. Grahn[1]

[1] Department of Microtechnology and Nanoscience – MC2, Chalmers University of Technology, SE-41296 Gothenburg, Sweden
[2] Low Noise Factory AB, Nellickevägen 22, Gothenburg, SE-41663 Sweden
* isabelr@chalmers.se

Abstract

It is shown that the cryogenic InP HEMT LNA was strongly degraded with respect to noise temperature and gain in the presence of a perpendicular magnetic field. This was correlated with a strong reduction in the source-to-drain current of the InP HEMT kept at 2 K. A large angular dependence of the source-to-drain current with respect to the magnetic field was observed. The observations suggest a very strong geometrical magnetoresistance occurring in InP HEMTs at 2 K, pointing to the importance of precise alignment of the cryogenic InP HEMT LNA in the presence of a magnetic field.

Introduction

In many sensitive detection systems, HEMT-based low-noise amplifiers (LNAs) at cryogenic temperatures (1-10 K) are used to read out tiny RF signals. Some of these systems rely on strong magnetic fields, e.g. mass spectrometry [1] and magnetic resonance imaging [2]. It is important to be aware of the effect of the magnetic field on the LNA electrical properties. We have investigated this for the cryogenic InP HEMT LNA, the most sensitive amplifier in today's read-out applications.

Experimental

RF measurements were done on a 0.3-14 GHz InP HEMT MMIC LNA [3] placed in a dilution fridge and exposed to a perpendicular (angle of rotation = 90°) static magnetic field up to 10 T at 2 K. The DC-measurements on the InP HEMTs, fabricated in the same technology as in [3], were done under equivalent conditions but in a different set-up, which permitted vary the angle of rotation of the HEMT with respect to the applied magnetic field from 0 to 180°.

Results and discussion

Figure 1 shows the experimental set-up and measurements of the LNA up to 1.5 T at 3, 5, 8, and 10 GHz. Noise temperature strongly increases with the magnetic field, and the gain drops considerably. The dependence in Fig. 1(c) is much stronger than for a cryogenic GaAs HEMT LNA [4].

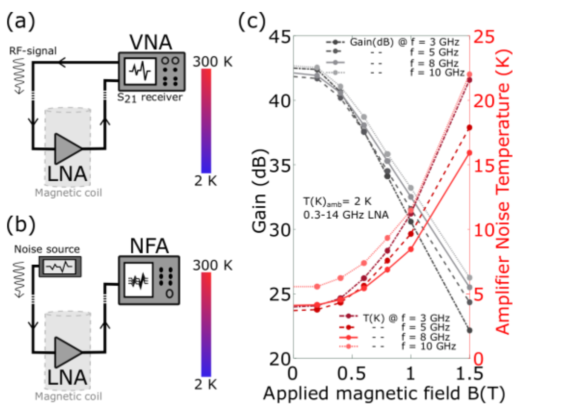

Figure 1. Schematic of the experimental set-up for (a) gain and (b) noise temperature of the InP HEMT MMIC LNA. Results are shown in (c).

Figure 2 shows the normalized source-to-drain current of the transistor as a function of the rotation angle for magnetic fields up to 10 T. When applying the magnetic field, a large reduction of the current with respect to angular dependence is observed for the InP HEMT. We interpret the data seen in 2 as a strong geometrical magnetoresistance effect in the device [5]. This is due to the very high electron mobility in the 2DEG for a cryogenic InP HEMT and the high aspect ratio in the device layout, i.e. a short gate length and long gate width.

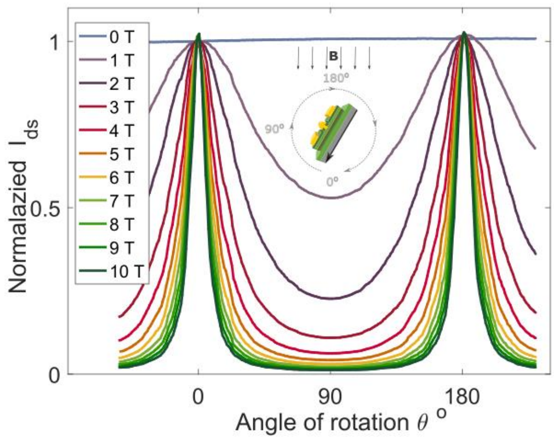

Figure 2. Rotation sweep of the transistor showing the normalized drain current versus rotation angle. Ambient temperature was 2 K. Device size 2x50 µm. V_{ds}=V_{gs}=0.4 V.

Conclusions

The device experiment highlights the strong angular dependence of the cryogenic InP HEMT in a magnetic field. This is the reason for the rapid degradation in gain and noise temperature of the cryogenic InP HEMT LNA. The origin of this is related to the strong geometrical magnetoresistance occurring in the cryogenic InP HEMT. As a result, the cryogenic InP HEMT LNA must be precisely aligned parallel with the applied magnetic field.

Acknowledgments

This work was performed in GigaHertz Centre in a joint research project between Chalmers University of Technology, Low Noise Factory AB, Wasa Millimeter Wave AB, Omnisys Instruments AB and RISE Research Institutes of Sweden. We are grateful to Serguei Cherednichenko for assistance in the noise measurements and Niklas Wadefalk for the LNA design.

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