Magnetic Influence on Cryogenic InP HEMT LNAs

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I.INTRODUCTION

The cryogenic InP high electron mobility transistor (HEMT) is used in the most sensitive semiconducting low-noise amplifier (LNA) receivers today. However, the knowledge of InP HEMT LNAs when exposed to high magnetic fields, e.g. in MRI scanners [1], is limited. In [2], the magnetic influence on the noise temperature of GaAs HEMT LNAs were reported for frequencies below 1 GHz. It is of interest to re-examine these results using today's state of the art InP HEMT cryogenic LNAs at microwave frequencies.

In this work, we present both cryogenic DC measurements for a 1x100 µm InP HEMT [3] under the influence of static magnetic fields and RF measurements of the InP HEMT LNA [4].

The HEMT measurements were conducted in a physical property measurement system (PPMS), in which the device under test was electrically connected through wire bonding. The device was mounted in a cold stage and cooled down to 2 K in vacuum. A static magnetic field ranging up to 2 T was then applied. The LNA was a three-stage MMIC module [4] with a frequency band 0.3 – 14 GHz, processed in the same InP technology as the HEMT. The LNA was measured with equivalent conditions as the HEMT but in a different set up permitting RF characterization. All electrical measurements were performed in different orientations, varying the angle of the applied magnetic field.

II.RESULTS

The influence on the cryogenic HEMT DC current-voltage, when increasing the in plane (parallel) magnetic field from 0 to 2 T, was found to be insignificant; see Fig. 1 (a). In contrast, the DC behaviour of the HEMT was strongly affected when the transistor channel was oriented 90 degree out of plane (perpendicular) to the magnetic field. This resulted in a significant reduction of the output drain current as a function of drain voltage; see Fig. 1 (b). An angular sweep of the transistor revealed a clear angle dependence on the output current which became stronger when the magnetic field increased. As suggested by [2], this is due to a Lorentz force acting on the 2DEG in the HEMT.

The RF measurements on the LNA showed a clear dependence of the orientation when exposed to static magnetic fields up to 2 T. When aligned out of plane, the gain decreased significantly, leading to a high increase of the noise temperature of the LNA, with increased magnetic field. This was measured for different frequencies, as illustrated in Fig. 2. The noise temperature of the LNA increased with approximately 15 K, when the magnetic field increased from 0 to 1.5 T, whereas in the earlier study the noise temperature was barely affected below 1.5 T [2].

III. CONCLUSIONS

We observed a strong dependence in I-V on magnetic field when the InP HEMT is placed perpendicular to the field, compared to when aligned parallel. When aligned perpendicular to the field, the noise temperature of a cryogenic 0.3-14 GHz InP HEMT MMIC LNA increased with magnetic field.

The results point to the importance of aligning the InP HEMT in plane in a cryogenic LNA exposed to magnetic field in order for the read-out signal not to be distorted. The effect appears significantly stronger in today's low-noise InP HEMT technology, than what previously have been reported for GaAs HEMT LNAs [2].

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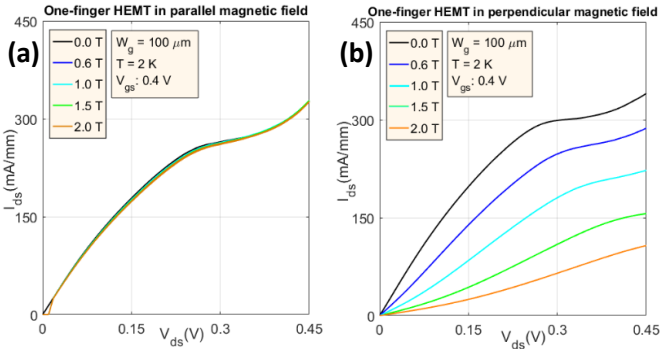

Fig.1. Drain current versus drain voltage at 2 K for various external applied magnetic fields, ranging from 0 to 2 T, with magnetic field aligned in plane (a) and out of plane (b).

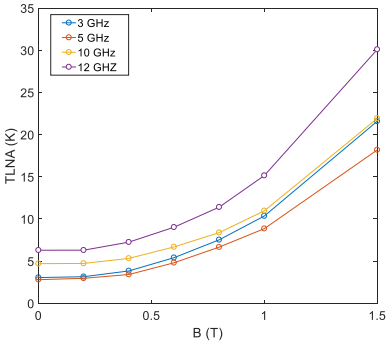

Fig.2. Noise temperature of InP HEMT LNA at various frequencies, when increasing applied magnetic field.