Comparison of Three Preamplifier Technologies: Variation of Input Impedance and Noise Figure With B_0 Field Strength

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Introduction

Array coil preamplifiers are subjected to large magnetic fields since they are placed close to each coil to minimize SNR losses due to cabling. Noise figure (NF) and input impedance are key parameters that must vary minimally with magnetic field strength and orientation [1,2] to ensure there are no differences in performance between the bench and the bore. In this work we compare the sensitivity to magnetic fields of three amplifiers based on different semiconductor technologies.

Methods

The following commercially available devices (DUTs) were chosen for comparison (in order of decreasing electron mobility): MGA-53543 (Avago, USA) GaAs pHEMT RFIC; MAR-8A+ (Mini-Circuits, USA) InGaP HBT in Darlington configuration; and BF998 (various vendors) N-channel Si dual-gate MOSFET.

An initial baseline noise figure measurement was performed in a radiofrequency (RF) lab in order to obtain a reference zero-field value. The measurement system (Fig. 1, [3]) was then placed outside the 5 gauss field line of a 9.4T magnet (205 mm bore, Magnex, UK). Double-shielded coaxial cables (RG223) 6 meters in length were used to connect the measurement system to the DUT through the magnet's RF cage. Each amplifier was positioned in three orthogonal orientations within the magnet bore and scattering (S) parameters were measured at 130 MHz at nine B_0 field strengths between 0 T and 9.4 T, varying the field as described in [1]. For each amplifier the orientation that produced the greatest change in S-parameters was chosen for a Y-factor noise figure measurement [4]. A calibrated 50 Ω noise source (NW1M500-6-CS, NoiseWave, USA) was used with its 6.69 dB excess noise ratio (ENR) corrected for the attenuation of the coaxial cable [5]. With the S-parameters measured previously and using corrections for second stage noise [4] and available gain [5], the noise figure of the amplifier was then determined for all nine field strengths.

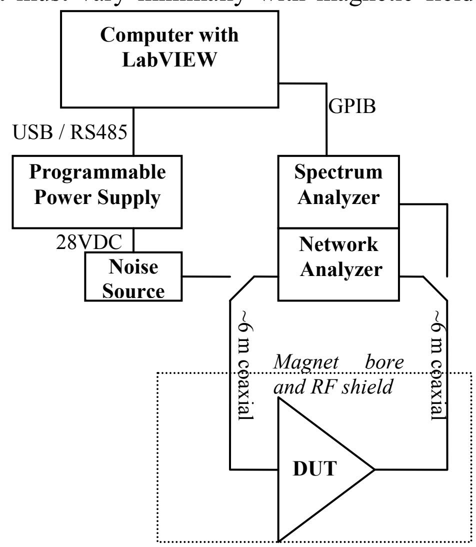

Figure 1: measurement setup

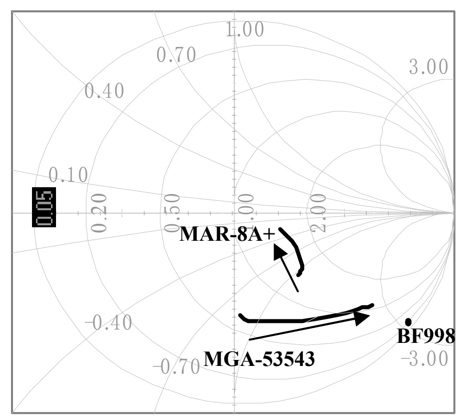

Figure 2: S_{11} variation as a function of B_0 (arrow indicates increasing B_0)

Results and Discussion

Greatest variations in S-parameters for the MGA-53543 and BF998 were with the magnetic field perpendicular to the circuit board while for the MAR-8A+ it was with the magnetic field parallel to the circuit board and ground pins [1]. Changes in the input reflection coefficient (S_{11}) were negligible for the BF998, moderate for the MAR-8A+, and large for the MGA-53543 (Fig. 2). Amplification (S_{21}) values at 0 T and 9.4 T were, respectively: 7.3 dB and 6.2 dB for the BF998; 27.7 dB and 23.5 dB for the MAR-8A+; 22.8 dB and 8.0 dB for the MGA-53543. Noise figure increased with the magnetic field strength in all cases (Fig. 3), with the BF998 seeing the smallest change and the MGA-53543 the largest. The bias current drawn by all amplifiers decreased as the magnetic field strength increased. However, similar variations in bias current in the absence of a magnetic field yielded little to no change in the noise figure [1].

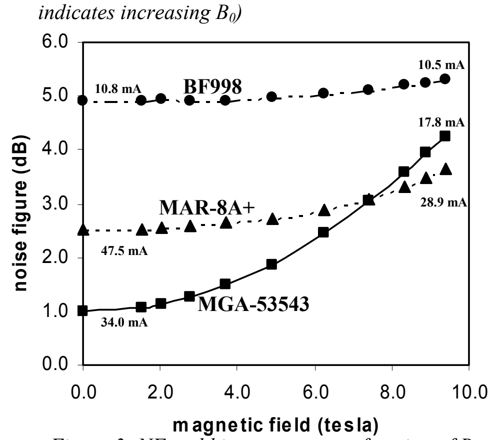

Figure 3: NF and bias current as a function of B_0 at 130 MHz

Conclusion

Our results confirm that the degradation of NF by high magnetic fields is worse for high-electron-mobility semiconductors such as GaAs and are observed at fields as low as 2–3T. GaAs devices allow the lowest noise figures to be obtained and are used by numerous coil manufacturers.

These measurements indicate that a field-tolerant preamp should have a MOSFET input stage for a large and stable S_{11} and a Si or InGaP second stage to provide a stable S_{21}. Active current biasing cannot stabilize NF due to the relatively small effect the current has on NF. Future work will explore field sensitivity of SiGe bipolar transistors [2] and discrete GaAs pHEMTs.

References

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Acknowledgements: funding from the Natural Sciences and Engineering Research Council (Canada), Alberta Cancer Research Institute, Canada Foundation for Innovation. We thank Drs. Cecilia Possanzini and David Hoult for stimulating discussions.