Influence of magnetic field on preamplifiers using GaAs FET technology

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Introduction

Parallel imaging is a very powerful technique which allows fast imaging and/or better spatial resolution. This technique requires the use of multi-element arrays as receivers. One method to decouple the elements of a multi-element array is to use a high (or low) input impedance preamplifier. Normally, high or low input impedance preamplifiers make use in the first stage of GaAs FET (Field Effect Transistors), which guarantees high impedance in combination with low noise figure. However, in this paper, we will show that GaAs FET have a strong dependency on magnetic field.

Methods and Materials

Input impedance (S11parameter) and gain (S21 parameter) were measured with a network analyser on the bench. At zero magnetic field, the typical input impedance at 128MHz is 450Ω, the gain is 22.6dB. The noise figure of around 0.5dB at 128MHz was measured with a noise meter (50 Ω related).

The S-parameter measurements were repeated on a 3T Philips Achieva system with the preamplifier on the patient support and the network analyser a few meters away from the magnet in order to minimize the influence of magnetic field. The measurements at zero magnetic field (patient table outside the bore) were similar to the measurements on the bench. Cables were calibrated out.

The same measurements were performed with the preamplifier inside a 3T system. The setup is identical to the previous experiment, only the preamplifier is moved inside the magnet. We measured the S-parameters of the preamplifier in the two situations of magnetic field perpendicular and parallel to the preamplifier.

Results and discussion

Fig. 1 shows the S-parameters of the preamplifier measured in a 3T magnetic field in both parallel (Fig.1a) and perpendicular (Fig.1b) to the preamplifier.

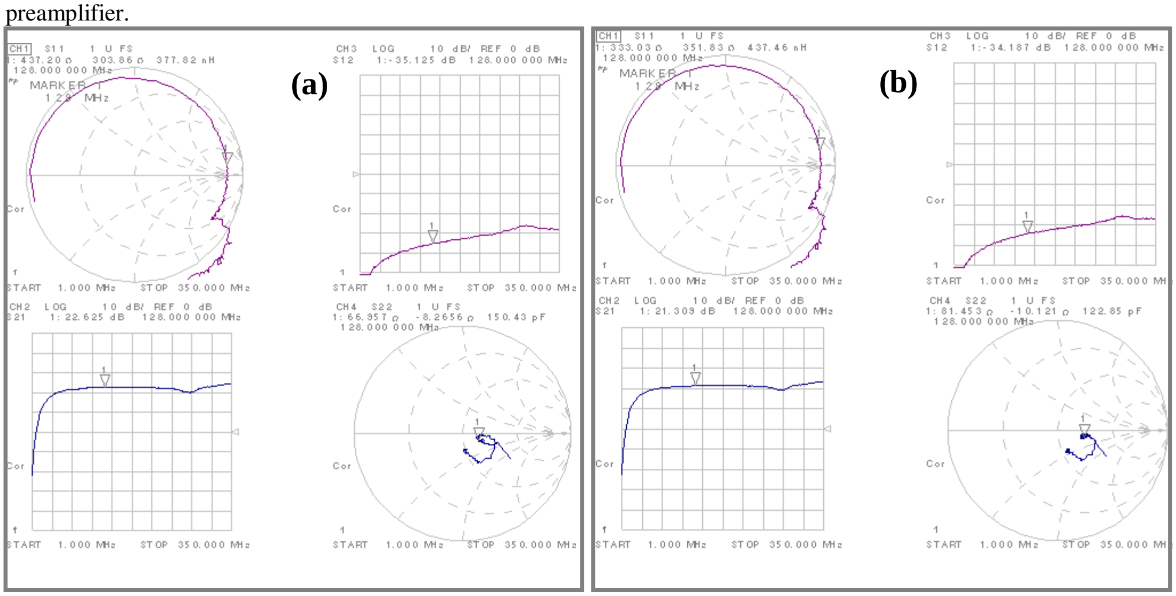

Fig. 1: S-parameters of the preamplifier build with GaAs FET measured with (a) magnetic field parallel to the FET and (b) magnetic field perpendicular to the FET.

In the direction of magnetic field parallel to the preamplifier (Fig.1a), the S-parameters are basically identical to the zero magnetic field measurements, whereas the S parameters change dramatically when the field is perpendicular to the preamplifier (Fig.1b): the input impedance becomes lower (330Ω), the gain drops 1.3dB and the bias current decreases 1.6mA. The noise behaviour of the FET is also compromised. Such behaviour is explainable in terms of Hall effect. GaAs transistors utilize the heterojunction between two semiconducting materials to confine electrons to a triangular potential well. This layer is called two dimensional gas because the carriers (electrons or holes) are free to move in two dimensions, but they are tightly confined in the third dimension. In a FET, in the presence of a magnetic field perpendicular to the flow current in the two dimensional gas, the carriers experience a force in a direction perpendicular to the magnetic field and the current (Hall effect). As a consequence, the carrier motion is affected, and therefore the S-parameters of the preamplifier get affected, as shown in Fig.1.

Conclusions

We have shown that magnetic field influences the S-parameters of a preamplifier built with FET, and therefore it affects the gain, the input impedance and the noise of the preamplifier. A preamplifier with a GaAs FET can be used in high magnetic field but in order to assure the correct functioning of the preamplifier it is necessary to align the plane of the two dimensional electron/hole gas in the FET parallel to the magnetic field. In this situation the preamplifier behaviour is not affected by the presence of the magnetic field.