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Hellah Balleh, Olivier Haas, Basile Dufay, Sébastien Saez, Christophe Dolabdjian. Sensitivity performance of magnetic field sensor based on magnonic crystals. European Magnetic Sensors and Actuators (EMSA) Conference 2018, Jul 2018, Athens, France. hal-03716349

HAL Id: hal-03716349

<https://hal.science/hal-03716349>

Submitted on 7 Jul 2022

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Sensitivity performance of magnetic field sensor based on magnonic crystals

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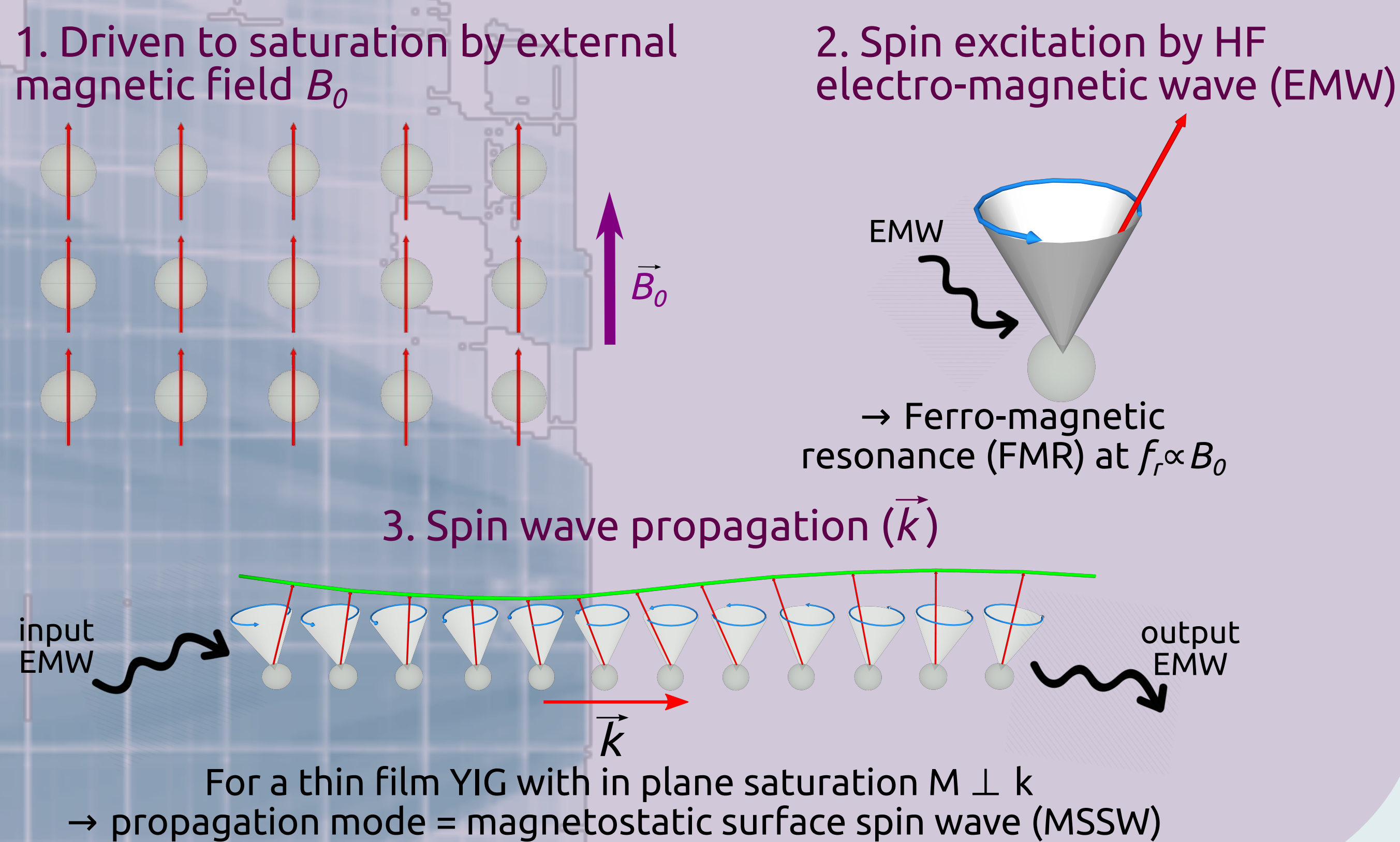
Abstract : Recent works [1, 2] presented an exploratory investigation of high sensitive magnetic field sensors based on magnonic crystals. They highlighted their strong potential for detecting weak magnetic fields with small-sized sensor operated at room temperature. The working principle relies on the propagation of surface magnetostatic spin-wave through a periodic structure, called magnonic crystals. These materials are made by periodically spatially modulating the magnetic properties along the propagation line of the spin wave. This structure acts as a reflector whenever the spatial periodicity matches the spin wave wavelength, resulting in a band-gap in the transmission spectrum.

In [1, 2], the measurement of the complex transmission coefficient (S_{21}) shows a significant frequency shift of the band-gap absorption peak depending on the applied DC magnetic field. As a consequence, authors propose to use these variations as a magnetic field sensor. We investigate the ability of magnonic crystals to be used as a magnetometer and measured its expected output sensitivity, expressed in unit of V/T, according to the external magnetic field variations. For this, a sine electromagnetic wave at a fixed frequency, $f_{exc} = 1$ GHz, is applied to the magnonic crystal. The induced spin wave propagates along the main length direction. When the external DC magnetic field varies, the amplitude of the sensed signal at f_{exc} strongly changes, resulting in an AM signal. Based on a classical amplitude demodulation conditioning circuitry, an output sensitivity of 200 V/T is obtained. Considering, presently, that dominating noise sources are those due to the electronic conditioning circuitry, such results allow to predict a sensor equivalent magnetic noise level around 20 pT/√Hz in white noise region.

Sensing element : magnonic crystal

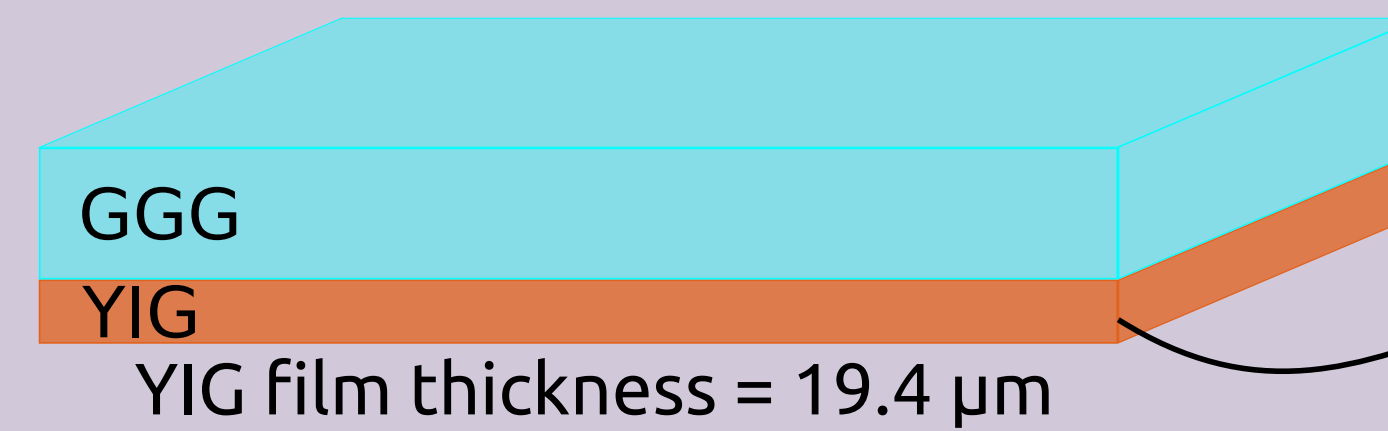
Physical principle

Yttrium Iron Garnet (YIG) : ferrimagnetic material

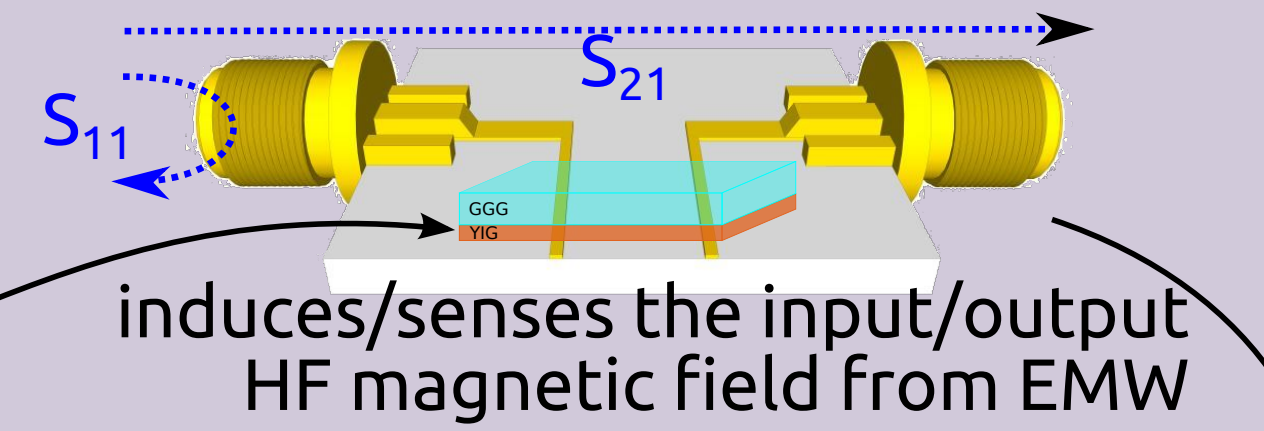


Material and characterisation setup

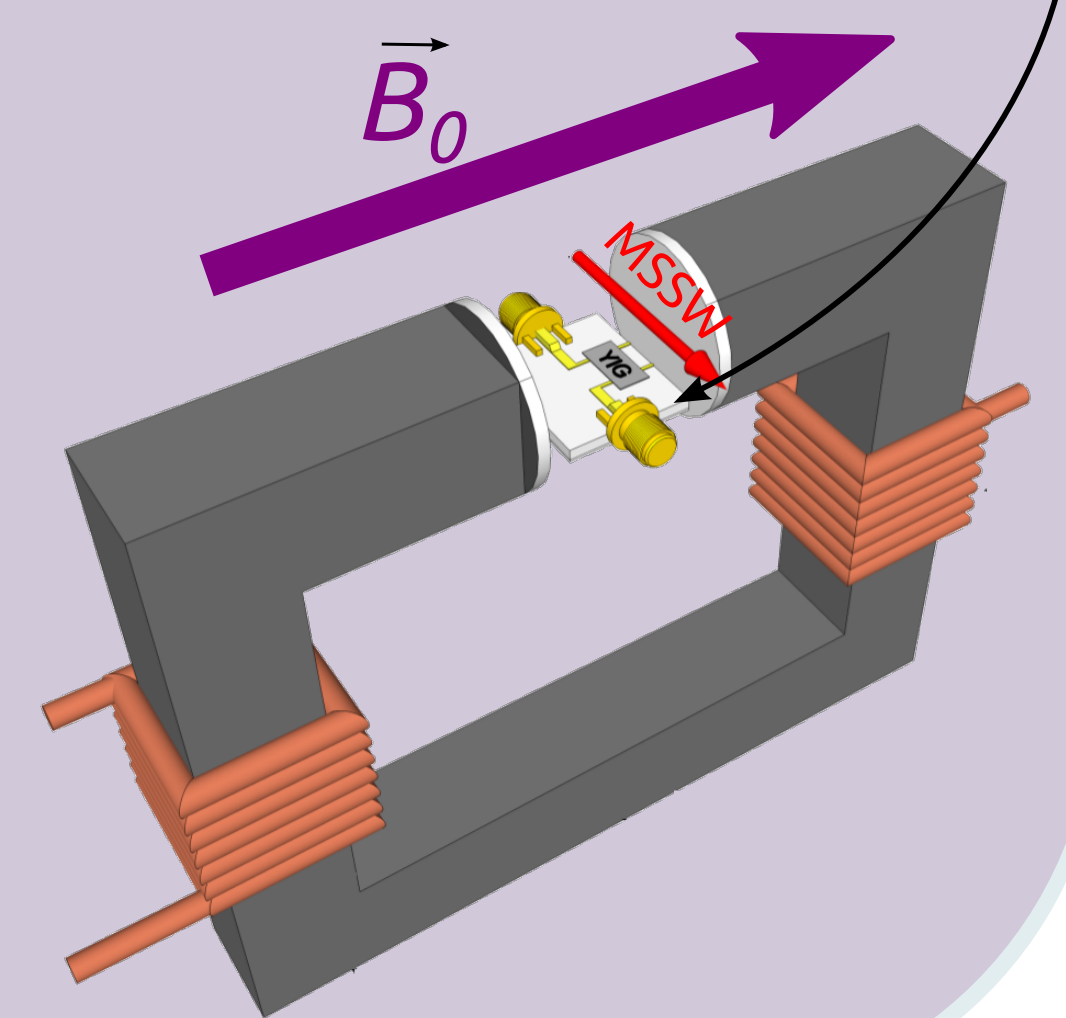
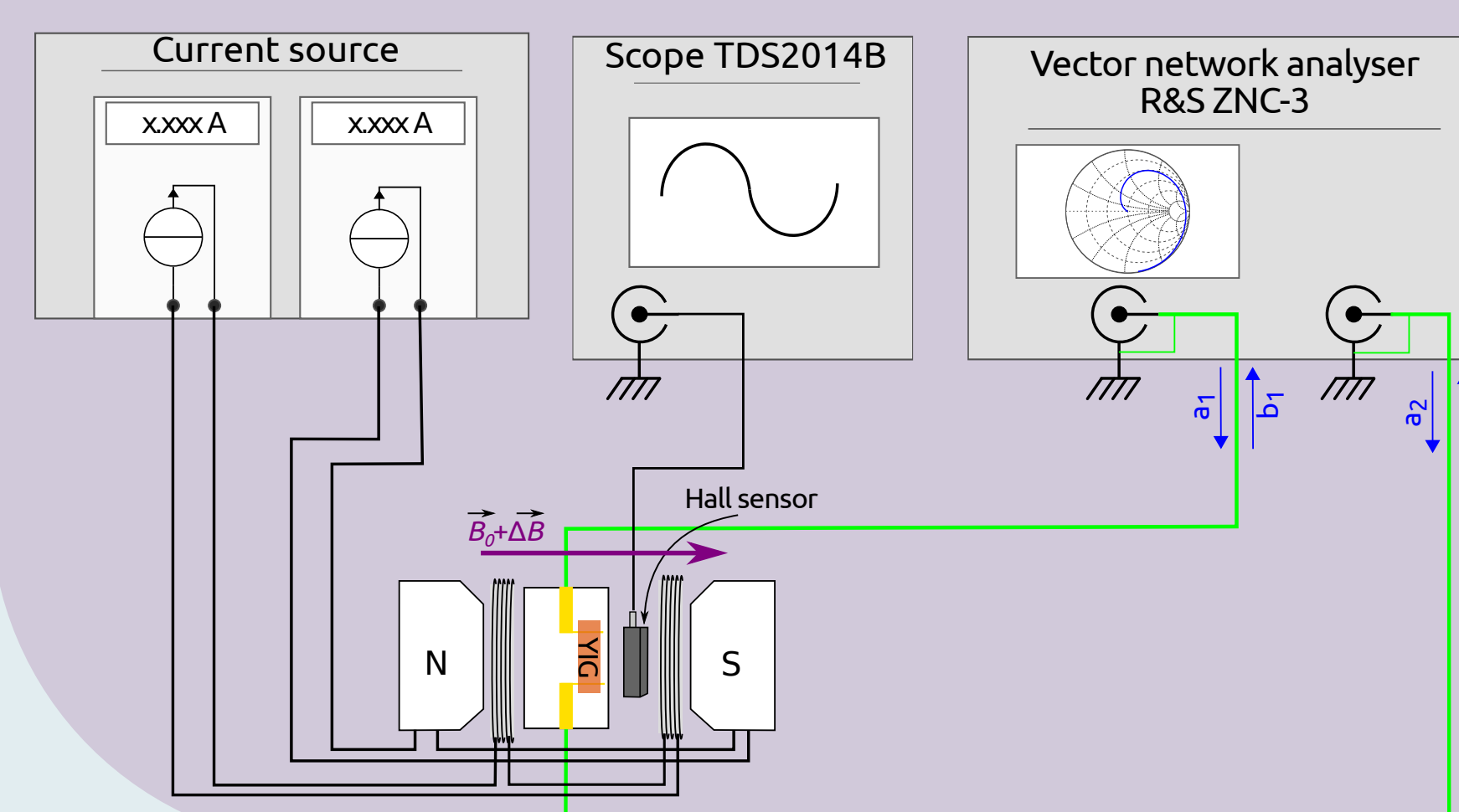
1. YIG film (111) grown by LPE on GGG substrate



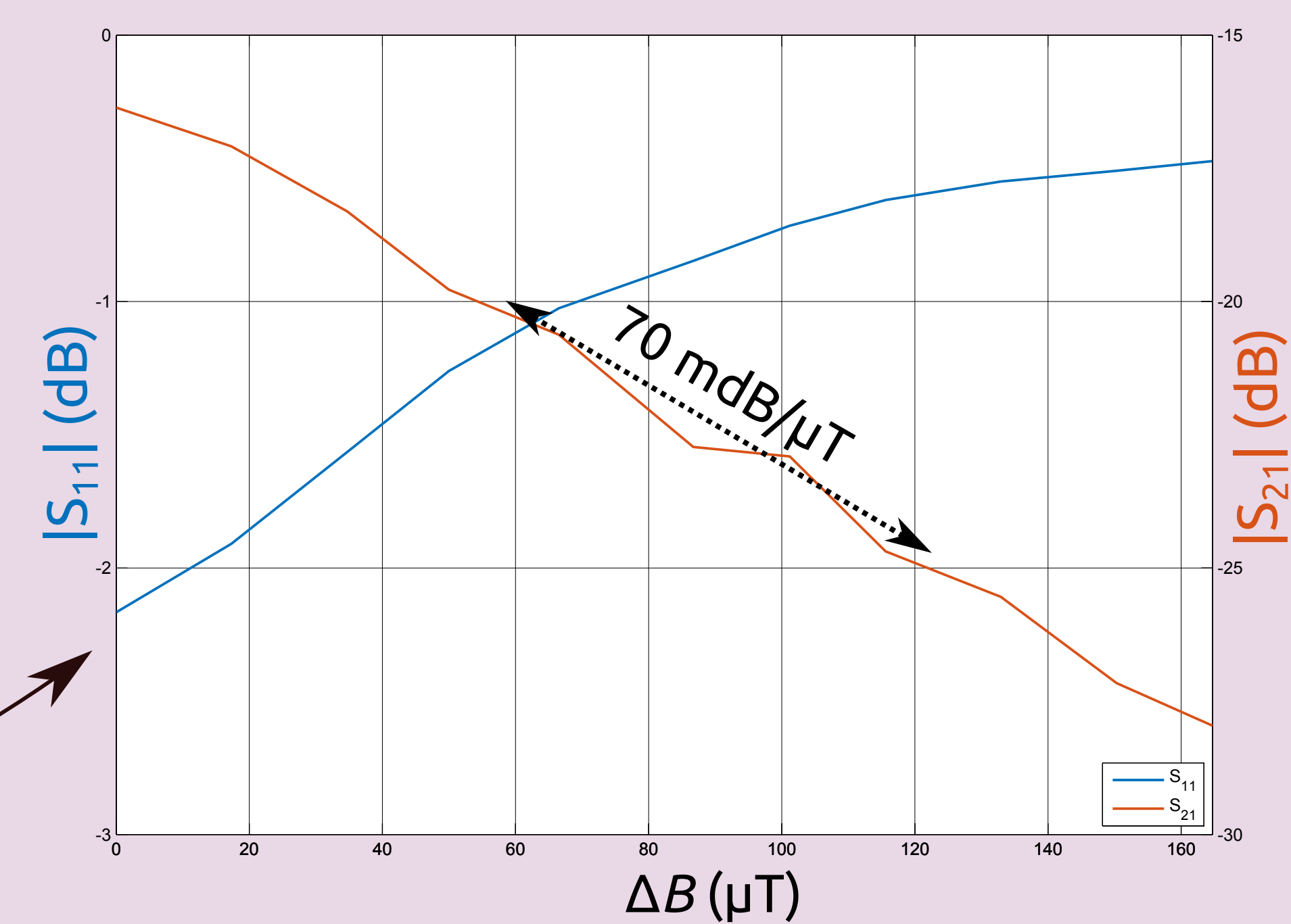
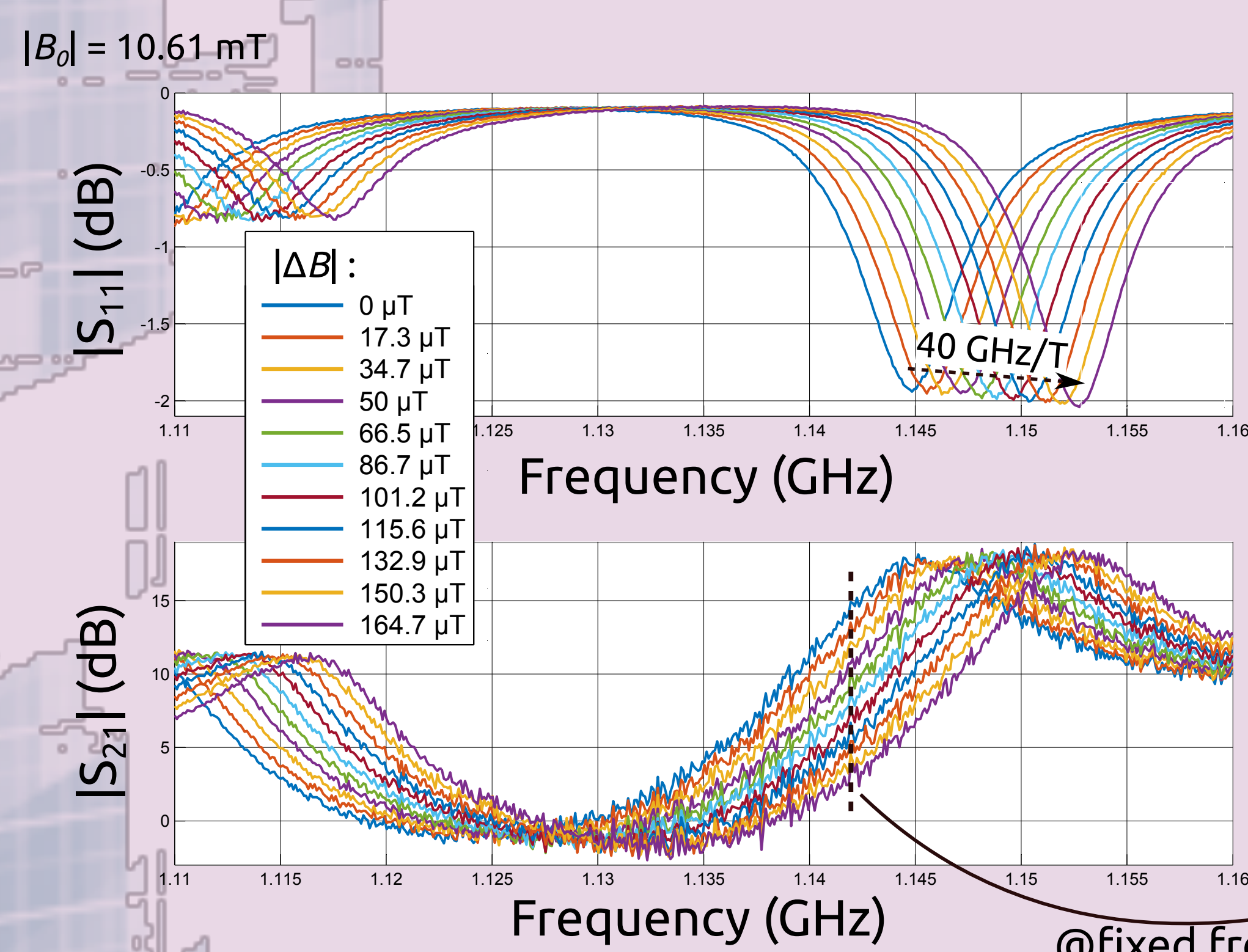
2. Sample holder with matched antennas :



3. Characterization setup

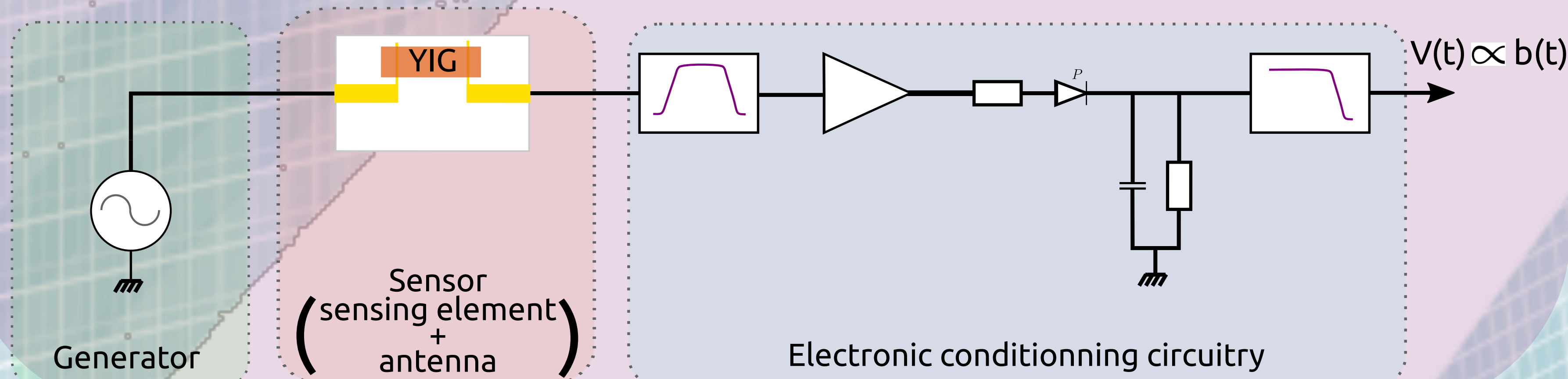


Sensor : working point...



...and conditioning circuitry

Parameters :
Excitation Frequency : 1.25 GHz
Excitation amplitude : +30 dBm or 0.1 V
Band-pass filter : -4dB between 1.0GHz and 1.5GHz
Amplifier : +25dB



Expected performances

Excitation : -30dBm 0,1V

Sensitivity : 0,18V/T 2,5V/T

Noise level : 1 nV/√Hz

Equivalent magnetic noise : 5,6nT/√Hz 400 pT/√Hz

[1] P. Talbot, A. Fessant and J. Gieraltowski, *Electromagnetic sensors based on magnonic crystals for applications in the field of biomedical and NDT*, Procedia Engineering vol. 120, pp. 1241–1244 (2015).

[2] S. Atalay, A. O. Kaya, V. S. Kolat, H. Gencer, T. Izgi, *One-Dimensional Magnonic Crystal for Magnetic Field Sensing*, J. Supercond. Nov. Magn. Vol. 28, pp 2071–2075 (2015)