Optimized off-diagonal GMI-based magnetometer

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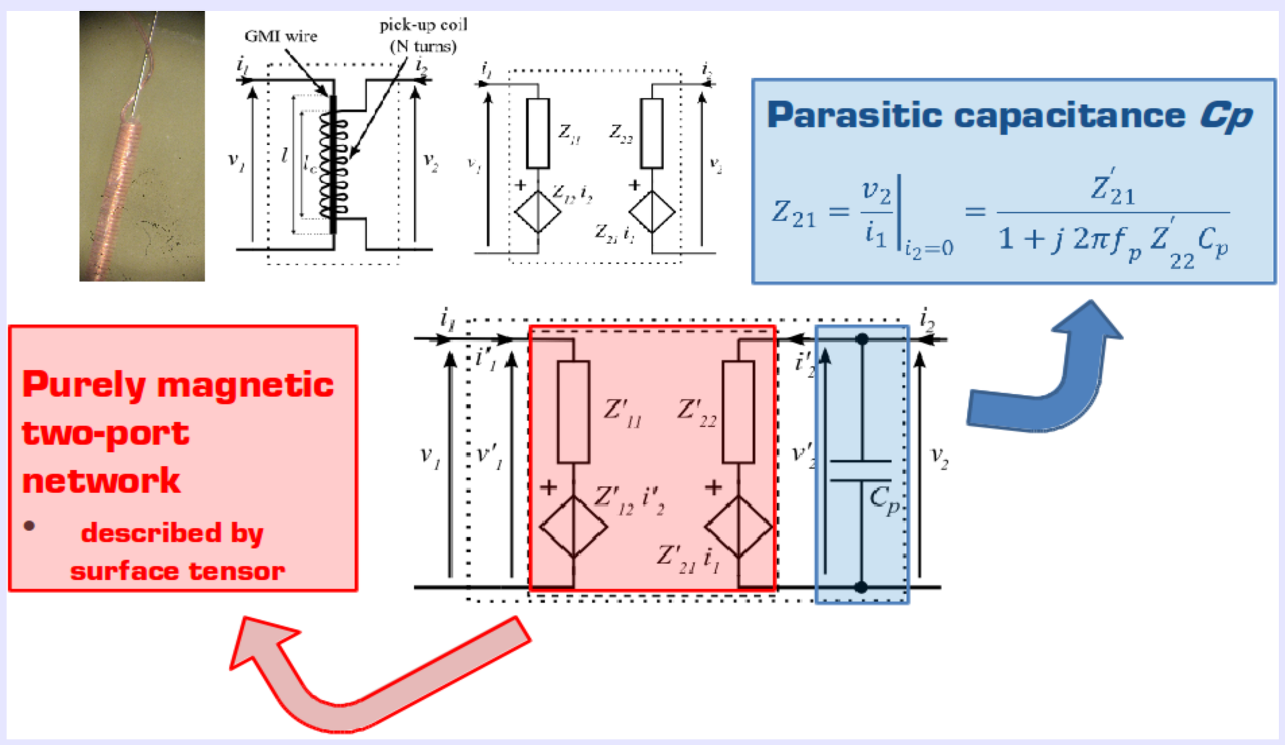
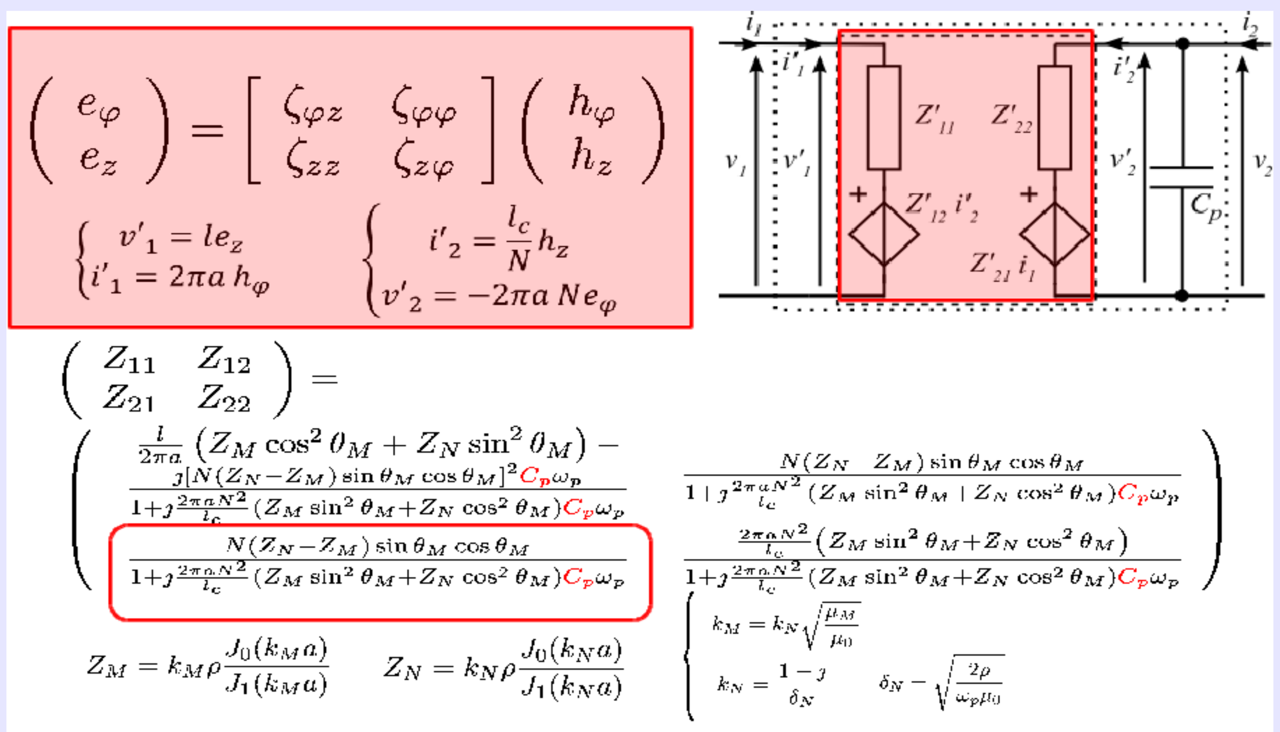
Abstract

An optimized giant magneto-impedance effect magnetometer has been developed, based upon an overall analysis of the measurement chain, including physical material properties, associated detection coil parameters, and equivalent magnetic noise performances. The field response model for the sensing element and the noise model yield good agreement with experimental results. The noise performance of the magnetometer, approximately 1.7 pT/ √Hz in the white noise region, with a band-pass of about 70 kHz, is competitive with that of other technologies. Present limitations are clearly established, leavingroom for further improvements.

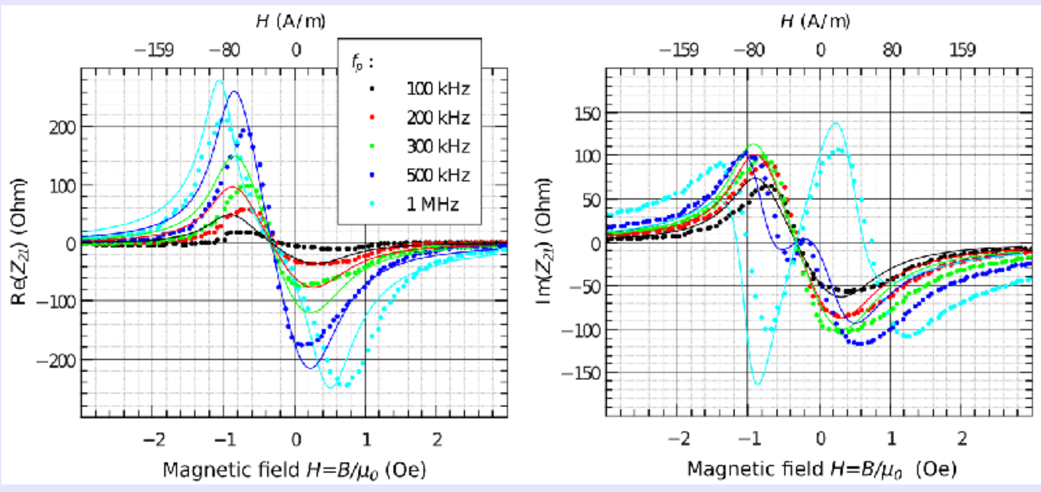
Index Terms—Giant magneto-impedance (GMI), magnetometer, noise.

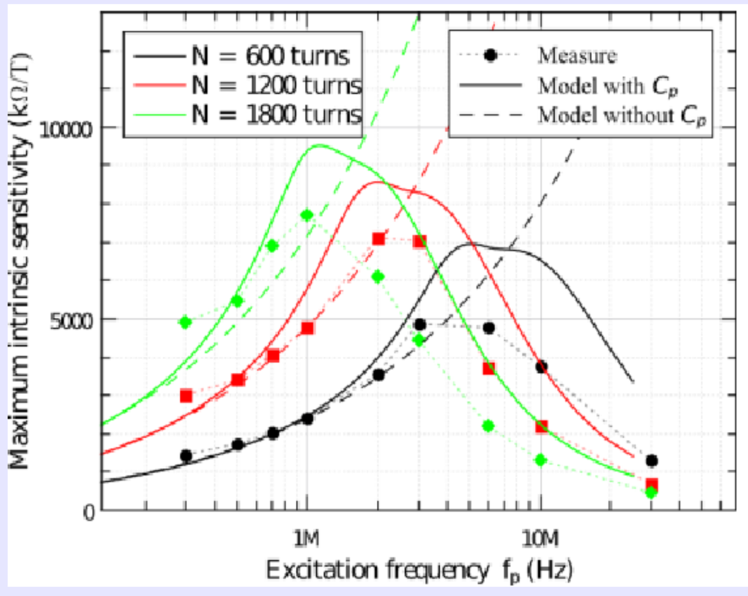
GMI-coil modelisation





Parasitic capacitance effect

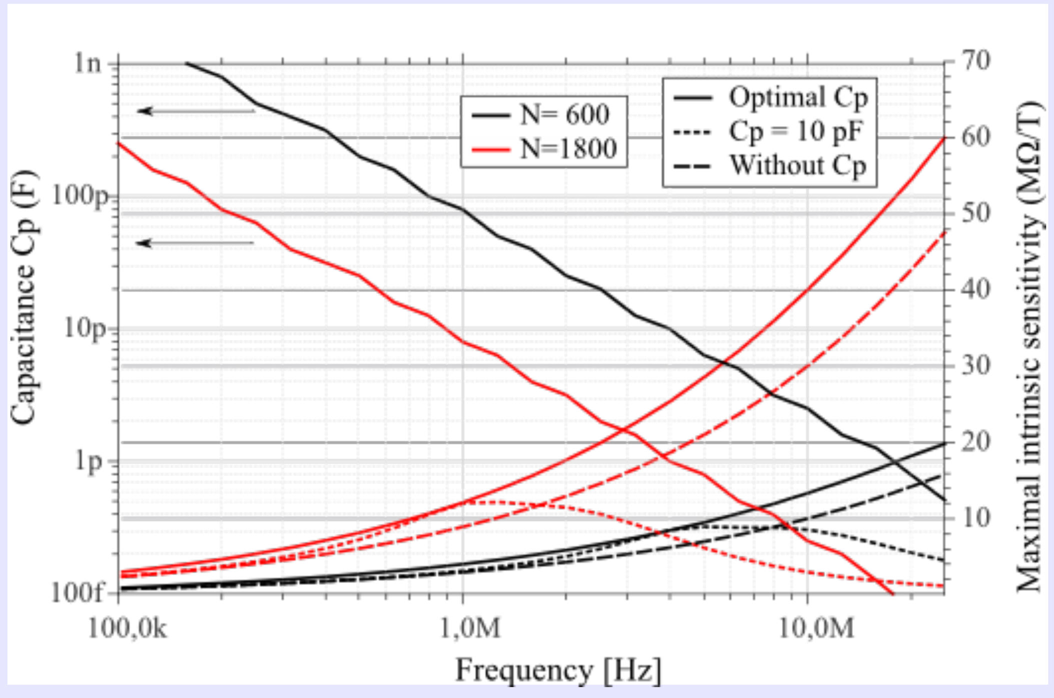




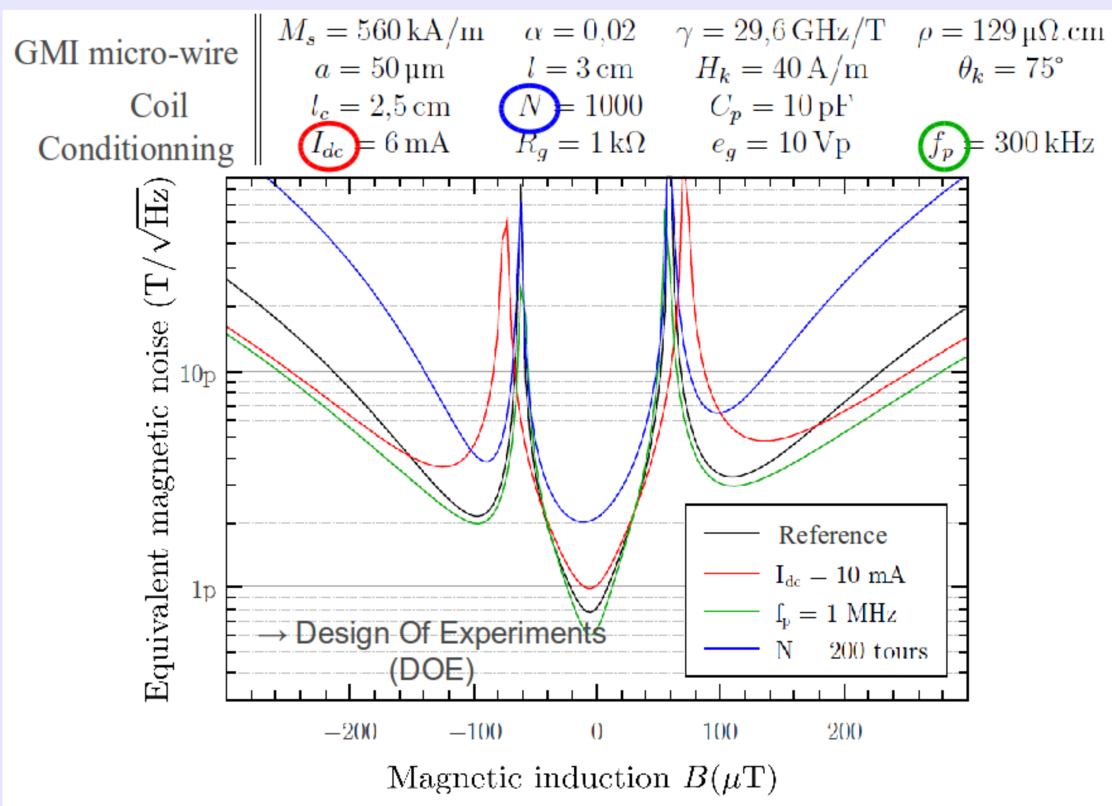
In this tested device, $Cp \approx 10$ pF due to:
- coil turn capacitance,
- core & layers capacitance,
- ....

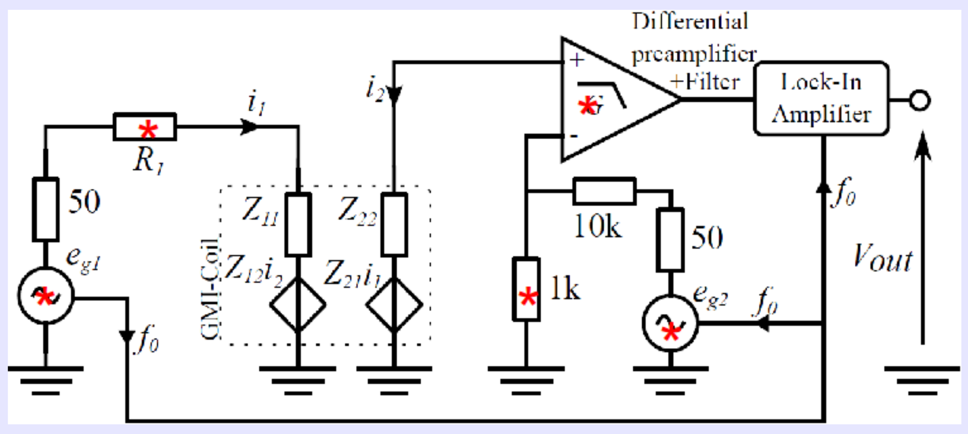
It is possible to increase capacitance value: *Cp + Cexternal*

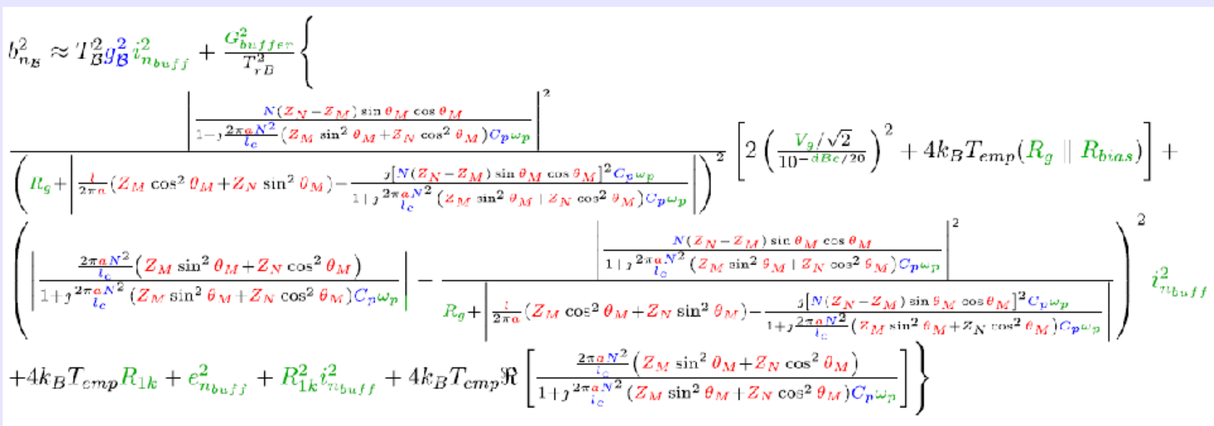
- Increase the number of turns allows to increase the sensitivity however the parasitic capacitance is the main limiting factor.
  - Adapt the excitation frequency (or to tune the parasitic capacitance)
  - Optimum between $\nearrow N$ and $\searrow C_p$



Noise modelisation

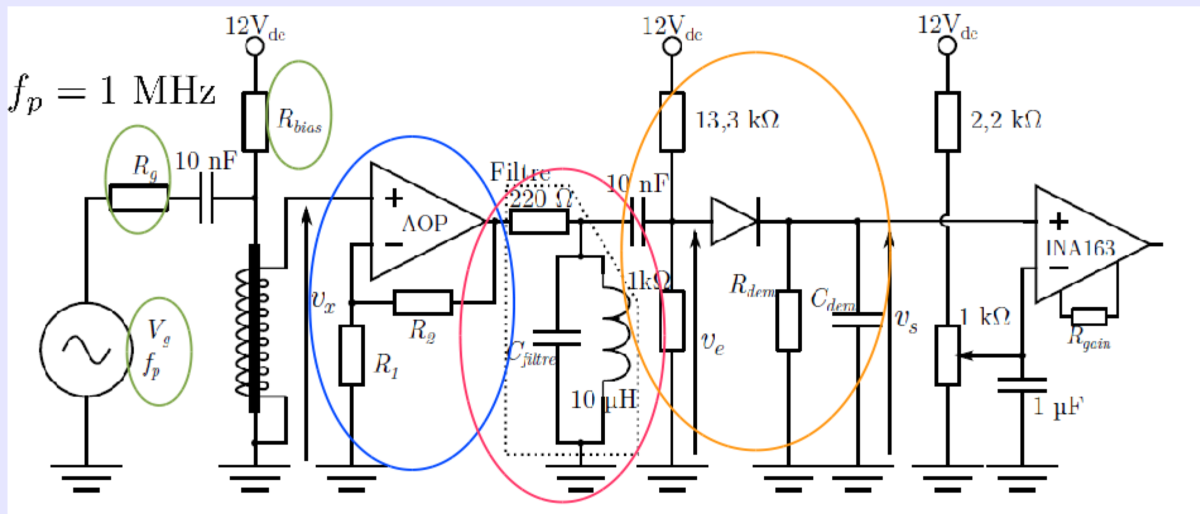






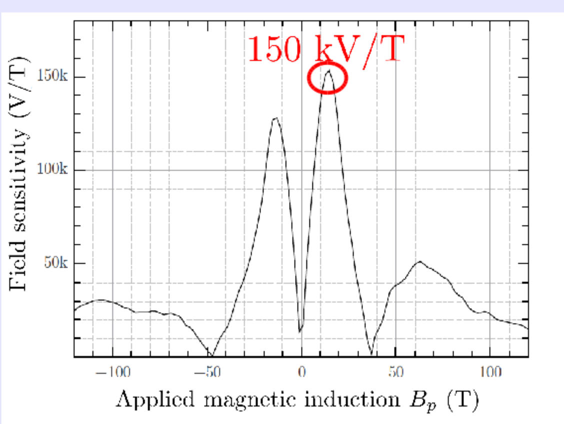
. GMI wire . Detection coil $(C_p,\ N)$. Electronic conditioning (*excitation, detection, ...*)

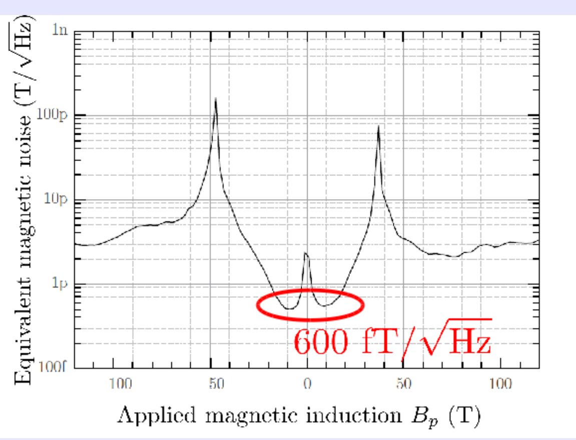
Optimized open loop



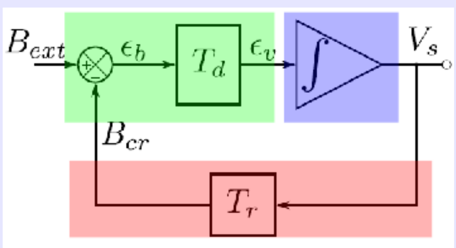
$$T_r \approx \frac{V_g}{2}\frac{|S_{\Omega_{21}}(\omega_p)|}{|Z_{11}(\omega_p,B_p)|+R_g}$$

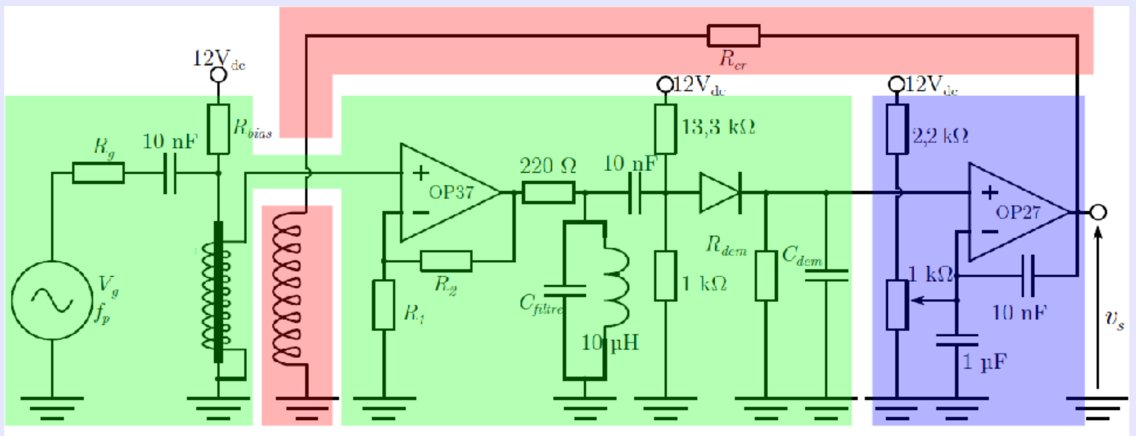
$$e^2_{n_{total}} = 2\left\{G^2_{buffer}G^2_{filtre}\left[\left(\frac{Z_{21}(\omega_p,B_p)}{Z_{11}(\omega_p,B_p)+R_g}\right)^2\left(e^2_{nl}+e^2_{nR_g}\right)+e^2_{nth}+\frac{e^2_{nR_2}}{G^2_{buffer}} +e^2_{n_{buff}}+e^2_{nR_1}+i^2_{n_{buff}}R_1^2+i^2_{n_{buff}}\left(Z_{22}(\omega_p,B_p)-\frac{Z_{12}(\omega_p,B_p)Z_{21}(\omega_p,B_p)}{Z_{11}(\omega_p,B_p)+R_g}\right)^2\right] +e^2_{n_{Hpol-HF}}+G^2_{filtre}e^2_{n_{BF}}\right\}+e^2_{n_{Rdem}}+e^2_{n_{Hpol-BF}}+e^2_{n_{Ampl}}+k^2_\beta g^2_\beta i^2_{n_{buff}}$$



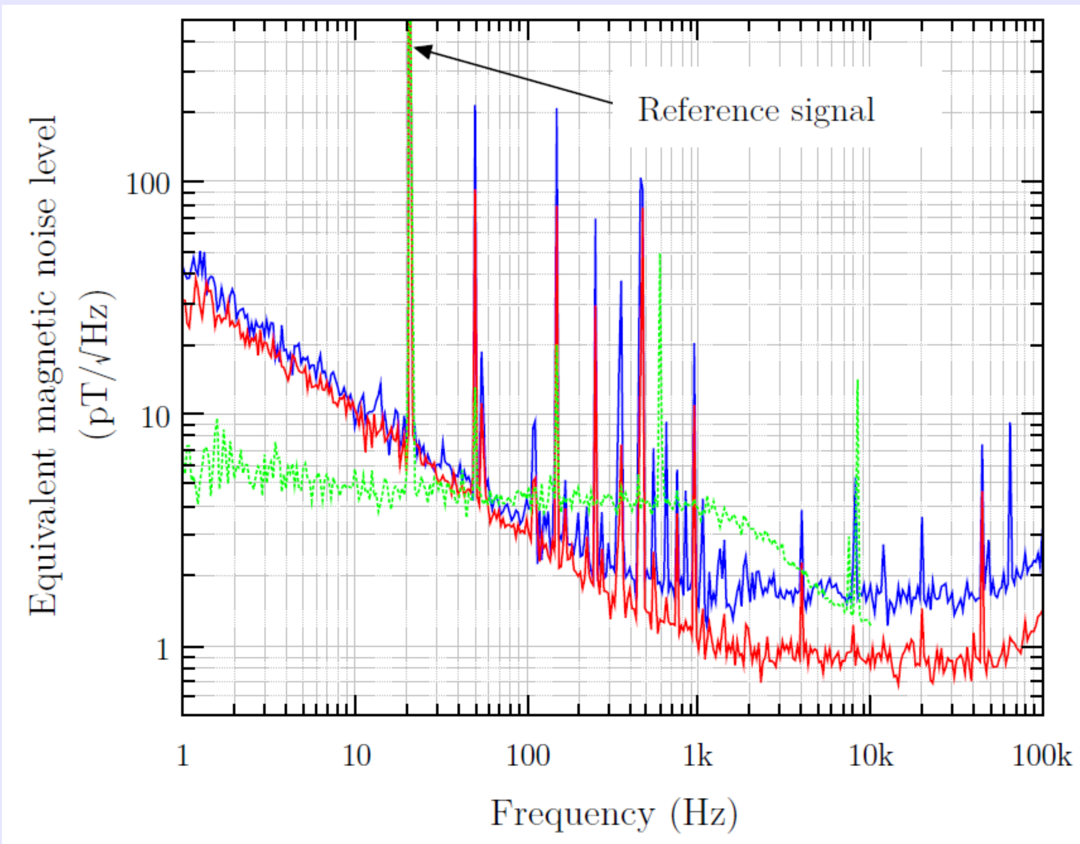


Optimized Magnetometers (field feedback loop)





< 1 pT/$\sqrt{\text{Hz}}$ @ Bruit blanc



Magnetometer	Sensitivity	Band-pass	Noise at 1 Hz	White noise	Maximum excursion	Dimension
	kV/T	Hz	pT/√Hz	pT/√Hz	µT	Length × diameter (mm)
GMI External feedback coil	490	DC to 90 kHz	35	0.9	±20	50×40
GMI re-use of detection coil	100	DC to 70 kHz	35	1.6	±100	25×3
Flux-Gate Bartington (Mag-03)	143	DC to 3 kHz	4	4	±70	30×8

- Model of the whole measurement chain
From physical properties to noise performance

Noise performance:

- < 1 pT/$\sqrt{\text{Hz}}$ in white noise range
Well competitive compared to other main challengers such as Flux-Gate

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[2] *L. G. C. Melo, D. Ménard, A. Yelon, L. Ding, S. Saez, and C. Dolabdjian*, J. Appl. Phys. 103, 033903, 2008
[3] Characterization of an optimized off-diagonal GMI-based magnetometer. *B. Dufay, S. Saez, C. Dolabdjian, A. Yelon, D. Menard,* IEEE Sensors Journal (12) 2012, DOI: 10.1109/JSEN.2012.2216521)