



# Pursuit of Ultrasensitive Magnetoresistive Sensors

Vasco Freitas

Supervisor: Dr. Susana Freitas

# Goals

Sensitivity

Noise

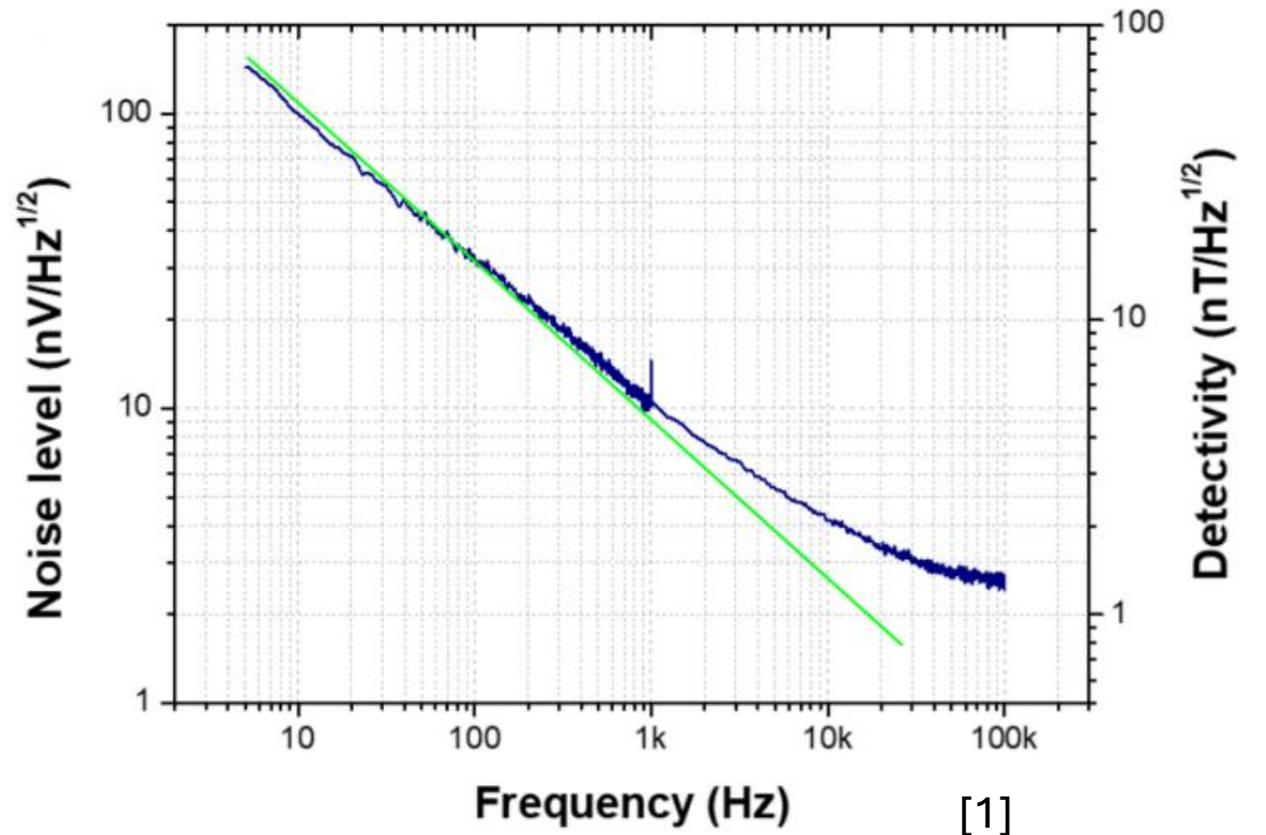
Detectivity

# The final product

Resistance ( $\Omega$ )	Detectivity @ 100 Hz (nT/ $\sqrt{\text{Hz}}$ )	Sensitivity (V/V/T)	Linearity (%)	Cross-field sens. (%)	Sensor dimension ( $\mu\text{m}^2$ )	Device area ( $\text{mm}^2$ )	Hysteresis ( $\mu\text{T}$ )		
> 10k	< 0.6	> 20	< 1%	< 0.1%	-	0.25	$\pm 14$ mT range	$\pm 1$ mT range	$\pm 100$ $\mu\text{T}$ range

# Noise

- $1/f$  dominates for **low frequencies**
- **Thermal** noise dominates at **high frequencies**
- Can be modeled as **linear + offset** at **100Hz**



# Sensor arrays and vertical stacking

- **Higher detectivity** due to **low noise** and **higher signal**

- Detectivity improves with  $\sqrt{XY}$

$$D = \frac{S_v^{total}}{S_{V/T}} = \frac{r\Delta H}{i\Delta r} \frac{1}{\sqrt{XY}} \sqrt{4k_B T + \alpha_H \frac{i^2 r}{n_c f}}$$

- Higher device **footprint** and **power consumption**

# Sensor arrays and vertical stacking

## Vertical stacking

- **Harder to fabricate** topologies
- **Higher resistance** in inactive areas (contacts and connections)
- Especially **hard to connect in series** vertically
- Uneven number of parallel and series connections leading quickly to **diminishing returns**

$Z$	$w$ ( $\mu m$ )	$S$ (%/T)
1	3	1.2
5	3	0.34
5	10	0.8

[1]

# Magnetic flux concentrators

- **Concentrate field** lines close to the sensing layer
- A **gain,  $G$** , can be defined
- Depends on **material permeability,  $\mu_r$** , and shape **demagnetization factor,  $N$**

$$G = \frac{H_{sensor}}{H_{ext}}$$

$$G = \frac{\mu_r}{1 + (\mu_r - 1)N}$$

# Conclusion

## **State of the art and challenges**

- Room temperature operation
- Low fields limit

## **Future works**

- Design and fabrication
- Characterization and redesign
  - Electrical noise measurements
  - Magnetic response curves

# References

[1] Silva, M. (2022). *Novel architectures to integrate ultra sensitive sensors to detect biomedical signals*. (Doctoral dissertation, Universidade de Lisboa, Instituto Superior Técnico).

[2] Valadeiro, J. P. D. (2014). *Magnetoresistive sensors with pico-Tesla sensitivities* (Master's thesis). Universidade de Lisboa, Instituto Superior Técnico, Lisbon, Portugal.