Magnetic sensors @ Faculty od Electrical Engineering, Czech Technical University in Prague

Pavel Ripka

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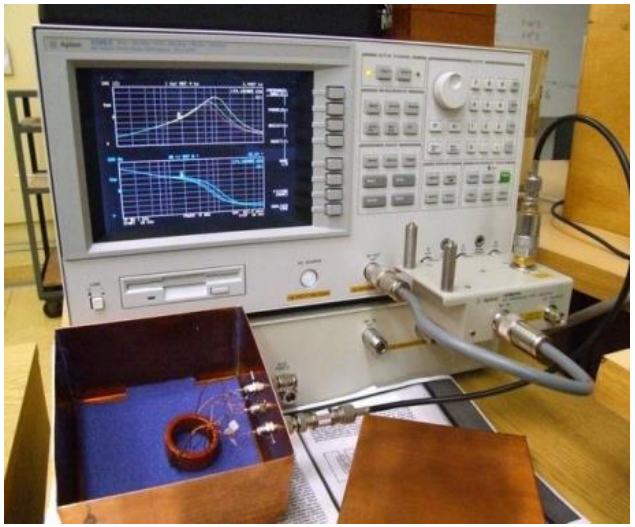
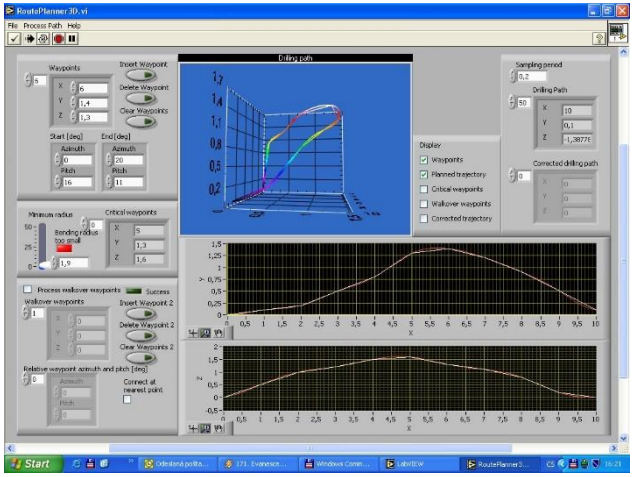
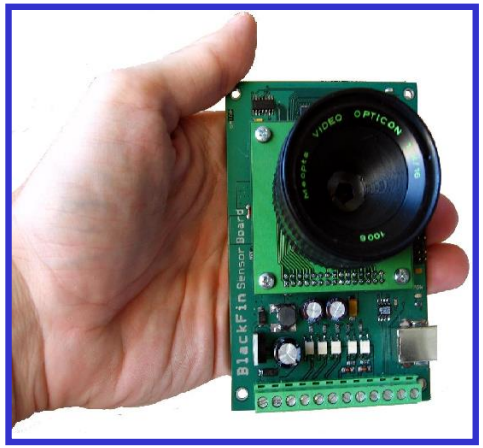
Department of Measurement

Electric measurements
Metrology
Sensors
Videometry
Instrumentation
Airborne systems
NDT
Distributed systems
Embedded systems
Human factors







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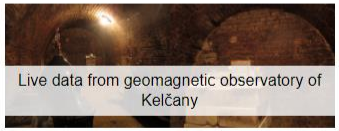
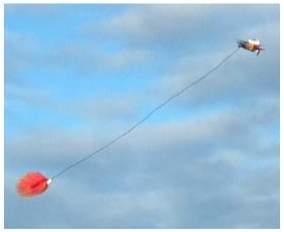


Czech Technical University in Prague

Faculty of Electrical Engineering

Department of Measurement



UAV-MAG at Alaska

December 2, 2021 | Uncategorized

Another set of UAV-MAG triaxial fluxgate magnetometers from MAGLAB is measuring magnetic fields around the globe, recently close to Anchorage, Alaska, USA. The drone unit sensor got a nice skirt to help with stabilization during the flight. It helps to keep orientation steady which improves overall data quality (less disturbances caused by non-compensated residual non-orthogonalities […]

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New 3D "Merritt" coils in MAGLAB

November 9, 2021 | Workshop

Generation of various magnetic fields is basic activity needed for magnetic sensors development testing and calibration. Ideally one can take advantage of a system that can generate an arbitrary vector of magnetic field. In this case a triaxial coil system is needed. Often the coils are made as Helm-holtz coil system (two circular coils per […]

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Magnetic Field Probe with MMC5983

November 3, 2021 | Workshop

Created within the Team project in the first year of Master's study program Cybernetics and Robotics at FEE, CTU in Prague – Authors: Roman Zima, Matúš Kaintz, Vít Machanec and Vojtěch Nydrle, supervised by Vojtech Petrucha (2021). It proved to be a useful tool to roughly check the magnetic

Main activities in magnetic sensors

Sensor and magnetometer development:

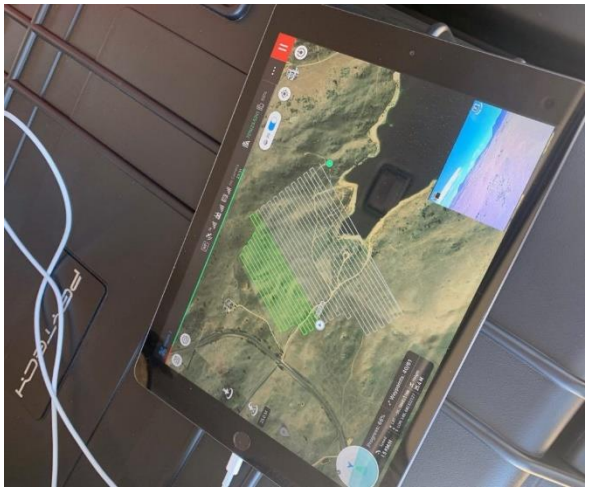
- AMR sensors
- Induction coils
- Fluxgate sensors
- Magnetic position and speed sensors
- Electric current sensor

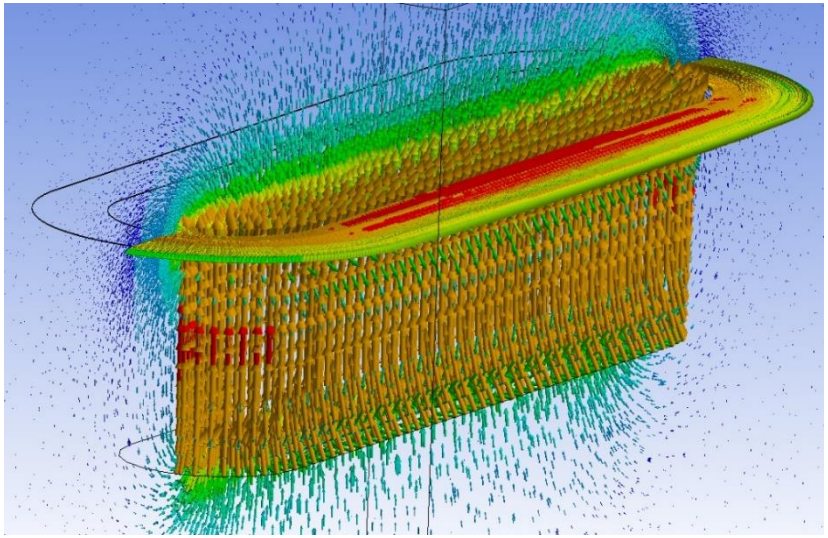
Magnetic measurements incl. rock and soil samles

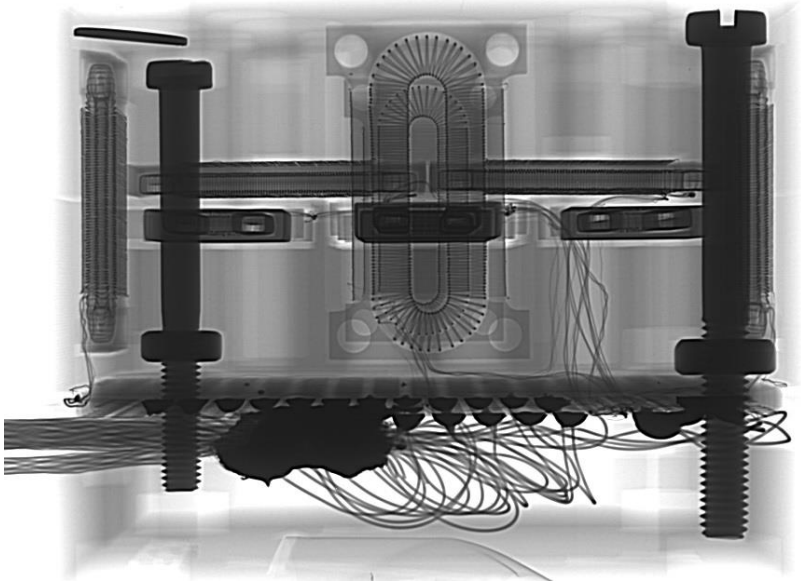
Applications:

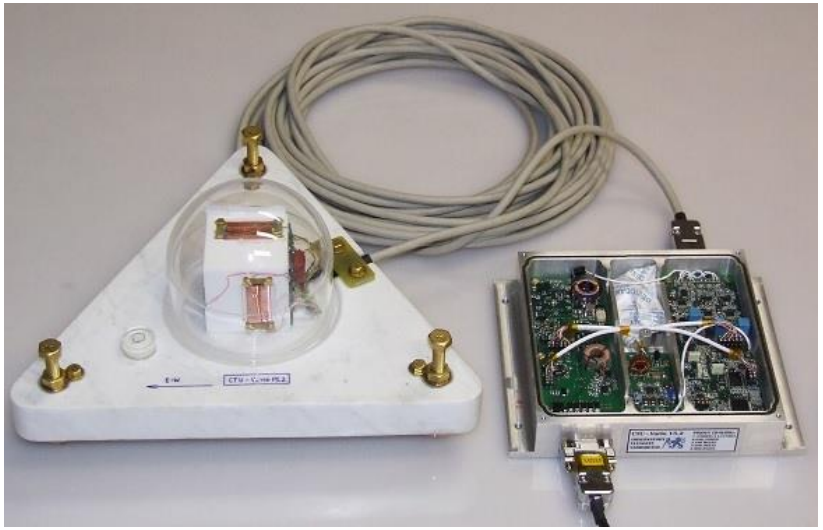
- Space research
- NDT, Geophysics, Security
- Biomedical, Industrial

UAV-magnetometer in Australia

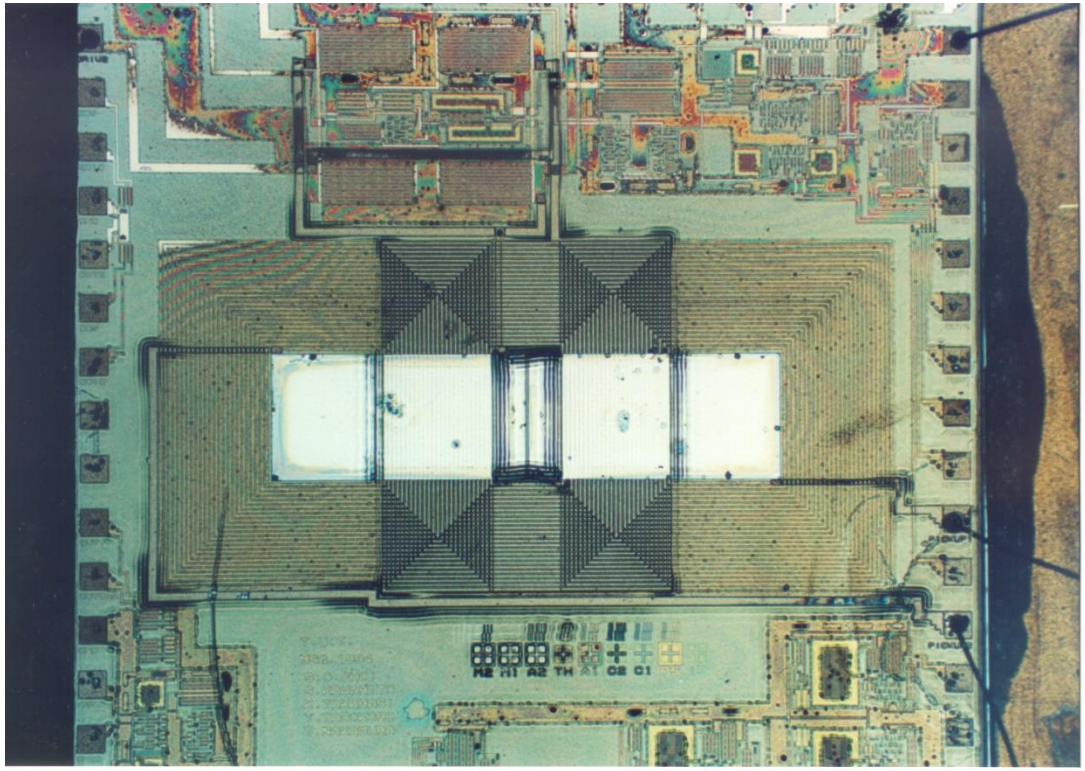








Micro-fluxgate sensors



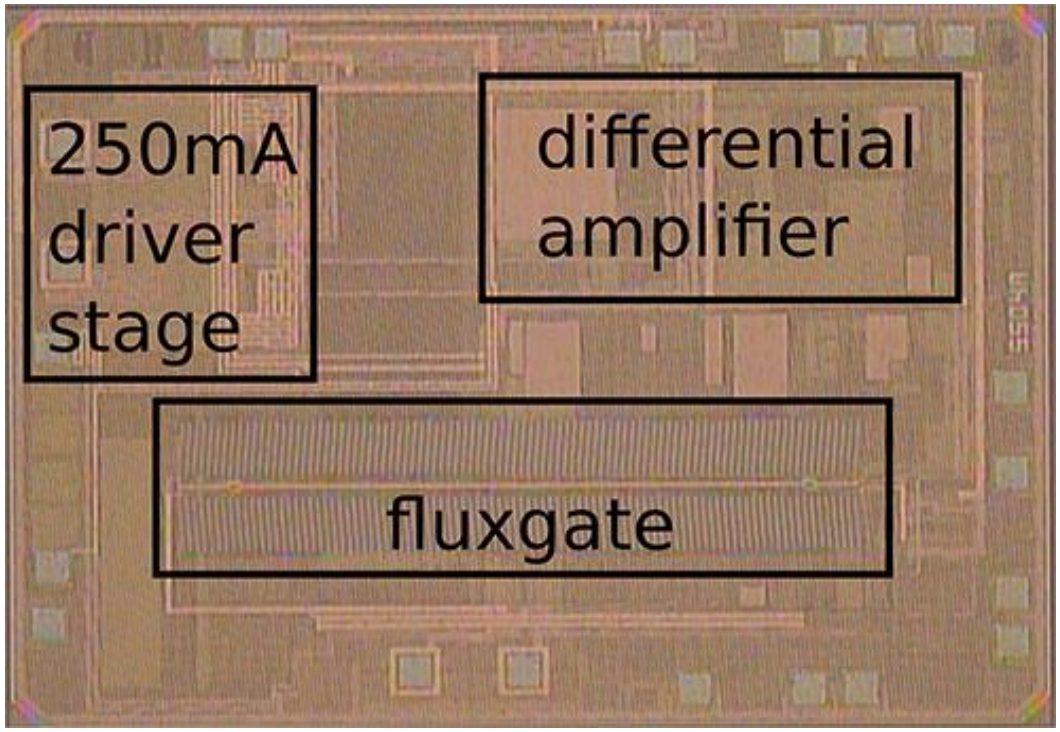
- flat coils
- electrodeposited core or amorphous strips
- electronics on chip

- cheap
- resolution still higher than MR

Shizuoka University

P. Ripka, S.O.Choi, S. Kawahito , A. Tipek, M. Ishida: Micro-fluxgate sensor with closed core, Sensors and Actuators A 91 (2001), pp. 65-69.

TI microfabricated fluxgate DRV425



M. F. Snoeij, V. Schaffer, S. Udayashankar, Mikhail V. Ivanov:
An Integrated Fluxgate Magnetometer for use in Closed-Loop/Open-Loop Isolated Current Sensing,
IEEE Journal of Solid-State C, Vol.51 Issue:7, July 2016

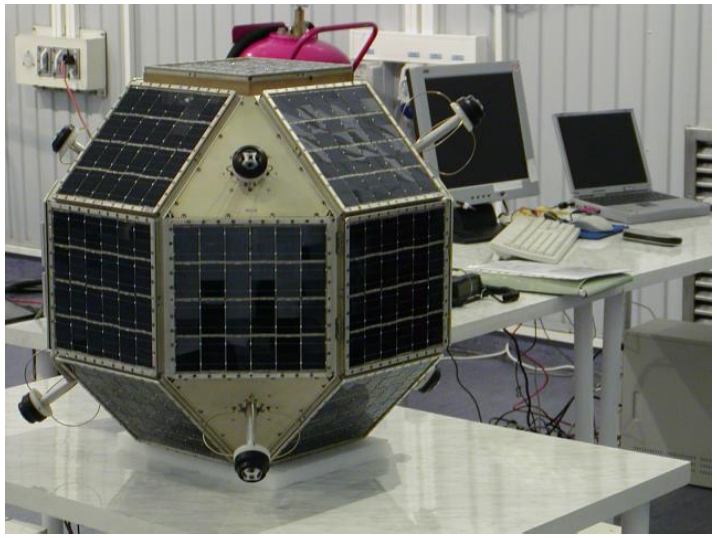
P. Ripka, M. Přibil, V. Schaffer, M. Snoeij: Flugate sensor with pulse feedback, IEEE Trans. Magn. 52 (2016) Issue: 5 Article Number: 4000704 doi: 10.1109/TMAG.2016.2524516

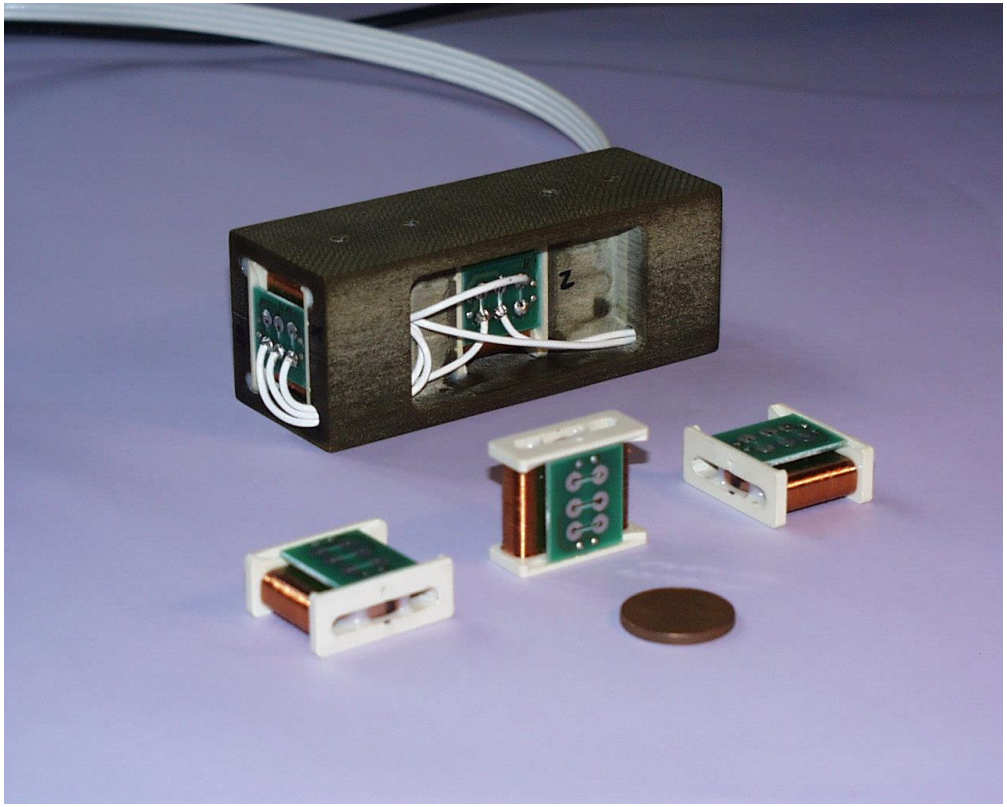
Parameters: DRV425 vs other magnetic sensors

	TI fluxgate DRV425	Honeywell AMR HMC1001	KMZ 51 (NXP)	AA002 NVE	Infineon TLE 4997
	Single chip fluxgate	AMR module Open loop, S/R on	AMR sensor	GMR sensor	Hall
Noise @ 1 Hz	5 nT	.5 nT	2 nT/	6 nT	100 µT rms
Noise @ 100 Hz	1 nT	.2 nT	0.3 nT/		
Offset	500 nT < 8 µT	20 nT < 60 nT	60 µT/		100 µT < 1 mT
Offset drift	5 nT/K	20 nT/K	240 nT/K		5 µT/K
Gain drift (ppm/K)	+/- 7	- 600 ppm/K		+/- 3 000	20 % -40 to + 125 °C
Hysteresis (10 mT sweep)	1.4 µT (10 mT sw)	0.1 µT < 0.2 µT (200 µT sweep)		40 µT 4 %	
Linearity	0.1 %	0.1 % (< 2 %)		2 %	
Range	2 mT	0.2 mT	0.2 mT	1 mT	200 mT
Supply curr min max	5 mA 30 mA	27 < 35 mA	5 mA to 30 mA		
Price	3 US$	HMC1001: 27 US$ + ? HMR2300: 300 US$	10 US$		

Magnetometer for Mimosa satellite (2003)

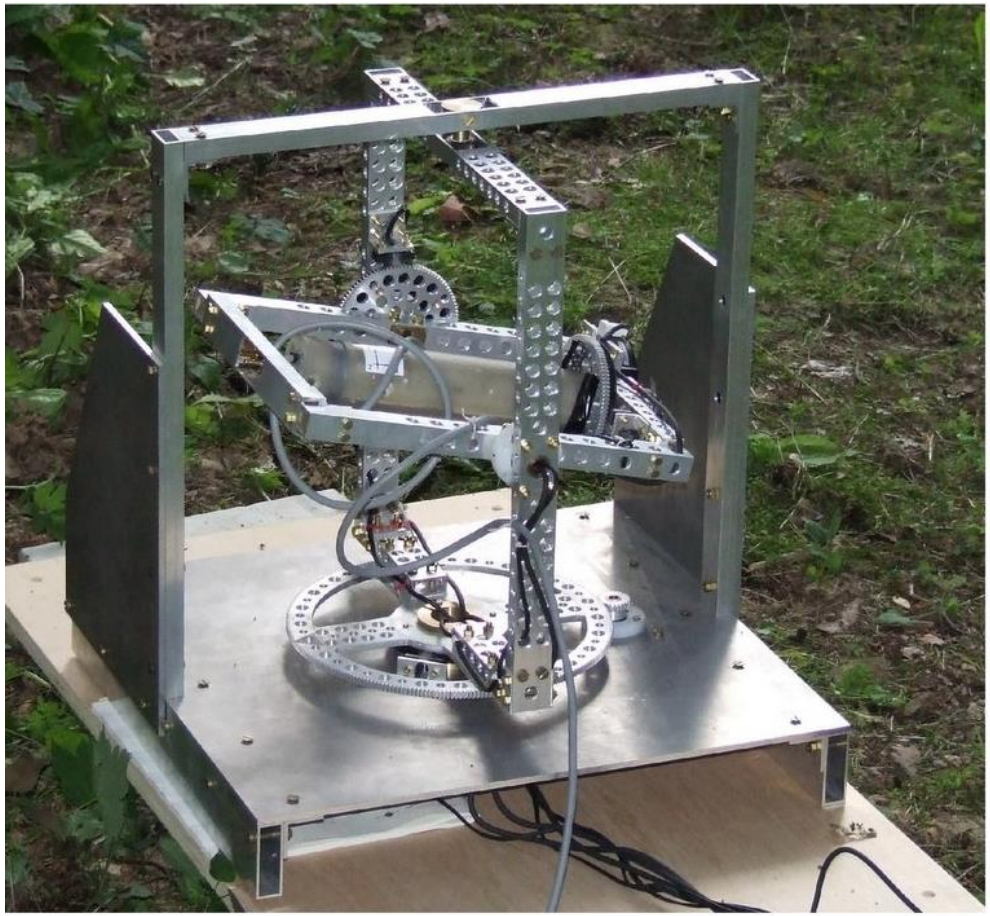
+ topology of the solar cells – design and FEM simulation





Scalar calibration of 3-axial magnetic sensor head

$$\begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix} = \begin{bmatrix} K_x \\ K_y \\ K_z \end{bmatrix} \cdot I \cdot \begin{bmatrix} \frac{1}{\cos\theta_x} & 0 & -\frac{\sin\theta_x}{\cos\theta_x} \\ -\frac{\cos\varphi_y}{\cos\theta_x \cdot \sin\varphi_y} & \frac{1}{\sin\varphi_y \cdot \cos\theta_y} & -\frac{\sin\theta_y}{\sin\varphi_y \cdot \cos\theta_y} + \frac{\sin\theta_x \cdot \cos\varphi_y}{\cos\theta_x \cdot \sin\varphi_y} \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix} - \begin{bmatrix} O_x \\ O_y \\ O_z \end{bmatrix}$$



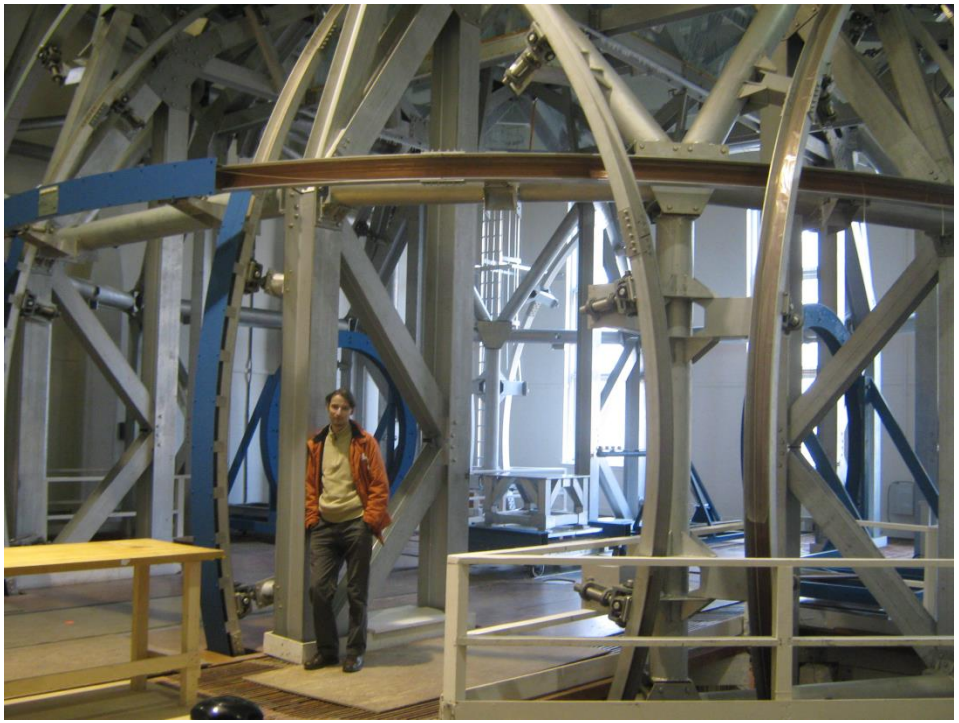
Non-magnetic positioning platform (V. Petrucha)

Petrucha, V. - Ripka, P. - Kašpar, P. - Merayo, J.: Automated System for the Calibration of Magnetometers J. Appl. Phys. 105, 07E704 (2009)
http://link.aip.org/link/?JAPIAU/105/07E704/1

Cooperation on Oersted +Astrid 2 magnetometers (for DTU)

Microaccelerometer simulator and tester - for VZLU (SWARM)

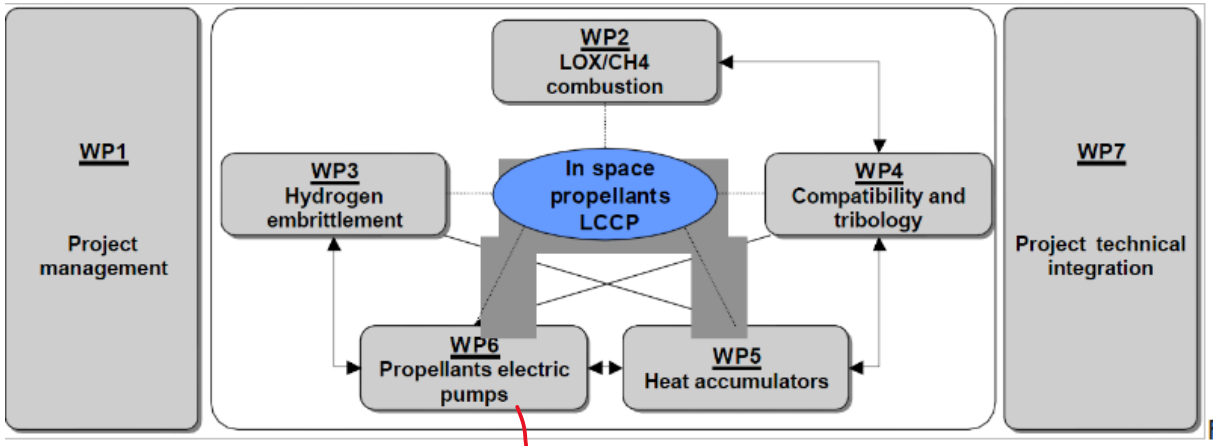
Scalar calibration of 3-D coils



A. Zikmund, P. Ripka, R. Ketzler, H. Harcken, and M.Albrech:
Precise scalar calibration of Braunbek system,
IEEE Trans Magn. Vol 51 , Article#: 4000704

axis	Sensitivity [nT/A]	N-S (H)	W-E (h)	Vertical (Z)
N-S (H)	56929.32	-	89.96°	89.96°
W-E (h)	19311.16	89.96°	-	91.16°
Vertical (Z)	37121.03	89.96°	91.16°	-

In Space Propulsion – 1 (ISP-1) – project

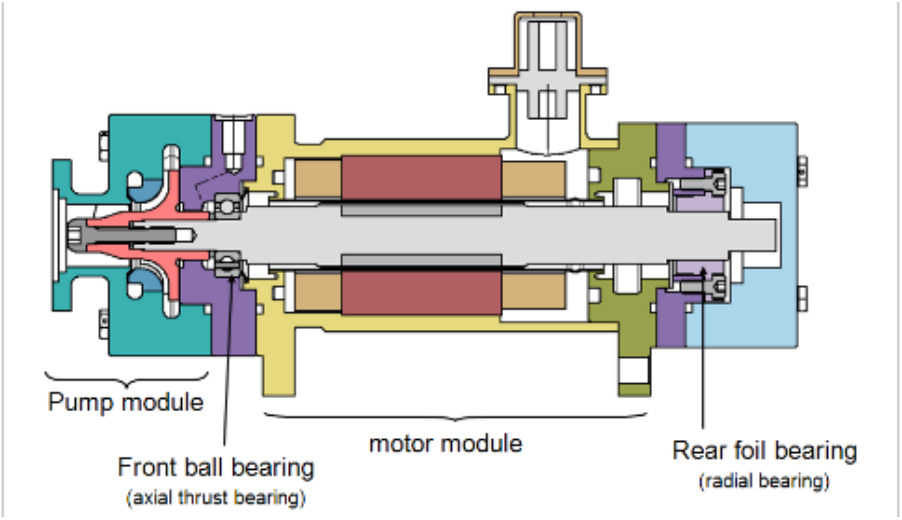


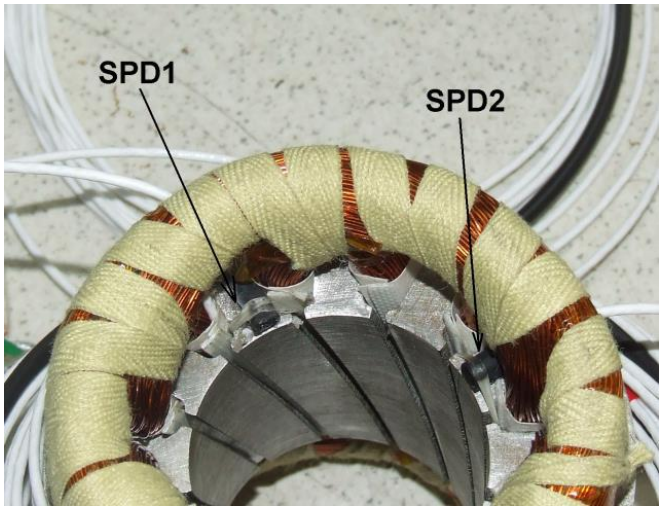
SP-1 project partners

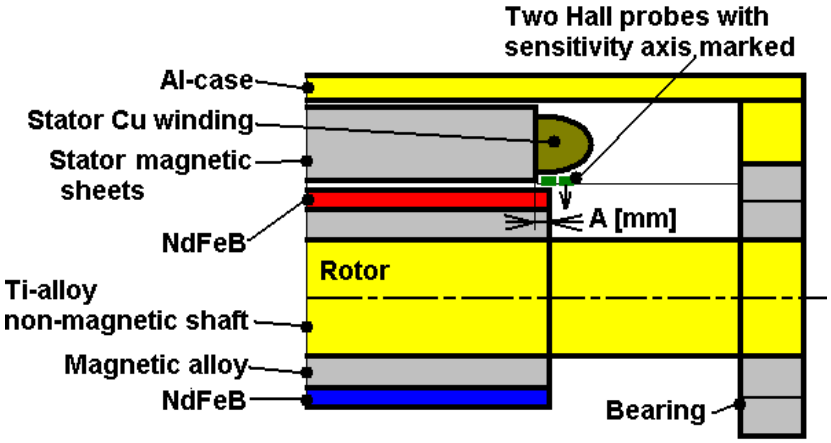
1. Snecma S.A., France
2. ASTRIUM GmbH, Germany
3. AVIO S.P.A, Italy
4. Centre National d'Etudes Spatiales CNES, France
5. Deutsches Zentrum für Luft- und Raumfahrt EV DLR, Germany
6. Office National d'Etudes et de Recherches Aérospatiales ONERA, France
7. Université de Liège ULg, Belgium
8 Commission of the European Communities – Directorate General Joint Research Center, Belgium
9. Institut Supérieur de Mécanique de Paris ISMEP, France
10. Mikroma SA, Poland
11. Ceske Vysoke Uceni Technicke v Praze, Czech Republic
12. Universitat Politecnica de Catalunya UPC, Spain
13. Alcimed, France
14. Universita degli studi di Roma la Sapienza, Italy
15. Université de Poitiers LMS, France
16. SAS Bonatre, France

Our role: sensors, instrumentation, testing, data acquisition

ISP: sensors for cryogenic pump

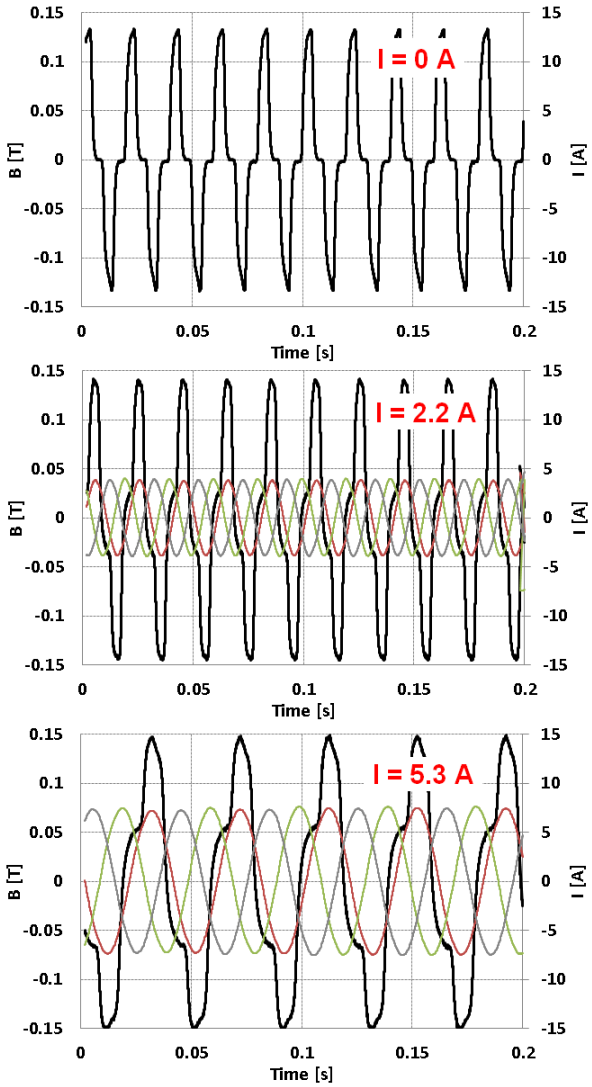


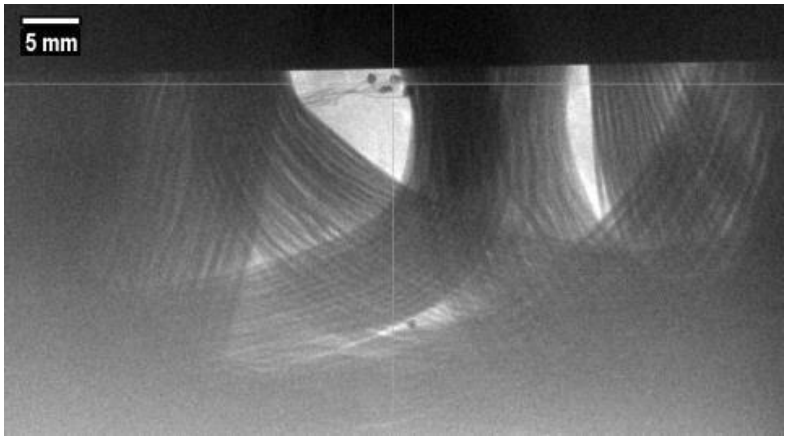


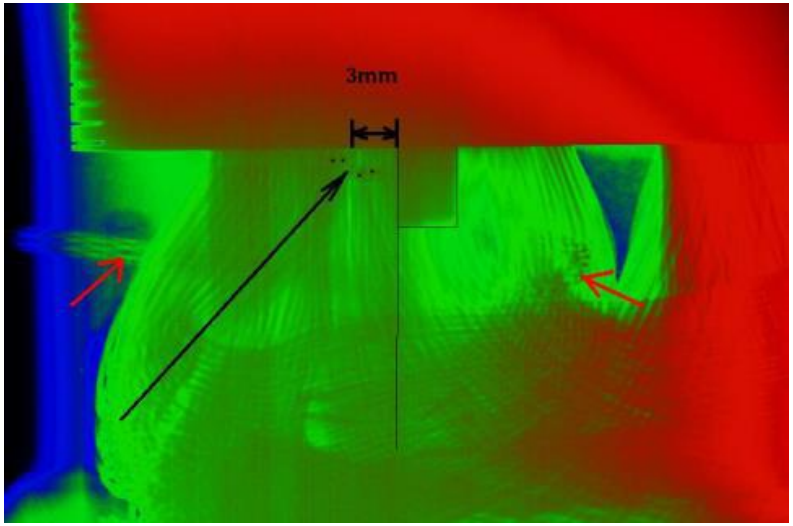


V. Petrucha, P. Ripka: Rotational speed measurement and angular position reference for a cryogenic propellant electric pump, J. of Elect. Eng.-Elektrotechnicky Casopis, Vol. 66, Iss. 7 Special Issue: SI Pages: 199-202 Published: DEC 2015

Hall sensor inside the motor







Digital triaxial magnetometer with high resolution – C3MAG

datasheet v 2018

www.fel.cvut.cz
Czech Technical University in Prague, Faculty of Electrical Engineering

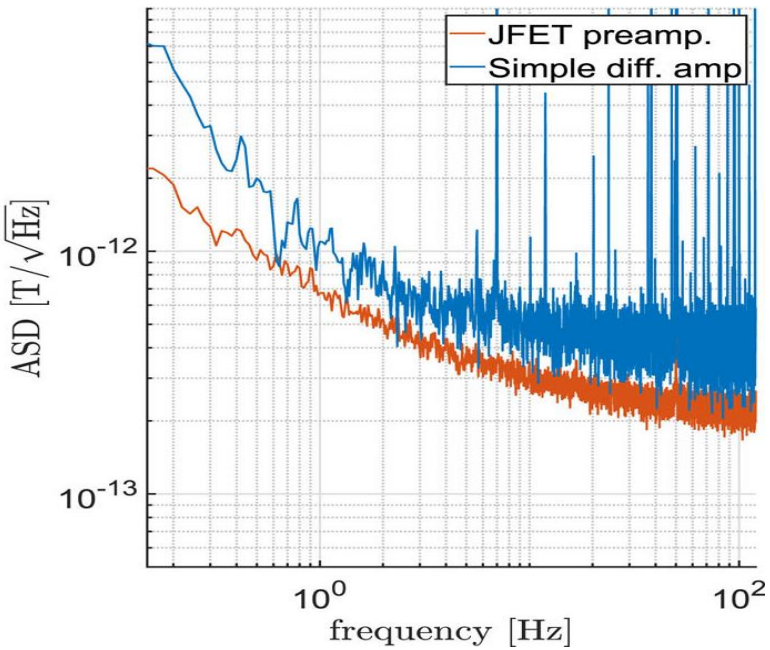
www.csrc.cz
BD Sensors – Space division, CSRC

Triaxial magnetometer with analog and digital output features detachable sensor head and isolated power supply. As opposed to available instruments, it features 100 Hz bandwidth, and not only analogue output can be used, but also the digital output of the 24-bit, simultaneously sampled A/D converter. Two versions of sensor heads are available – **S** (standard) and (**L –** low noise). The serial communication uses simple ASCII protocol which is easily processed (demonstration program is available on request).

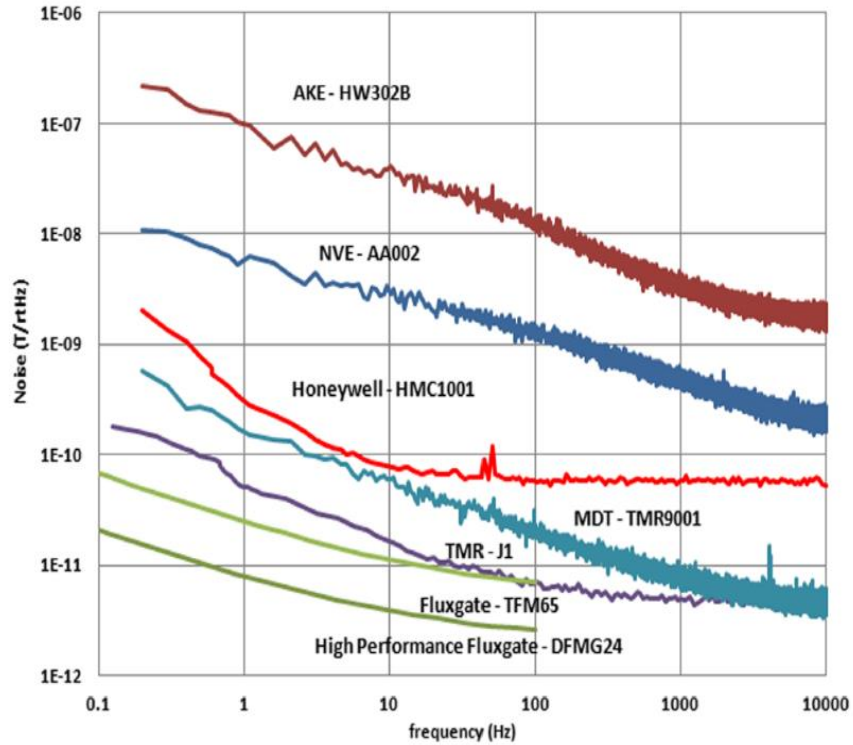
The instrument has been developed in joint collaboration of Czech Technical University in Prague and Czech Space Research Centre / BD Sensors – Space division.

Magnetometer with triaxial probe and 2-m cabling

Low-noise fluxgate magnetometer



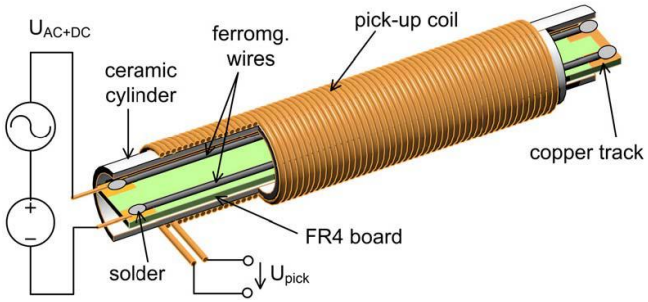
0.7 pT/√Hz @ 1Hz

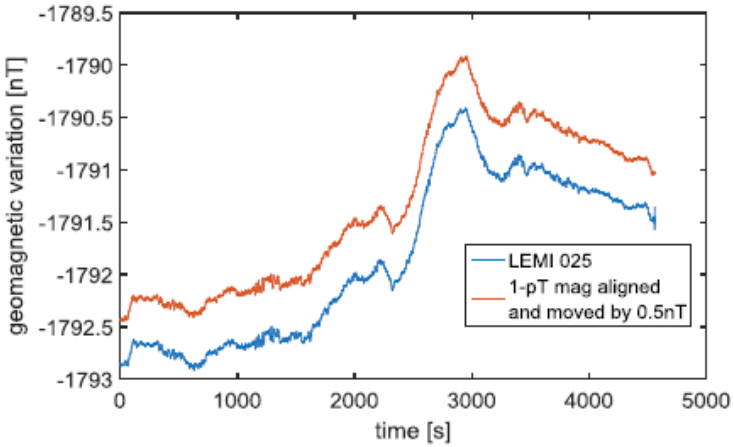


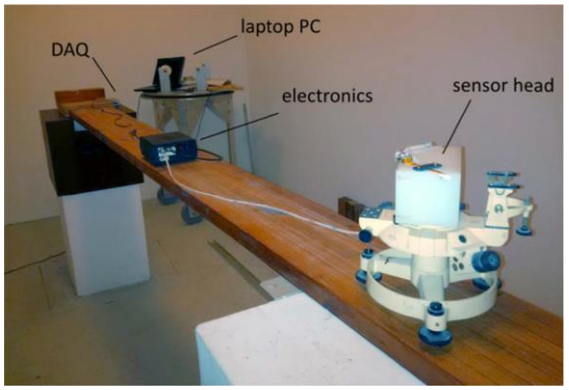
J. G. Deak, Z. M. Zhou, and W. F. Shen, *AIP Advances*, vol. 7, 2017.

Dressler, M.; Janošek, M.; Butta, M.
Reduction of magnetic noise limits of orthogonal fluxgate sensor
AIP Advances. 2021, 11(1), ISSN 2158-3226.

Applications of low-noise fluxgate







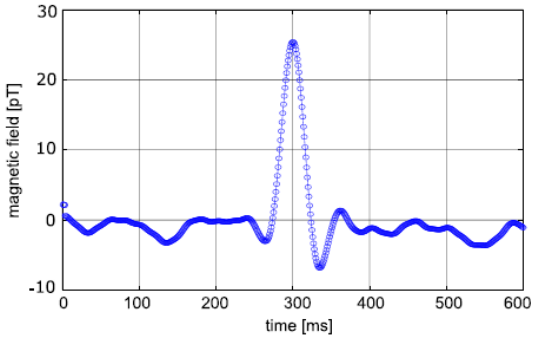
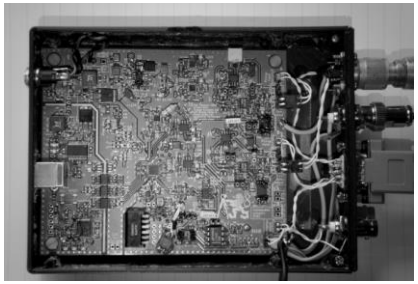
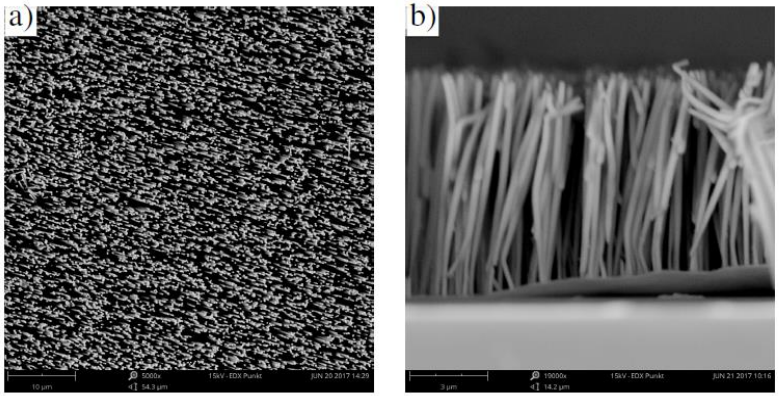


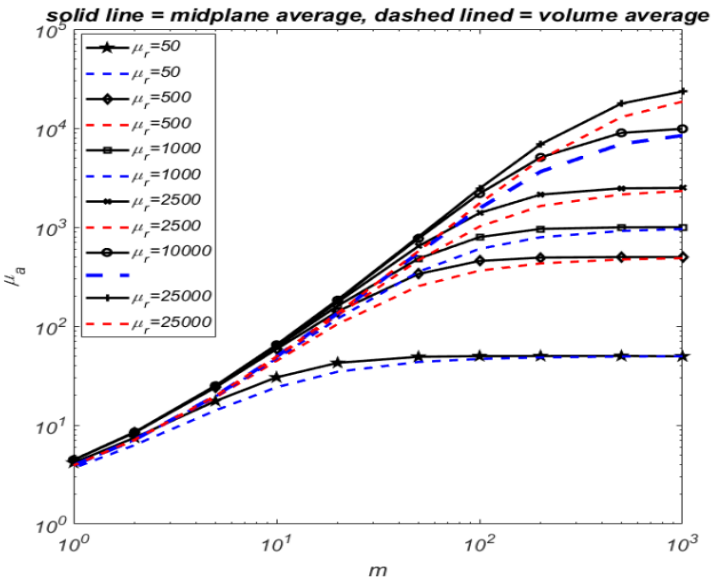
Fig. 19. MCG signal obtained when averaging 30 peaks.

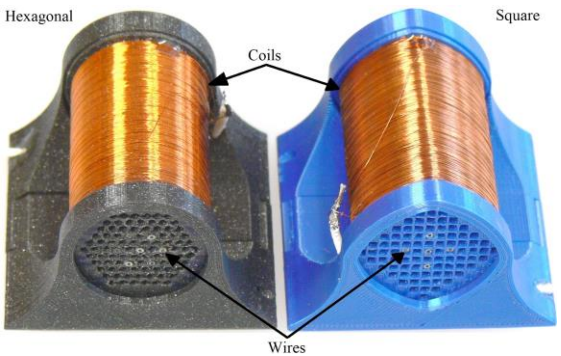


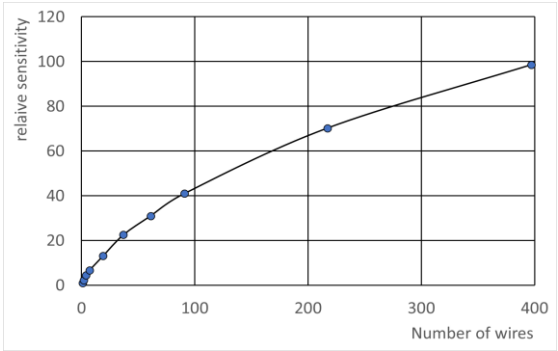
Janošek, M.; Butta, M.; Dressler, M.; Saunderson, E.; Novotný, D.; Fourie, C.
1-pT noise fluxgate magnetometer for geomagnetic measurements and unshielded magnetocardiography
IEEE Transactions on Instrumentation and Measurement. 2020, 69(5), 2552-2560. ISSN 0018-9456.

Demagnetization coefficient and effective permeability of nanowires and nanowire arrays



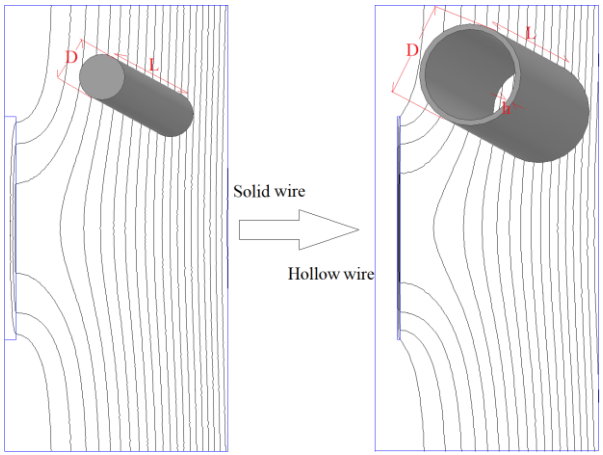


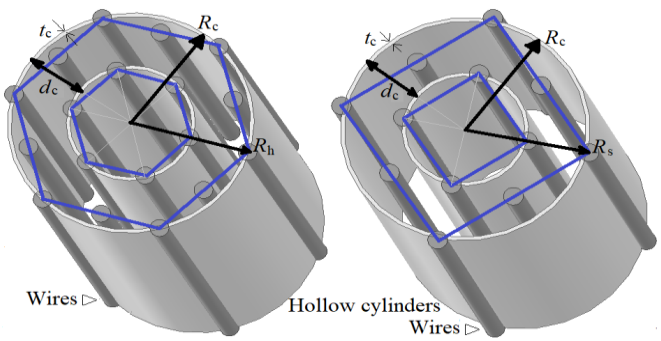


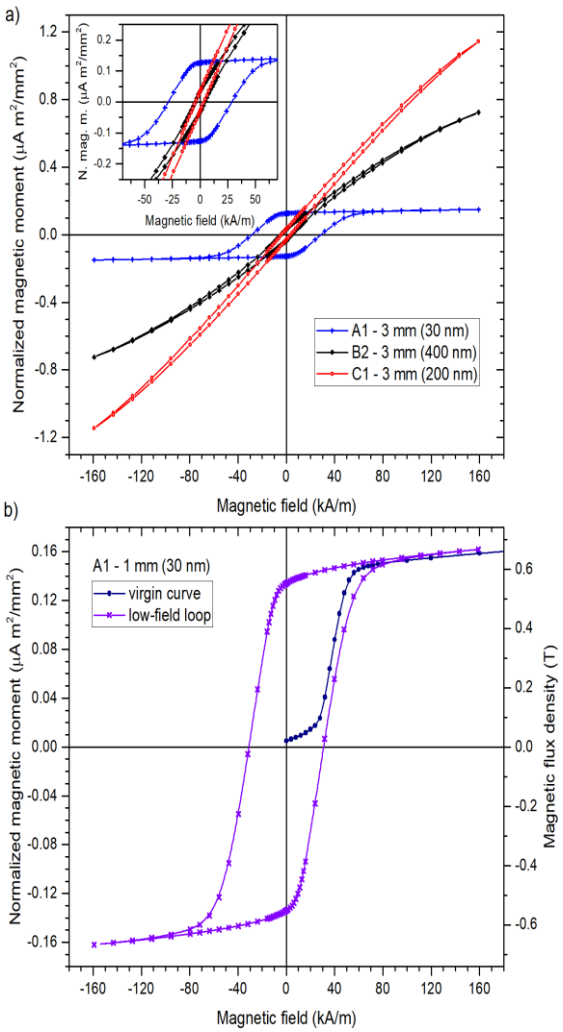


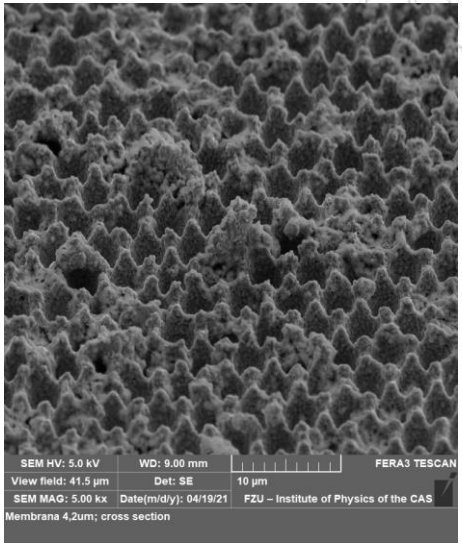
P. Ripka, V. Grim, M. Mirzaei, D. Hrakova, J. Uhrig, F. Emmerich, C. Thielemann, J. Hejtmanek, O. Kaman, and R. Tesar: Modelling and measurement of magnetically soft nanowire arrays for sensor applications, Sensors 2021, 21(1), 3,

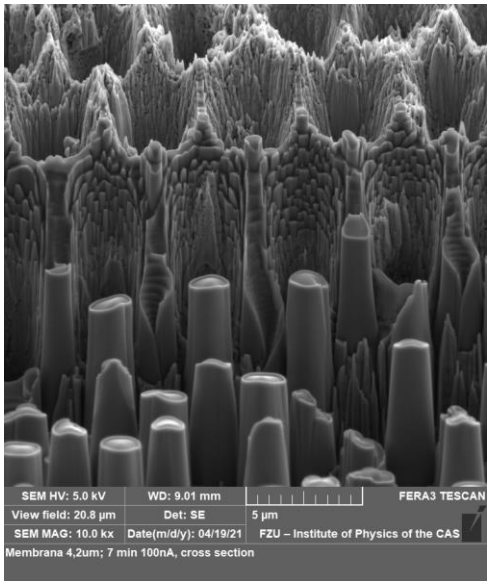
Modelling and measurement of millions of nanowires





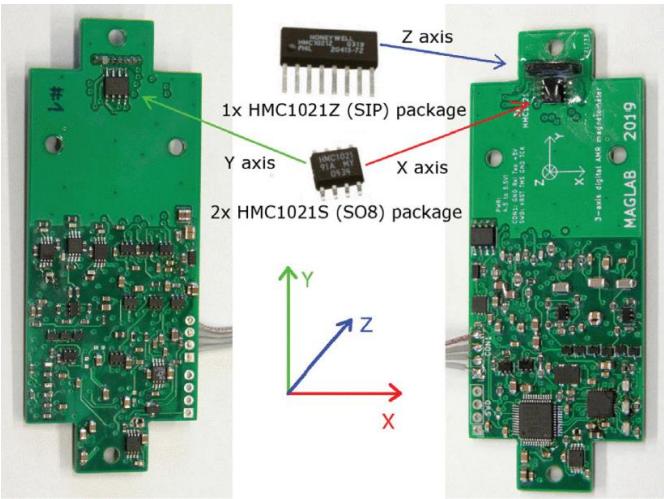


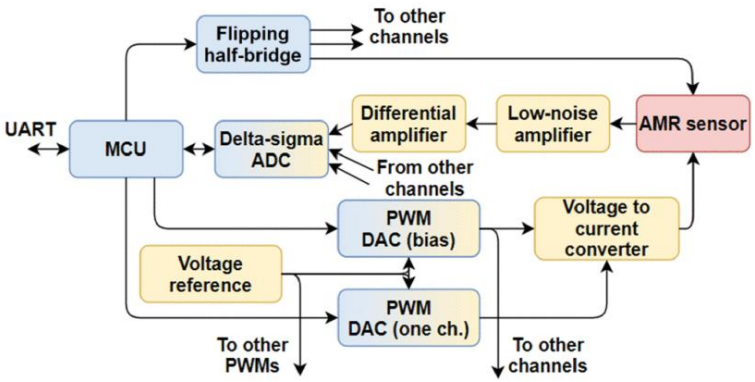




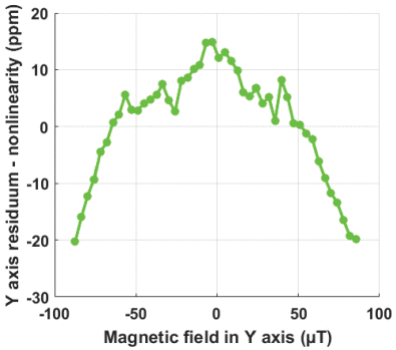
M. Mirzaei, P. Ripka. V. Grim: A Simplified 2D Equivalent Model for Magnetic Wire Array, IEEE Trans Magn. early access 10.1109/TMAG.2021.3085485

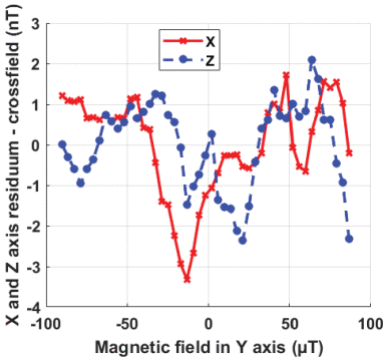
AMR magnetometer for nanosatellites

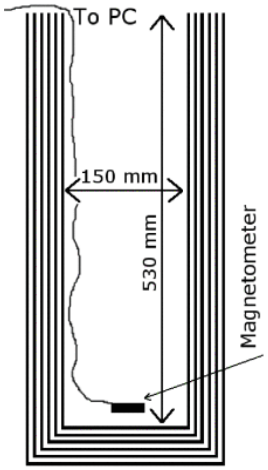


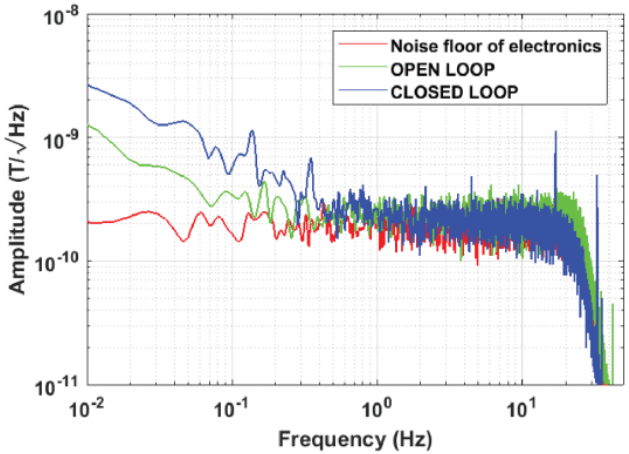


Measurement range: ± 100 µT
Linearity error: ± 0.01 % of Full Scale
Orthogonality error: < 0.1°
Offset temperature drift: < 2 nT/K
Sensitivity temperature drift: < 0.005 %/K
Noise (dig. output): < 300 pT_{RMS}/sqrt(Hz) at 1 Hz
Maximum TID (gamma): 50 krad (component level)









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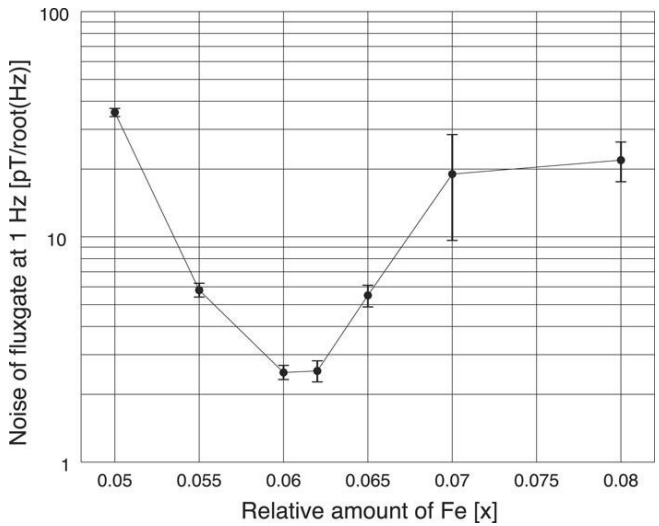
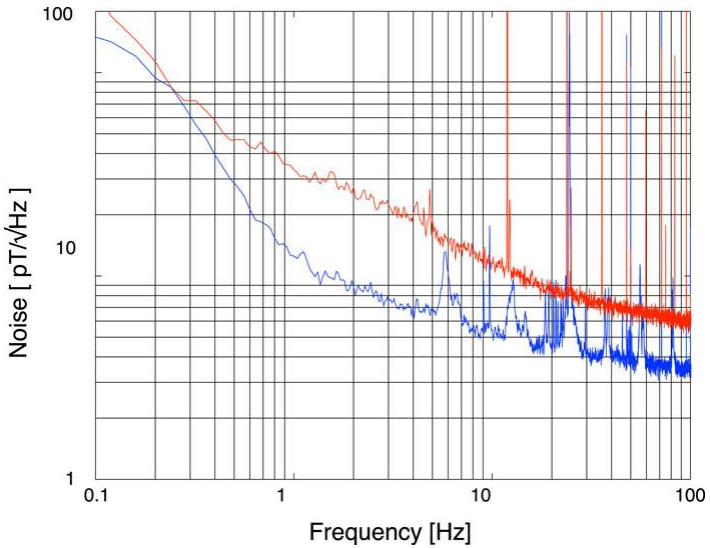
Amorphous wire based fluxgate





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Dependence of the noise of an orthogonal fluxgate on the composition of its amorphous wire-core
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