Building an Affordable Helmholtz Magnetic Simulator for CubeSat Satellites

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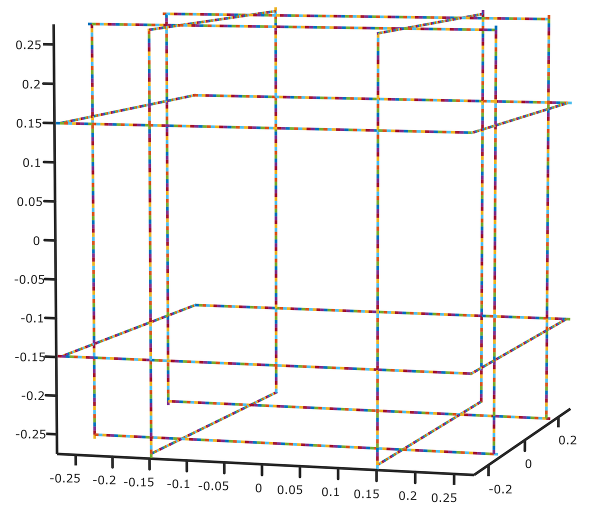
Analysis

Numerical analysis of square Helmholtz coils

The task of numerical analysis was to obtain magnetic flux density vectors for a system of square Helmholtz coils
Coils dimensions: 20 turns, side length a = 0.54 m, spacing b = 0.30 m (ratio between a and b is 0.55)
Each coil represented with 400 current elements, Biot-Savart law used to determine field strength of each element
Magnetic flux density was evaluated in 3-D polar coordinates by principle of superposition of all coils and elements
Resulting magnetic flux density in the center of the coil pairs is 300 μT at 100 A (~10 % lower than with circular coils)

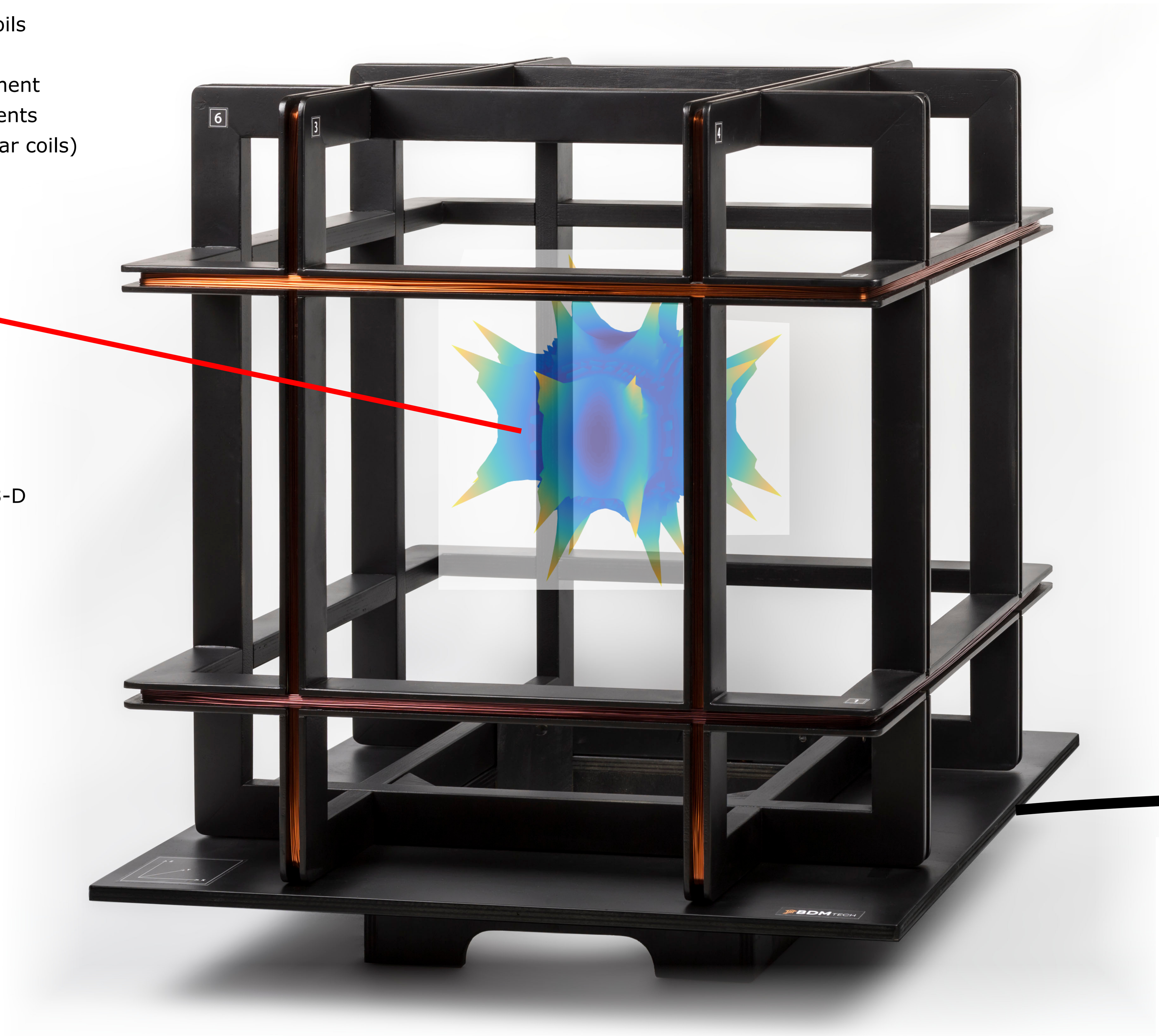


3-D representation of current elements (in total of 2400)

Homogenous field volume
approx. 10 cm x 10 cm x 10 cm
less than 1 % field discrepancy

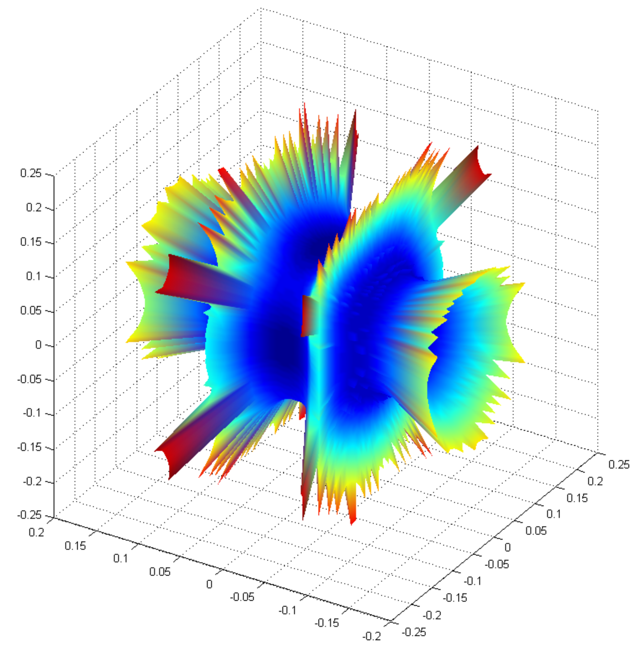
Homogeneous volume boundaries visualization

Boundary of the 1 % homogeneity region was searched for in 3-D
Arbitrary shaped homogeneous volume was determined
Volume boundary parameterized in polar coordinates



Outer cage dimensions
60 cm x 60 cm x 65 cm

Clean back of the unit



Homogeneity border (1 %) in one axis

Interface

Big alphanumeric LCD on front panel of the driver with an encoder knob

Display of coil currents, magnetic flux densities (references and measurements)
Display of coil and driver temperatures
Encoder used to move between different menus, change parameters
Coil currents or reference magnetic flux densities can be altered manually
Easily-accessible on/off switch on the front

Built-in galvanically isolated USB connection or Ethernet

Cross-platform library for use in Windows, linux (including embedded systems)
Interface example for C and Matlab (Simulink S-function)
Remote access for monitoring and control

```
 Pri  SP     PV     Mag
X: +000.0  +000.0 uT
y: +010.0  +010.0 uT
z: +000.0  +000.0 uT
```

```
A +0.42 +0.18 -0.57
          x|
          y|
          |z
```

```
Coils temperatures
x: 26.68°C  23.45°C
y: 23.00°C  21.87°C
z: 26.25°C  24.68°C
```

Control

Optional reference FLC3-70 fluxgate magnetometers
Integrated 3-channel digital controller with closed-loop control
Unique controller freeze mode that allows the removal of the reference probe
Dynamic control of magnetic field
Built-in separate coil temperature sensors for failsafe operation

Construction

Lightweight wooden coils cage

The cage is made of wood parts, then painted in matte black
Professional, clean look of the device

Coils wound using 1 mm copper wire

The coils are wound to achive +/- 200 μT of magnetic flux density

Heavy-duty connector

Hassle-free connection between the driver and the coils
Allows the cage to be easily disconnected and moved or stored

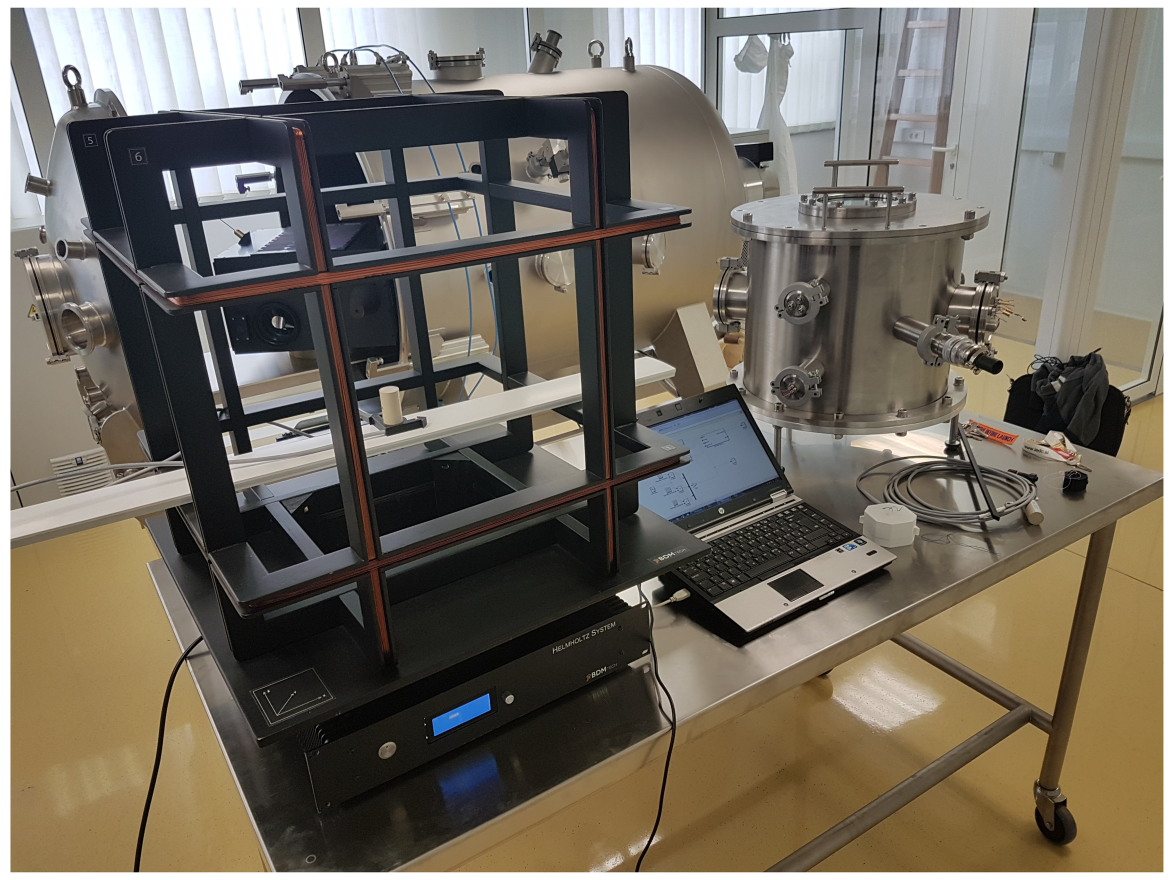
Driver case suitable for use in 19'' rack

Custom driver design

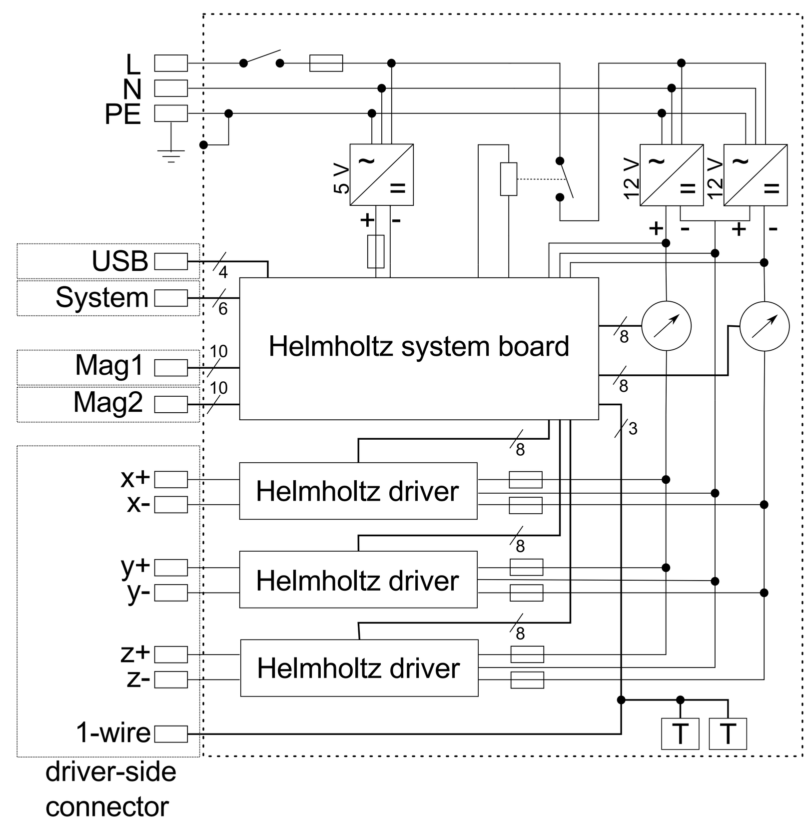
User-driven design (compact unit, easy to setup and use)
Microcontroller based driver, allowing digital closed-loop control
Multiple options of amplifier design evaluated,
MOSFET class AB closed-loop voltage-current amplifier implemented

Integrated temperature sensors

Digital temperature sensors integrated into the cage frame
to directly observe coil temperatures



Device testing in the laboratory



Driver architecture

Check video demo

Univerza v Ljubljani
Fakulteta za elektrotehniko

Laboratory of Modelling, Simulation and Control

Laboratory of Autonomous Mobile Systems

Developed for SPACE-SI in cooperation with BDM-Tech

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