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
Cylindrical coordinates were assumed
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)

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

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

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
Coils are wound to achieve +/- 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

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Device testing in the laboratory

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
Easy-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

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

Check video demo

Developed for SPACE-SI in cooperation with BDM-Tech

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