BSmag Toolbox User Manual

version 20150407

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1. Introduction

The BSmag Toolbox is a Matlab toolbox for the numerical integration of the Biot-Savart law. It provides a simple and efficient solution to calculate the magnetic flux density generated by an arbitrary current carrying filament in the magnetostatic approximation.

2. Installation

To use the BSmag Toolbox, you need to add the folder "BSmag Core" to the MATLAB path using the '`path`' command. Information on this command can be obtained by typing '`help path`' at the MATLAB prompt.

3. Cite

If you use BSmag, consider citing:

[1] L. Quéval, "BSmag Toolbox User Manual," Tech. report, Dept. Elect. Eng., University of Applied Sciences Düsseldorf, Germany, April 2015. Available: http://www.lqueval.com [Accessed April. 07, 2015].

4. BSmag Structure

Data for a BSmag analysis are placed into a data structure denoted BSmag.

`BSmag.Nfilament`	Number of filaments
`BSmag.filament(*).*`	Filament structure
`BSmag.filament(*).Gamma`	Filament points coordinates (x,y,z), one point per line [m,m,m]
`BSmag.filament(*).I`	Filament current (flows from first point towards last point) [A]
`BSmag.filament(*).dGamma`	Filament max discretization step [m]

5. Core functions

A listing and brief description of the core routines of the BSmag toolbox follows. Detailed documentation of these functions is contained with the m-files.

`BSmag_init.m`	Initializes a Biot-Savart magnetostatic analysis.
`BSmag_add_filament.m`	Adds a current carrying filament.
`BSmag_plot_field_points.m`	Plots all the field points (where we want to calculate the field) in the default figure.
`BSmag_get_B.m`	Calculates B at field points.

6. Other Scripts

Additional scripts are provided in the folder "BSmag Others". Detailed documentation of these scripts is contained with the m-files.

`validation_finite_straight_filament.m`	Comparison of numerical and analytical solutions for a finite straight filament
`validation_loop_filament_onAxis.m`	Comparison of numerical and analytical solutions for a loop filament (on axis)

7. Examples

1. Finite straight filament

Consider the finite straight filament shown in Fig.1. The script to calculate the magnetic flux density at the field points (black cross) is shown below. This script is named `example_1D_straight_filament.m` and is located in the `BSmag Examples` folder of the `BSmag 20150407` directory.

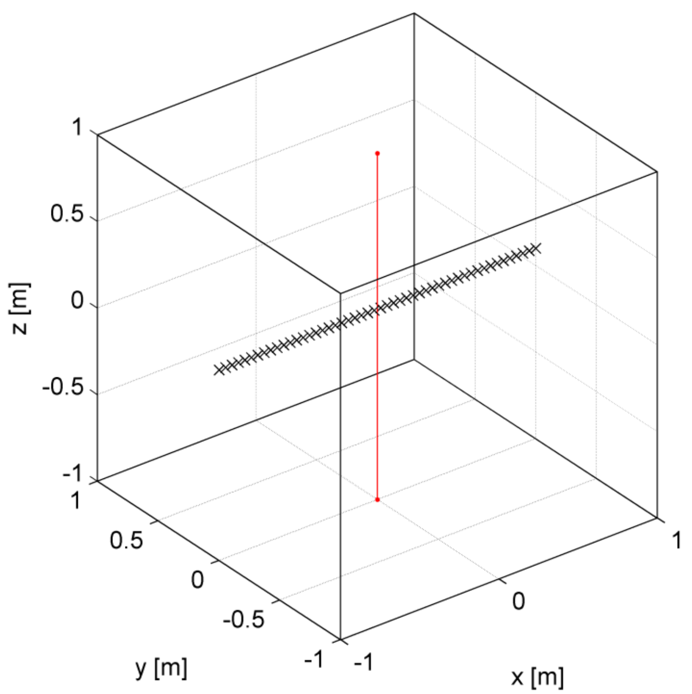

Figure 1 – Finite straight filament geometry and field points.

```
% Initialize
clear all, close all, clc
BSmag = BSmag_init(); % Initialize BSmag analysis

% Source points (where there is a current source)
Gamma   = [0,0,-1; % x,y,z [m,m,m]
           0,0,1];
I = 1; % filament current [A]
dGamma = 1e-3; % filament max discretization step [m]
[BSmag] = BSmag_add_filament(BSmag,Gamma,I,dGamma);

% Field points (where we want to calculate the field)
x_M = linspace(-1,1,50)'; % x [m]
y_M = zeros(50,1); % y [m]
z_M = 10e-2*ones(50,1); % z [m]
BSmag_plot_field_points(BSmag,x_M,y_M,z_M); % -> shows the field point line
```

```
% Biot-Savart Integration
[BSmag,X,Y,Z,BX,BY,BZ] = BSmag_get_B(BSmag,x_M,y_M,z_M);

% Plot B/|B|
figure(1)
    normB=sqrt(BX.^2+BY.^2+BZ.^2);
    quiver3(X,Y,Z,BX./normB,BY./normB,BZ./normB,'b')

% Plot By on the line
figure(2), hold on, box on, grid on
        plot(X, BY, 'x-b')
xlabel ('x [m]'), ylabel (' By [T]')
```

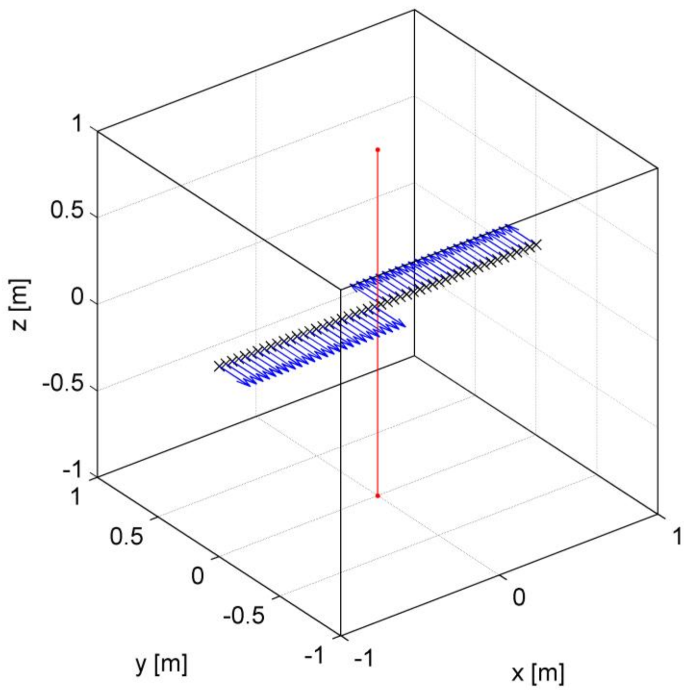

Figure 2 – Finite straight filament normalized field at field points.

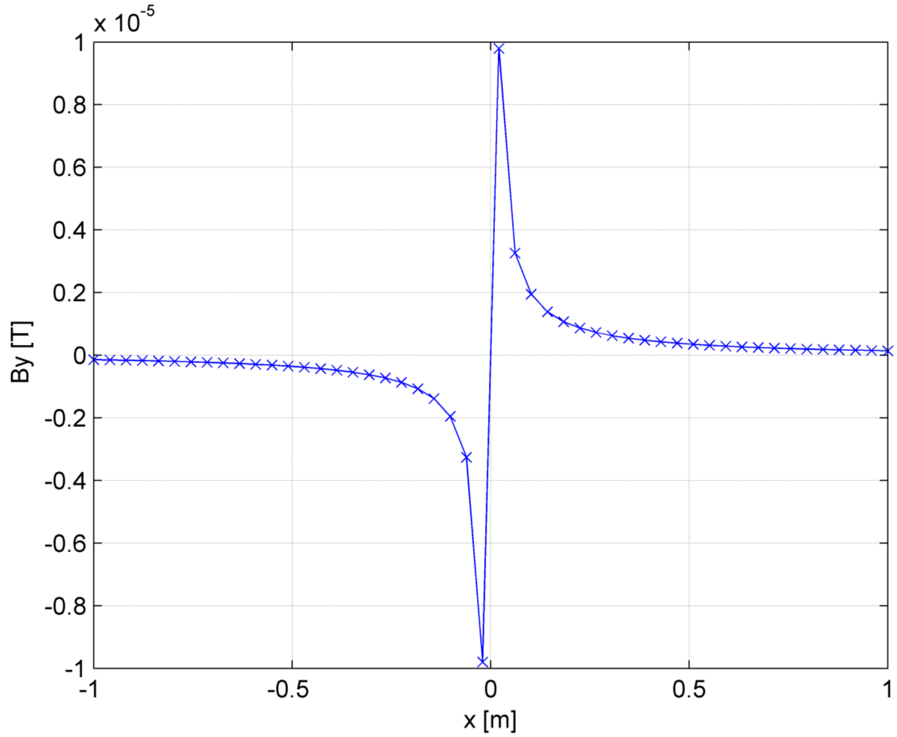

Figure 3 – Finite straight filament magnetic flux density y-component at field points.

2. Two bent filaments

Consider the two bent filaments shown in Fig.4. The script to calculate the magnetic flux density at the field points (black cross) is shown below. This script is named `example_2D_bent_filaments.m` and is located in the `BSmag Examples` folder of the `BSmag 20150407` directory.

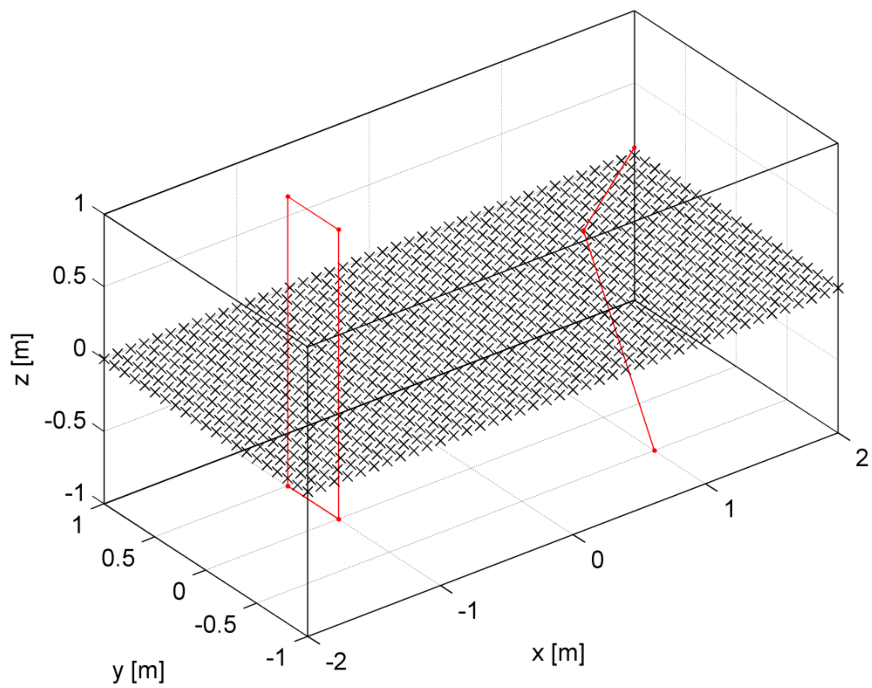

Figure 4 – Two bent filaments geometry and field points.

```
% Initialize
clear all, close all, clc
BSmag = BSmag_init(); % Initialize BSmag analysis

% Source points (where there is a current source)
Gamma1 = [1,-0.5,-1; % x,y,z [m,m,m]
          1,0.2,0.2;
          1,-0.3,1];
I1 = 2; % filament current [A]
dGamma1 = 1e-3; % filament max discretization step [m]
[BSmag] = BSmag_add_filament(BSmag,Gamma1,I1,dGamma1);

Gamma2 = [-1,0,-1; % x,y,z [m,m,m]
          -1,0,1;
          -1,0.5,1;
          -1,0.5,-1
          -1,0,-1];
I2 = 5; % filament current [A]
dGamma2 = 1e-3; % filament max discretization step [m]
[BSmag] = BSmag_add_filament(BSmag,Gamma2,I2,dGamma2);

% Field points (where we want to calculate the field)
x_M = linspace(-2, 2, 41); % x [m]
y_M = linspace(-1, 1, 21); % y [m]
[X_M,Y_M] = ndgrid(x_M,y_M);
Z_M = zeros(41,21); % z [m]
BSmag_plot_field_points(BSmag,X_M,Y_M,Z_M); % shows the field points plane

% Biot-Savart Integration
[BSmag,X,Y,Z,BX,BY,BZ] = BSmag_get_B(BSmag,X_M,Y_M,Z_M);
```

```
% Plot B/|B|
figure(1)
    normB=sqrt(BX.^2+BY.^2+BZ.^2);
    quiver3(X,Y,Z,BX./normB,BY./normB,BZ./normB,'b')

% Plot By on the plane
figure(2), hold on, box on, grid on
    contourf(X, Y, BY), colorbar
xlabel ('x [m]'), ylabel ('y [m]'), title ('By [T]')
```

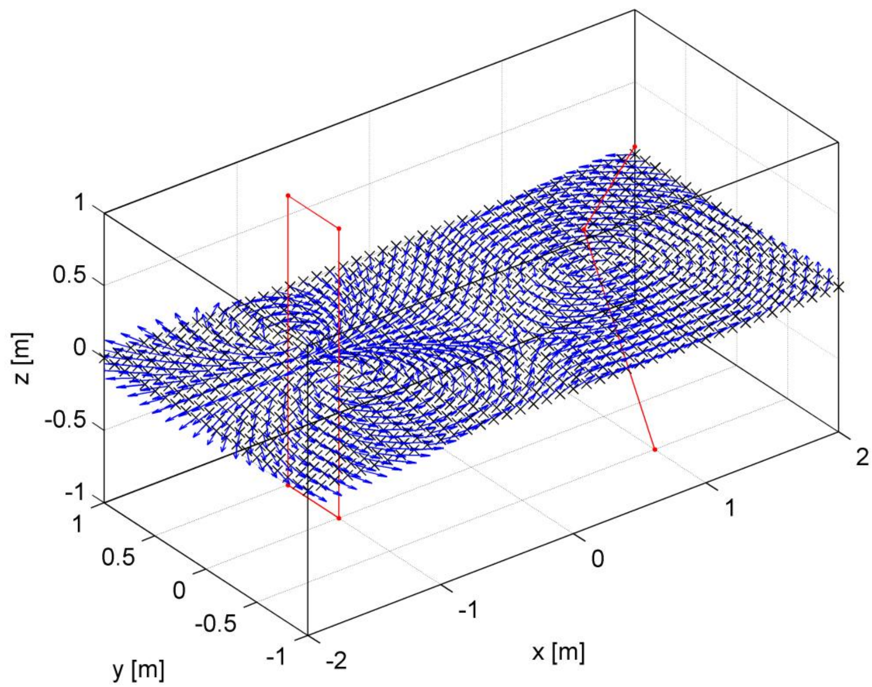

Figure 5 – Two bent filaments normalized field at field points.

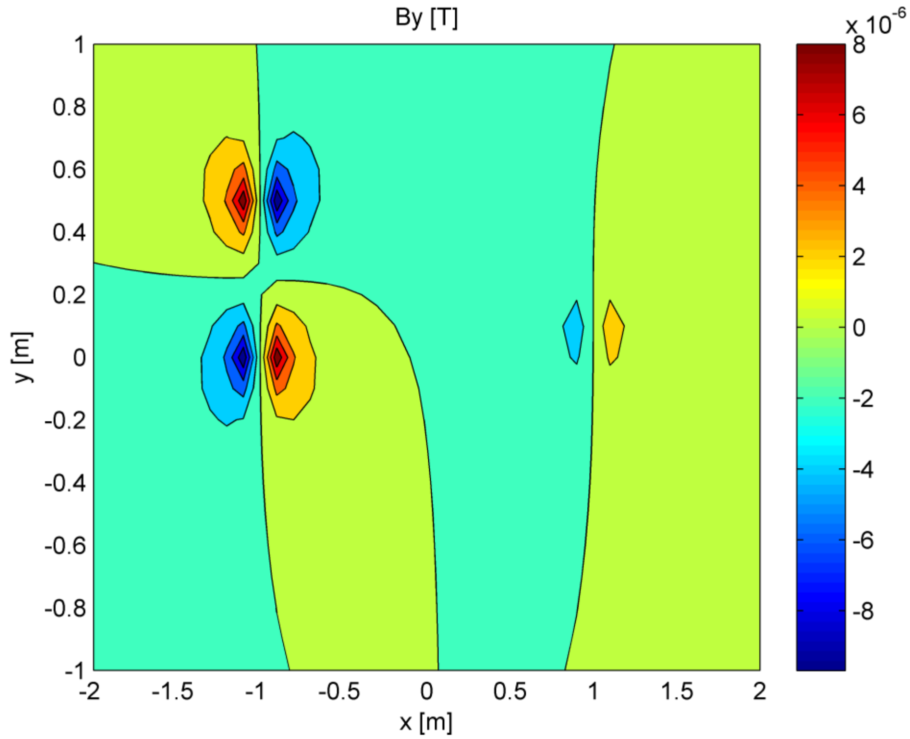

Figure 6 – Two bent filaments magnetic flux density distribution at field points.

3. Solenoid filament

Consider the solenoid filament shown in Fig.7. The script to calculate the magnetic flux density at the field points (black cross) is shown below. This script is named `example_3D_solenoid_filament.m` and is located in the `BSmag Examples` folder of the `BSmag 20150407` directory.

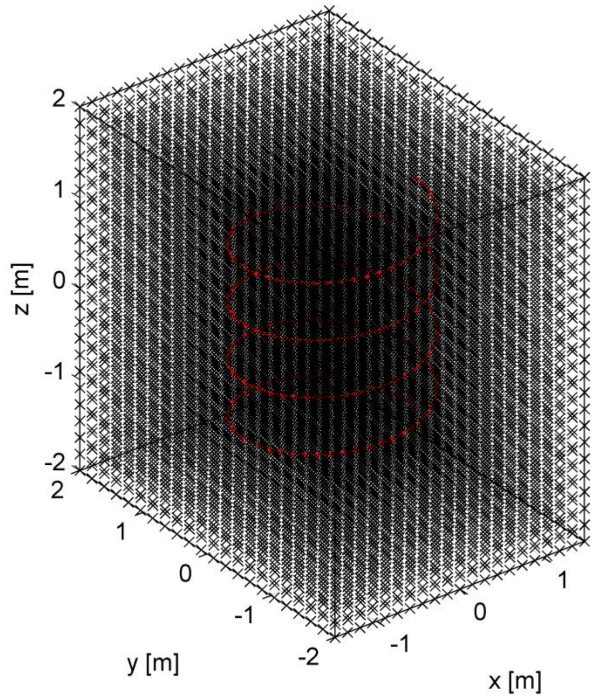

Figure 7 – Solenoid filament geometry and field points.

```
% Initialize
clear all, close all, clc
BSmag = BSmag_init(); % Initialize BSmag analysis

% Source points (where there is a current source)
theta = linspace(-2*2*pi,2*2*pi,2*100);
Gamma = [cos(theta'),sin(theta'),theta'/10]; % x,y,z [m,m,m]
I = 1; % filament current [A]
dGamma = 1e9; % filament max discretization step [m]
[BSmag] = BSmag_add_filament(BSmag,Gamma,I,dGamma);

% Field points (where we want to calculate the field)
x_M = linspace(-1.5,1.5,21); % x [m]
y_M = linspace(-2,2,22); % y [m]
z_M = linspace(-2,2,23); % z [m]
[X_M,Y_M,Z_M]=meshgrid(x_M,y_M,z_M);
BSmag_plot_field_points(BSmag,X_M,Y_M,Z_M); % shows the field points volume

% Biot-Savart Integration
[BSmag,X,Y,Z,BX,BY,BZ] = BSmag_get_B(BSmag,X_M,Y_M,Z_M);

% Plot B/|B|
figure(1)
    normB=sqrt(BX.^2+BY.^2+BZ.^2);
    quiver3(X,Y,Z,BX./normB,BY./normB,BZ./normB,'b')
%axis tight

% Plot Bz on the volume
figure(2), hold on, box on, grid on
        plot3(Gamma(:,1),Gamma(:,2),Gamma(:,3),'.-r') % plot filament
        slice(X,Y,Z,BZ,[0],[],[-1,0,1]), colorbar % plot Bz
```

```
xlabel ('x [m]'), ylabel ('y [m]'), zlabel ('z [m]'), title ('Bz [T]')
view(3), axis equal, axis tight
caxis([-0.5,0.5]*1e-5)

% Plot some flux tubes
figure(3), hold on, box on, grid on
        plot3(Gamma(:,1),Gamma(:,2),Gamma(:,3),'.-r') % plot filament
        [X0,Y0,Z0] = ndgrid(-1.5:0.5:1.5,-1.5:0.5:1.5,-2); % define tubes starting point
        htubes = streamtube(stream3(X,Y,Z,BX,BY,BZ,X0,Y0,Z0), [0.2 10]);
xlabel ('x [m]'), ylabel ('y [m]'), zlabel ('z [m]'), title ('Some flux tubes')
view(3), axis equal, axis tight
set(htubes,'EdgeColor','none','FaceColor','c') % change tube color
camlight left % change tube light
```

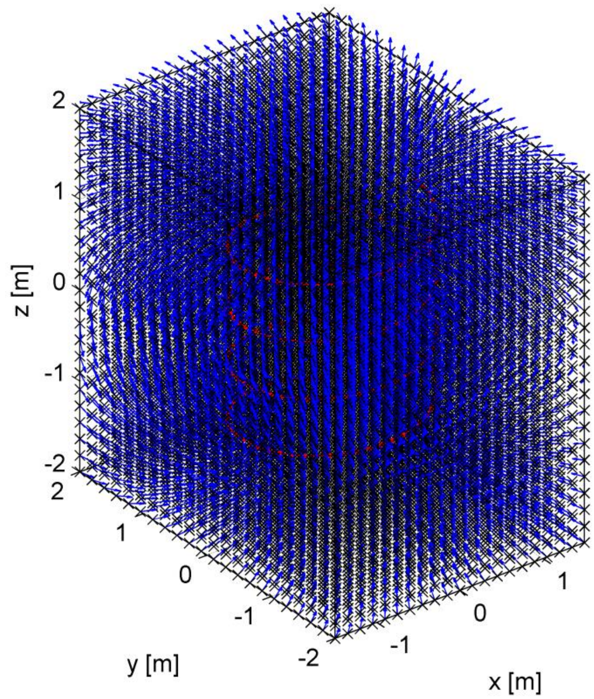

Figure 8 – Solenoid filament normalized field at field points.

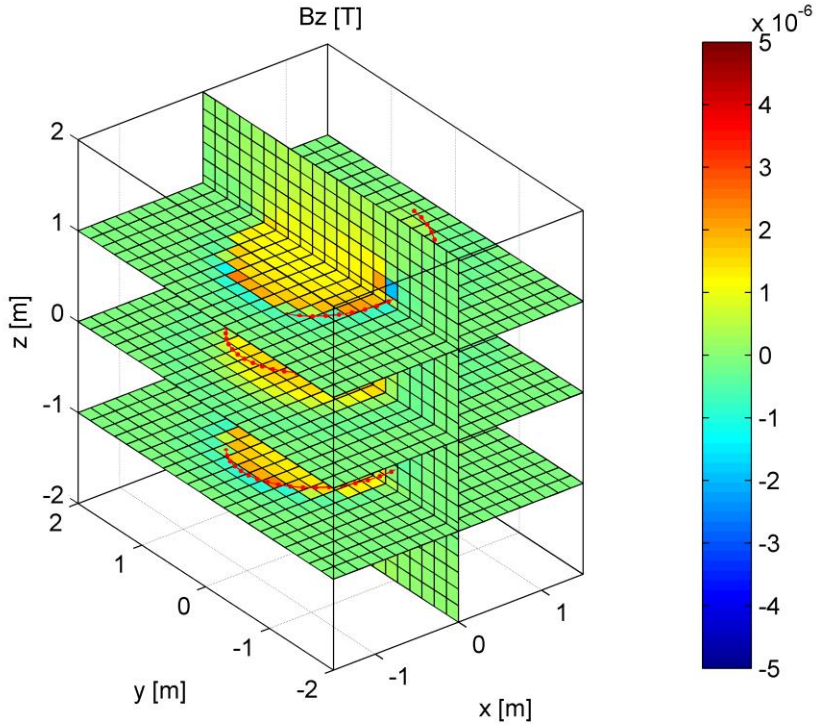

Figure 9 – Solenoid filament magnetic flux density distribution at (some) field points.

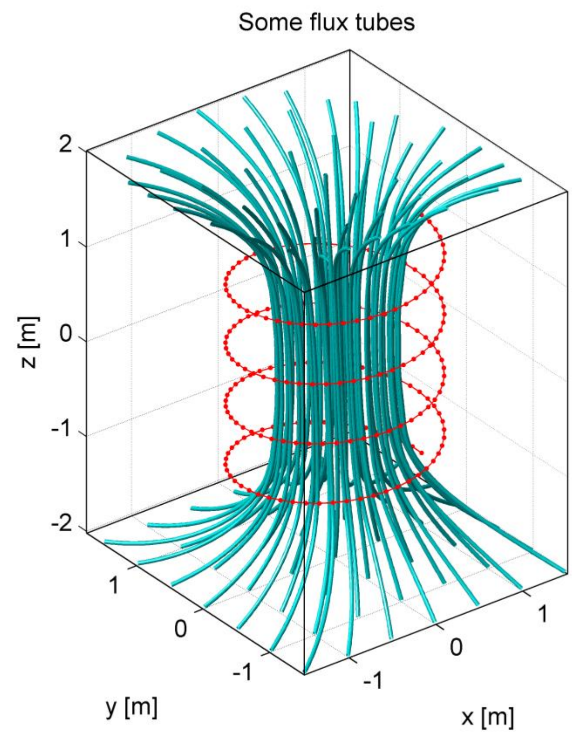

Figure 10 – Solenoid filament (some) flux tubes.

8. References

9. License