REPORT

Homework V

Attitude Determination and Control

UZB421E - 21265

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n = 48

Simulation of Magnetometer Measurements

I will explain the required information in the code.

```
n=48; % Student Number
t(1)=0; % (s) Initial time
t2(1)=0; % (s) Second Initial time
dt=0.1; % (s) The sample time
N=54000; % The Iteration Number
Me=7.943*(10^15); % (Wb*m) The magnetic dipole moment of the Earth
i=(80+0.5*n)*(pi/180); % (rad) The Orbit inclination (Multiply by
(pi / 180) to convert it to radians)
We=7.29*(10^-5); % (rad/s) The Spin Rate of the Earth
E=(11.7)*(pi/180); % (rad) The Magnetic Dipole Tilt
mu=3.98601*(10^14); % (m^3/s^2) The Earth gravitational constant
ro=(6378.14+500+2*n)*1000; % (m) The distance between the center of
mass of the satellite and the Earth.
Wo=sqrt(mu/ro^3); % (rad/s) The angular velocity of the orbit with
respect to the inertial frame
Worbit=0.0011; %  (rad/s) The angular orbit velocity of satellite
Nt=3.6*(10^-10); % (N*m) Disturbance torque acting on the satellite

% The moments of inertia of the satellite
Jx=2.1*10^-3;
Jy=2*10^-3;
Jz=1.9*10^-3;

% (rad) Initial data of the attitude angles
q1(1)=0.002*n;
q2(1)=0.001*n;
q3(1)=0.005*n;
q4(1)=sqrt(1-q1(1)^2-q2(1)^2-q3(1)^2);

% The initial data of the satellite's angular velocities
Wx(1)=0.0002+0.0001*n;
Wy(1)=0.0003+0.0001*n;
Wz(1)=0.0004+0.0001*n;
C=cell(N,1);   % cell contains all transformation matrices C
A=cell(N,1);   % cell contains all transformation matrices A

for i=1:N

    % Time increases per iteration
    t(i+1)=t(i)+dt;

    % The Angular Velocities
    Wx(i+1)=Wx(i)+(dt/Jx)*(Wz(i)*Wy(i)+Nt)*(Jy-Jz);
```

```
    Wy(i+1)=Wy(i)+(dt/Jy)*(Wx(i)*Wz(i)+Nt)*(Jz-Jx);
    Wz(i+1)=Wz(i)+(dt/Jz)*(Wx(i)*Wy(i)+Nt)*(Jx-Jy);

    % The Quaternions
    q1(i+1)=q1(i)-0.5*dt*(q2(i)*Wx(i)+q3(i)*Wy(i)+q4(i)*Wz(i));
    q2(i+1)=q2(i)+0.5*dt*(q1(i)*Wx(i)-q4(i)*Wy(i)+q3(i)*Wz(i));
    q3(i+1)=q3(i)+0.5*dt*(q4(i)*Wx(i)+q1(i)*Wy(i)-q2(i)*Wz(i));
    q4(i+1)=q4(i)-0.5*dt*(q3(i)*Wx(i)-q2(i)*Wy(i)-q1(i)*Wz(i));

    % The Transformation Matrix
    c11(i)=q1(i)^2-q2(i)^2-q3(i)^2+q4(i)^4;
    c12(i)=2*(q1(i)*q2(i)+q3(i)*q4(i));
    c13(i)=2*(q1(i)*q3(i)-q2(i)*q4(i));
    c21(i)=2*(q1(i)*q2(i)-q3(i)*q4(i));
    c22(i)=-q1(i)^2+q2(i)^2-q3(i)^3+q4(i)^2;
    c23(i)=2*(q2(i)*q3(i)-q1(i)*q4(i));
    c31(i)=2*(q1(i)*q3(i)+q2(i)*q4(i));
    c32(i)=2*(q2(i)*q3(i)-q1(i)*q4(i));
    c33(i)=-q1(i)^2-q2(i)^2+q3(i)^2+q4(i)^2;


C{i}=[c11(i),c12(i),c13(i);c21(i),c22(i),c23(i);c31(i),c32(i),c33(i)
];
end

% Each step taken from Homework 1.

for x=1:N

    % Time increases per iteration
    t2(x+1)=t2(x)+dt;

    % Earth's Magnetic Field Vector Components
    Hx(x)=(Me/Ro^3)*(cos(Wo*t(x))*(cos(E)*sin(i)-sin(E)*cos(i)*
    cos(We*t(x)))-sin(Wo*t(x))*sin(E)*sin(We*t(x)));
    Hy(x)=(-Me/Ro^3)*(cos(E)*cos(i)+sin(E)*sin(i)*cos(We*t(x)));
    Hz(x)=2*(Me/Ro^3)*(sin(Wo*t(x))*(cos(E)*sin(i)-sin(E)*cos(i)*
    cos(We*t(x)))-2*sin(Wo*t(x))*sin(E)*sin(We*t(x)));

    % Direction cosine elements of the magnetic field vector
    Hx0(x)=(1/sqrt(Hx(x)^2+Hy(x)^2+Hz(x)^2))*Hx(x);
    Hy0(x)=(1/sqrt(Hx(x)^2+Hy(x)^2+Hz(x)^2))*Hy(x);
    Hz0(x)=(1/sqrt(Hx(x)^2+Hy(x)^2+Hz(x)^2))*Hz(x);

     H{x}=[Hx(x);Hy(x);Hz(x)];
    H0{x}=[Hx0(x);Hy0(x);Hz0(x)];

end
```

```
% Each step taken from Homework 4.

% Standart Deviation of Each Magnetometer Error
sigmamc = 0.008;
sigmam = 1.66*(10^(-6));  % 1 W/m^2=1T=10^6nuT
```

$$\sigma_{m_c} = 0.008$$

$$\sigma_m = 1.66\mu T$$

$$1W/m^2 = 1T = 10^6\,\mu T$$

```
% Components of Magnetometer Bias Vector
```

b is the magnetometer bias vector as $b = \begin{bmatrix} b_x & b_y & b_z \end{bmatrix}^T$ and $v(k)$ is the zero mean Gaussian white noise, σ_m is the standard deviation of each magnetometer error, $b_c = \begin{bmatrix} b_{x_c} & b_{y_c} & b_{z_c} \end{bmatrix}^T$ is the magnetometer bias vector in terms of direction cosines.

```
bx = 3*(10^(-6));
by = 5*(10^(-6));
bz = 6*(10^(-6));
bcx = 0.04;
bcy = 0.06;
bcz = 0.08;
```

$$b_x = 3\mu T; b_y = 5\mu T; b_z = 6\mu T;$$

$$b_{x_c} = 0.04; b_{y_c} = 0.06; b_{z_c} = 0.08;$$

```
% Magnetometer Bias Vector
b = [bx;by;bz];
bc = [bcx;bcy;bcz];
C2=cell(N,1);  % Contains all the N number of C2
C2=C(1:1:54000);
Bm0=cell(N,1);
Bm=cell(N,1);
Bm0star=cell(N,1);
Bmstar=cell(N,1);
```

$$B_{m_c}(k) = C(k)H_o(k) + b_c(k) + \sigma_{m_c} randn \quad \text{and} \quad B^*_{m_c}(k) = C(k)H_o(k)$$

$$B_m(k) = C(k)H(k)10^6 + b(k) + \sigma_m randn \quad \text{and} \quad B^*_m(k) = C(k)H(k)$$

```
for x=1:N

   t2(x+1)=t2(x)+dt;

   Bm0{x}=C2{x}*H0{x}+bc+sigmamc*randn;
```

$$B_{m_c}(k) = C(k)H_o(k) + b_c(k) + \sigma_{m_c} randn$$

```
   Bm01(x)=Bm0{x}(1,1);
   Bm02(x)=Bm0{x}(2,1);
   Bm03(x)=Bm0{x}(3,1);

   Bm{x}=C2{x}*H{x}*10^6+b+sigmam*randn;
```

$$B_m(k) = C(k)H(k)10^6 + b(k) + \sigma_m randn$$

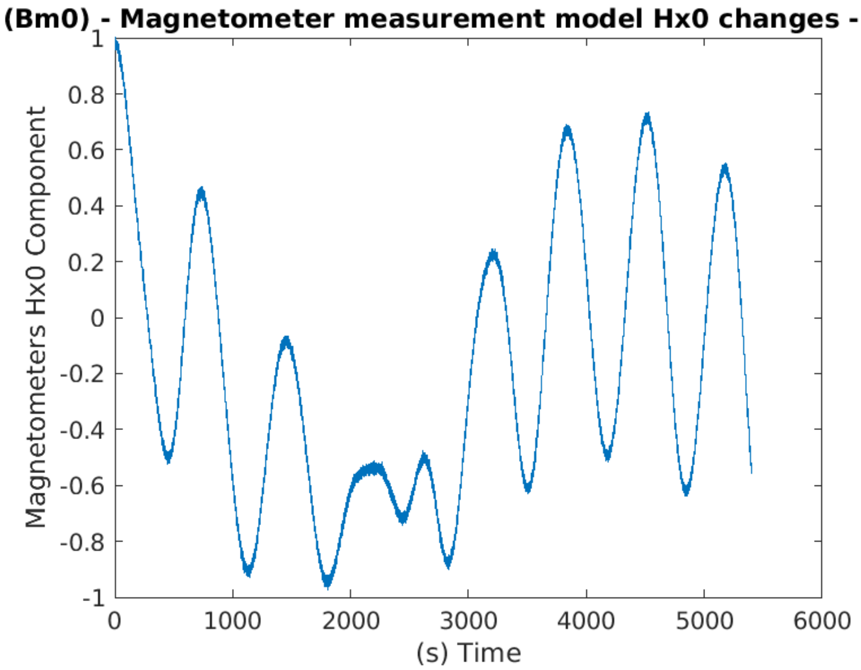
```
   Bm1(x)=Bm{x}(1,1);
   Bm2(x)=Bm{x}(2,1);
   Bm3(x)=Bm{x}(3,1);

   Bm0star{x}=C2{x}*H0{x};
   Bm0star1(x)=Bm0star{x}(1,1);
   Bm0star2(x)=Bm0star{x}(2,1);
   Bm0star3(x)=Bm0star{x}(3,1);

   Bmstar{x}=C2{x}*H{x}*(10^6);
   Bmstar1(x)=Bmstar{x}(1,1);
   Bmstar2(x)=Bmstar{x}(2,1);
   Bmstar3(x)=Bmstar{x}(3,1);

end

% Graphs
figure
plot(t2(1:54000),Bm01)
title('(Bm0) - Magnetometer measurement model Hx0 changes - time')
xlabel('(s) Time')
ylabel('Magnetometers Hx0 Component')
figure
plot(t2(1:54000),Bm0star1)
title('(Bm0*) - Magnetometer measurement model Hx0 changes - time')
xlabel('(s) Time')
ylabel('Magnetometer Hx0 Component')
figure
plot(t2(1:54000),Bm01)
hold on
plot(t2(1:54000),Bm0star1)
hold off
title('Magnetometer measurement model Hx0 changes - time')
```

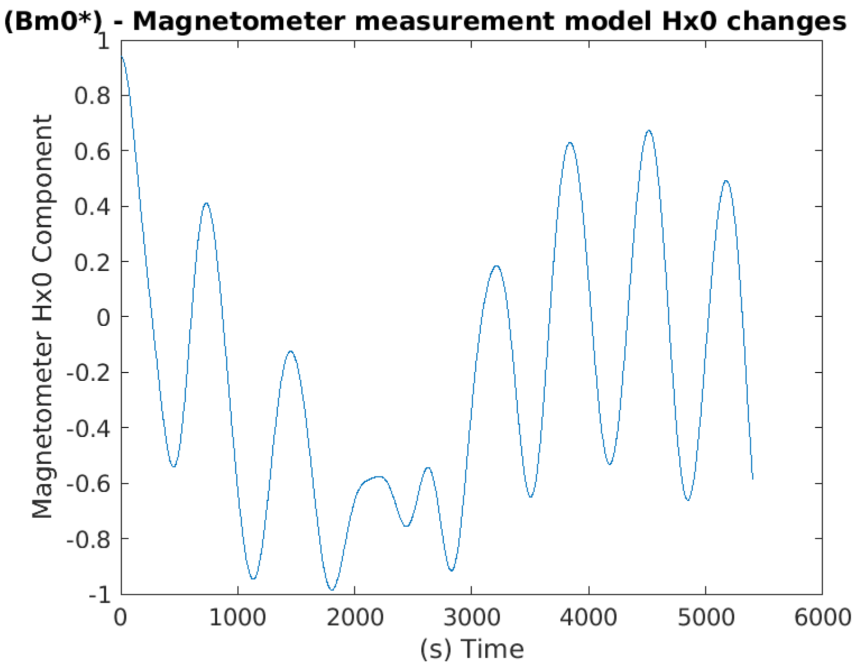
```
xlabel('(s) Time')
ylabel('Magnetometers Hx0 Component')
legend('B_m_0_1','B_m_0_1^*')
figure
plot(t2(1:54000),Bm02)
title('(Bm0) - Magnetometer measurement model Hy0 changes - time')
xlabel('(s) Time')
ylabel('Magnetometer Hy0 Component')
figure
plot(t2(1:54000), Bm0star2)
title('(Bm0*) - Magnetometer measurement model Hy0 changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hy0 Component')
figure
plot(t2(1:54000),Bm02)
hold on
plot(t2(1:54000),Bm0star2)
hold off
title('Magnetometer measurement model Hy0 changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hy0 Component')
legend('B_m_0_2','B_m_0_2^*')
figure
plot(t2(1:54000) , Bm03)
title('(Bm0) - Magnetometer measurement model Hz0 changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hz0 Component')
figure
plot(t2(1:54000) , Bm0star3)
title('(Bm0*) - Magnetometer measurement model Hz0 changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hz0 Component')
figure
plot(t2(1:54000),Bm03)
hold on
plot(t2(1:54000),Bm0star3)
hold off
title('Magnetometer measurement model Hz0 changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hz0 Component')
legend('B_m_0_3','B_m_0_3^*')
figure
plot(t2(1:54000), Bm1)
title('(Bm) - Magnetometer measurement model Hx changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hx Component')
figure
plot(t2(1:54000),Bmstar1)
```

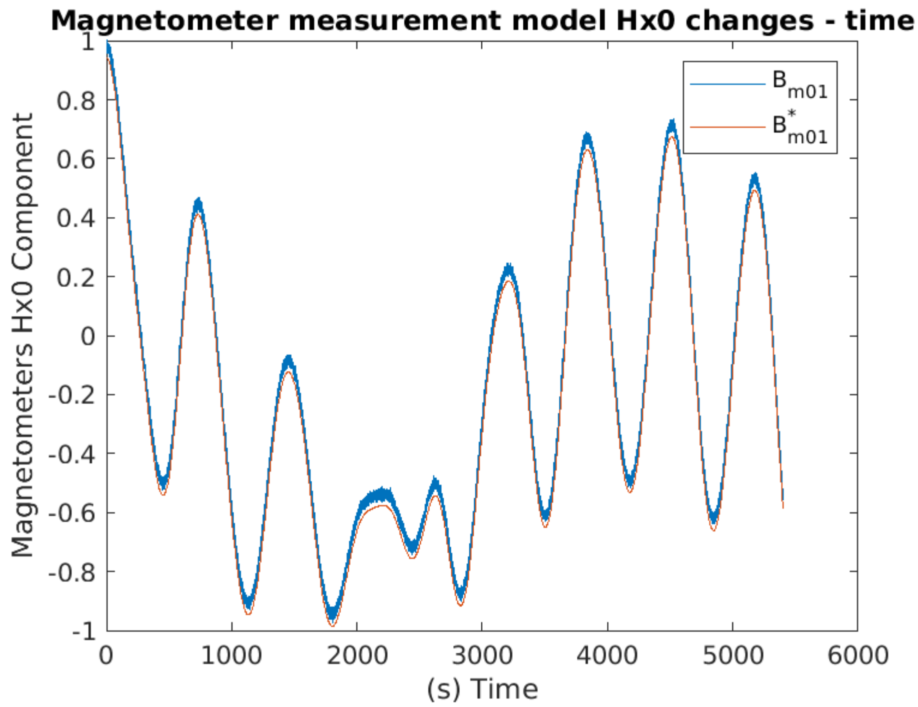
```
title('Bm*) - Magnetometer measurement model Hx changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hx Component')
figure
plot(t2(1:54000),Bm1)
hold on
plot(t2(1:54000),Bmstar1)
hold off
title('Magnetometer Measurement Model Hx changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hx Component')
legend('B_m_1','B_m_1^*')
figure
plot(t2(1:54000), Bm2)
title('(Bm) - Magnetometer measurement model Hy changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hy Component')
figure
plot(t2(1:54000), Bmstar2)
title('(Bm*) - Magnetometer measurement model Hy changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hy Component')
figure
plot(t2(1:54000),Bm2)
hold on
plot(t2(1:54000),Bmstar2)
hold off
title('Magnetometer measurement model Hy changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hy Component ')
legend('B_m_2','B_m_2^*')
figure
plot(t2(1:54000), Bm3)
title('(Bm) - Magnetometer measurement model Hz changes - time')
xlabel('(s) Time)')
ylabel('Mgnetometers Hz Component')
figure
plot(t2(1:54000), Bmstar3)
title('(Bm*) - Magnetometer measurement model Hz changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hz Component')
figure
plot(t2(1:54000), Bm3)
figure
plot(t2(1:54000),Bm3)
hold on
plot(t2(1:54000),Bmstar3)
hold off
```

```
title('Magnetometer measurement model Hz changes - time')
xlabel('(s) Time)')
ylabel('Magnetometers Hz Component [Wb/m^2]')
legend('B_m_3','B_m_3^*')
```

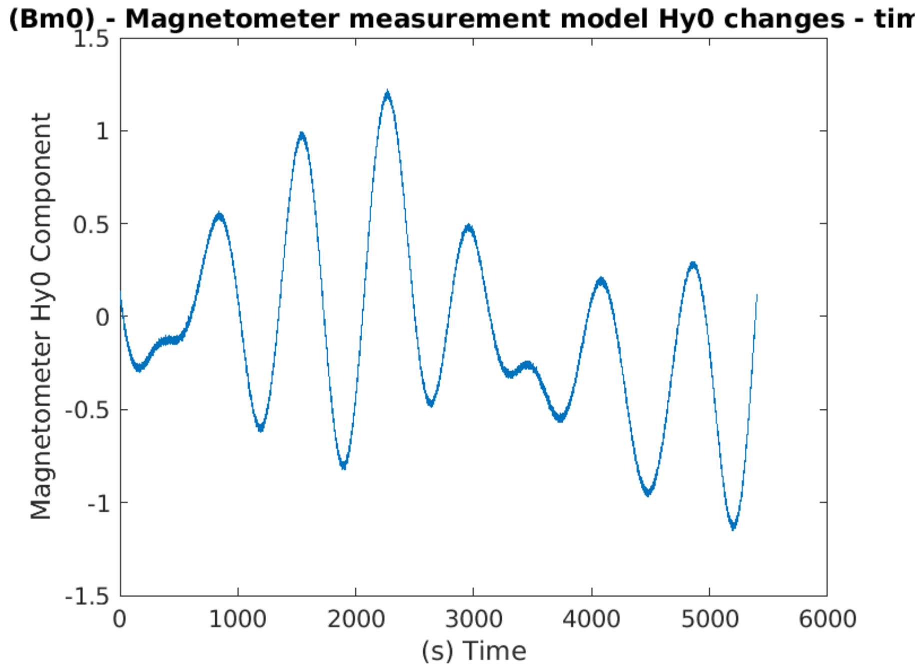
Graphs



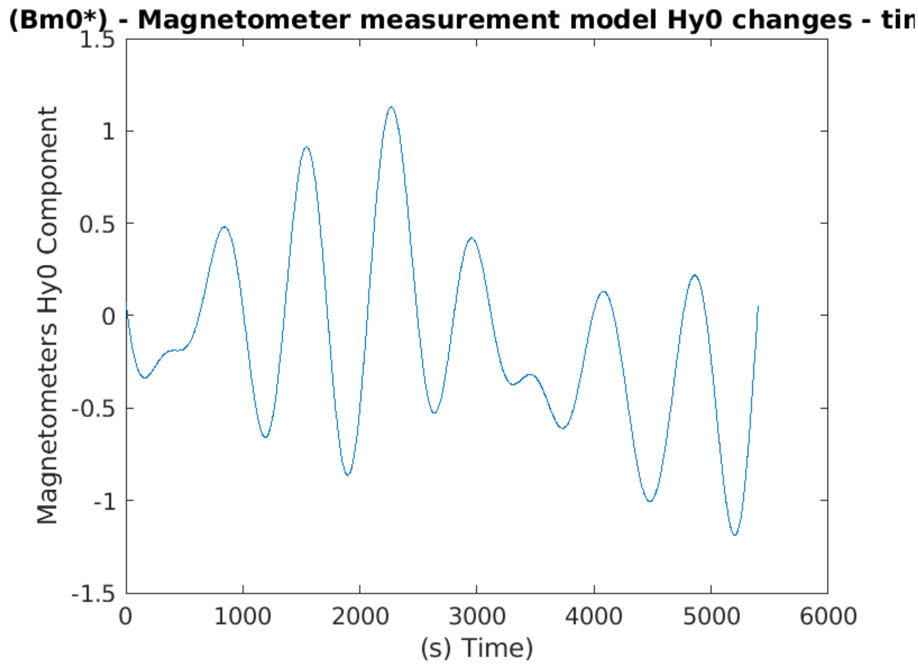


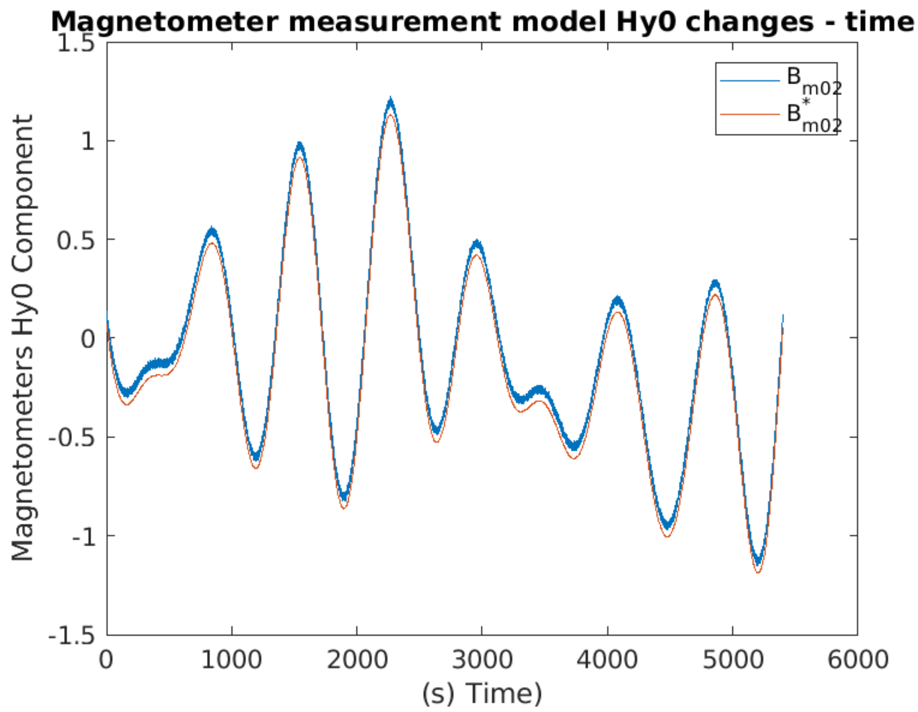


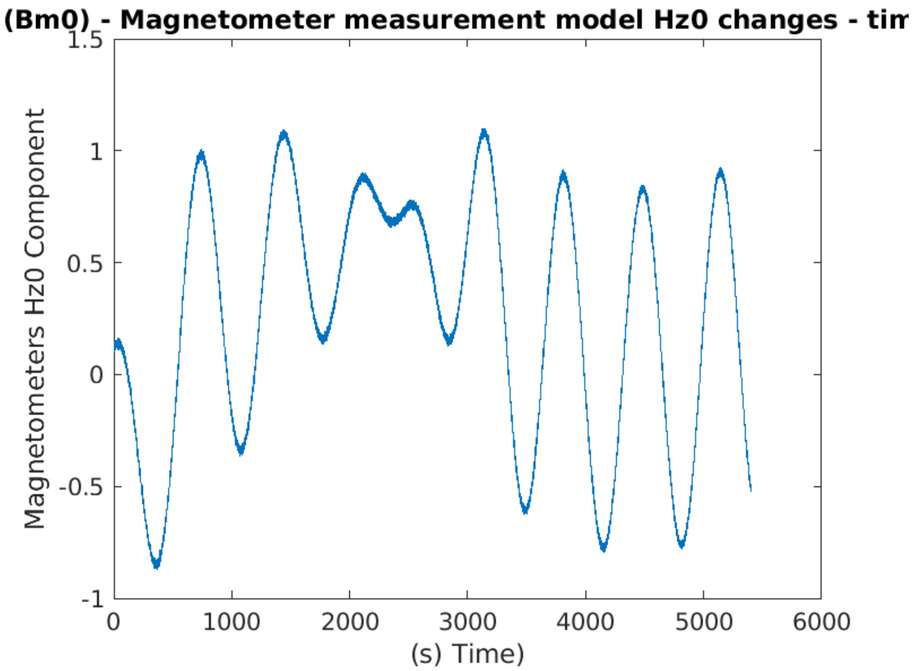
Magnetometer measurement model Hx0 changes - time
Magnetometers Hx0 Component
(s) Time
B_{m01}
B^*_{m01}
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1000
2000
3000
4000
5000
6000

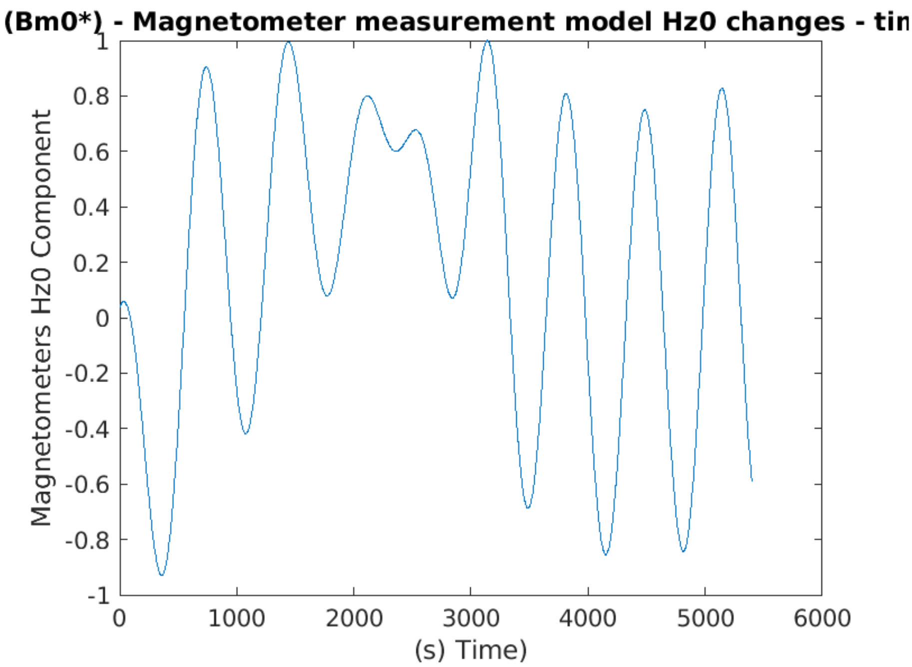


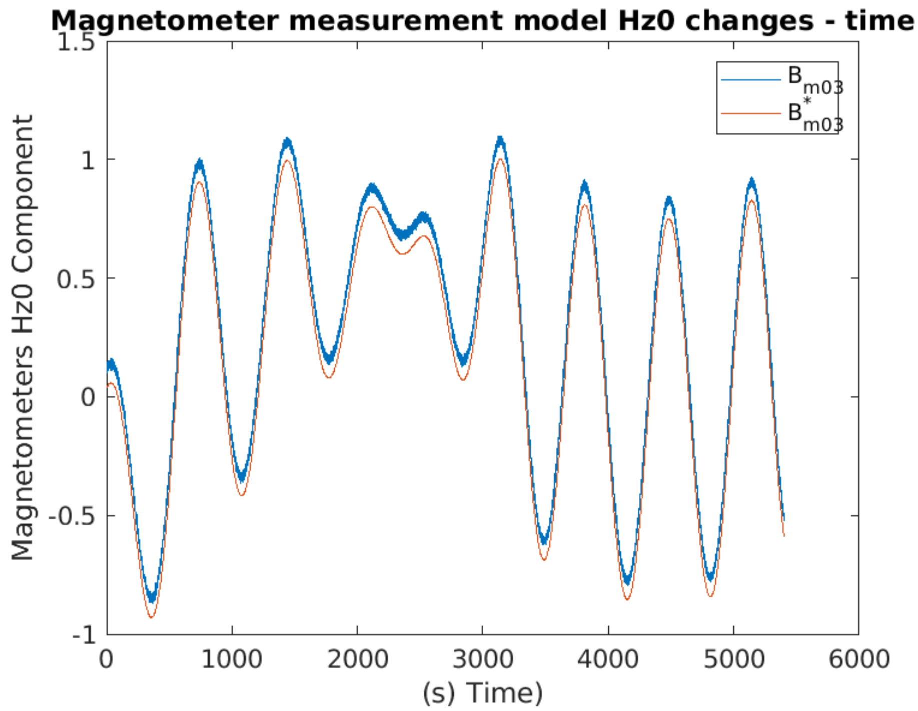
(Bm0) - Magnetometer measurement model Hy0 changes - tim
Magnetometer Hy0 Component
(s) Time
1.5
1
0.5
0
-0.5
-1
-1.5
0
1000
2000
3000
4000
5000
6000

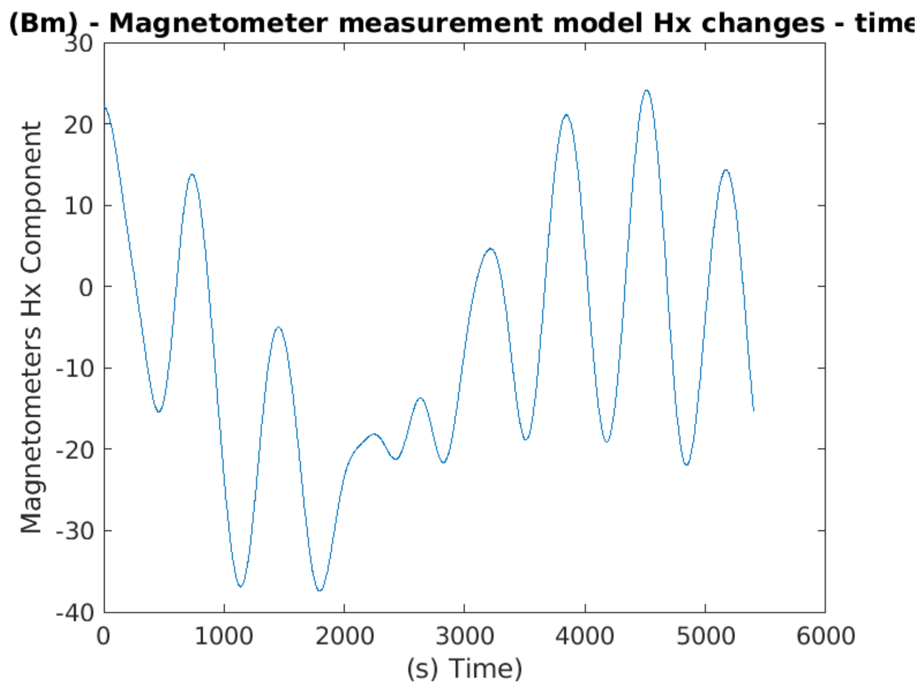

(Bm0*) - Magnetometer measurement model Hy0 changes - tir
Magnetometers Hy0 Component
(s) Time)

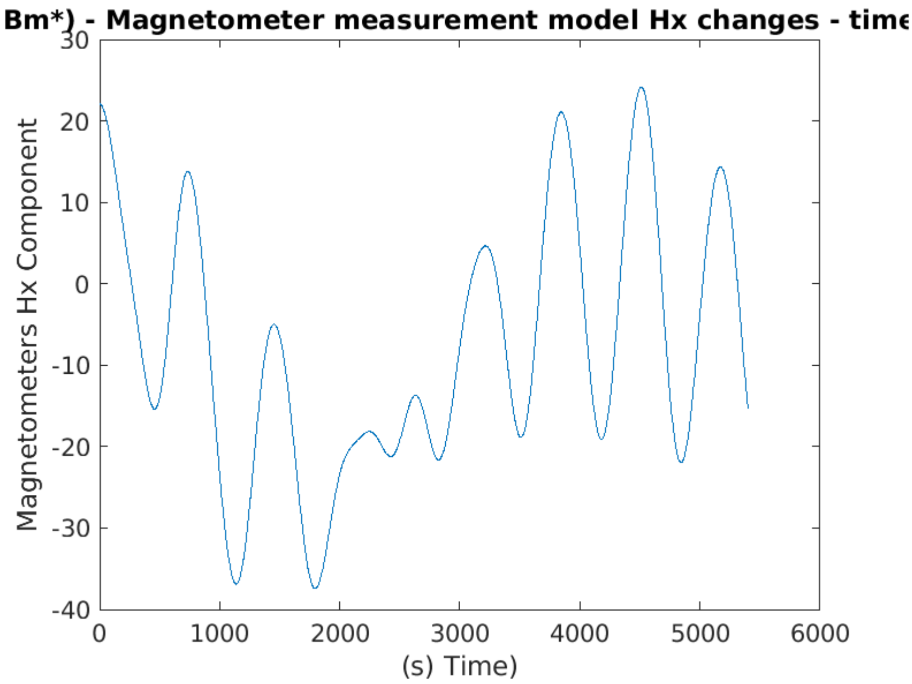

Magnetometer measurement model Hy0 changes - time
Magnetometers Hy0 Component
(s) Time)
B_{m02}
B^*_{m02}


(Bm0) - Magnetometer measurement model Hz0 changes - tim
Magnetometers Hz0 Component
(s) Time)
1.5
1
0.5
0
-0.5
-1
0
1000
2000
3000
4000
5000
6000

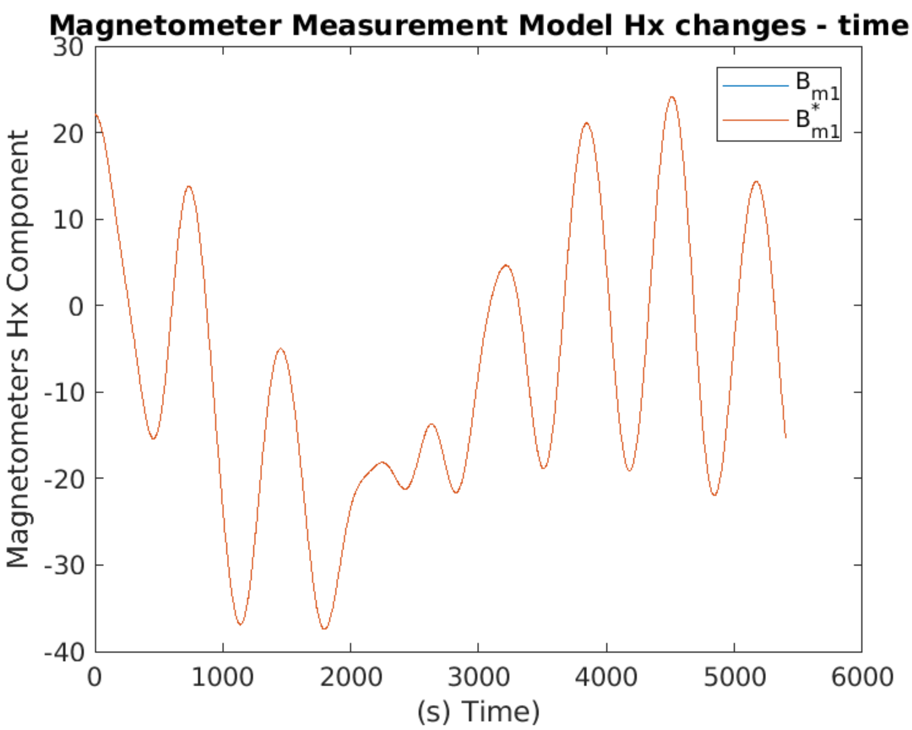

(Bm0*) - Magnetometer measurement model Hz0 changes - tim
Magnetometers Hz0 Component
(s) Time)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1000
2000
3000
4000
5000
6000


Magnetometer measurement model Hz0 changes - time
Magnetometers Hz0 Component
(s) Time)
B_{m03}
B^*_{m03}

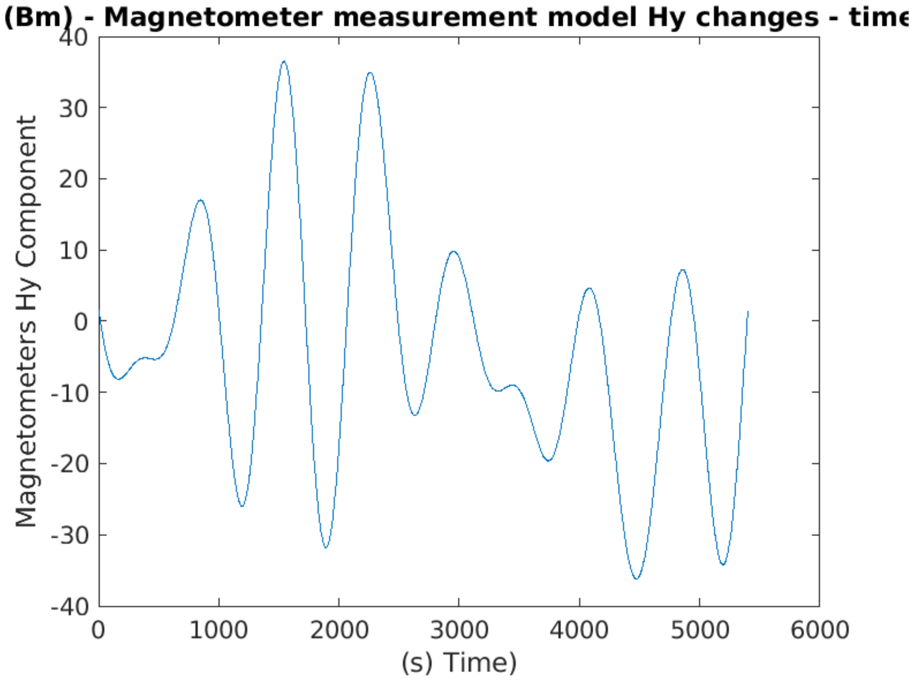

(Bm) - Magnetometer measurement model Hx changes - time
Magnetometers Hx Component
(s) Time)

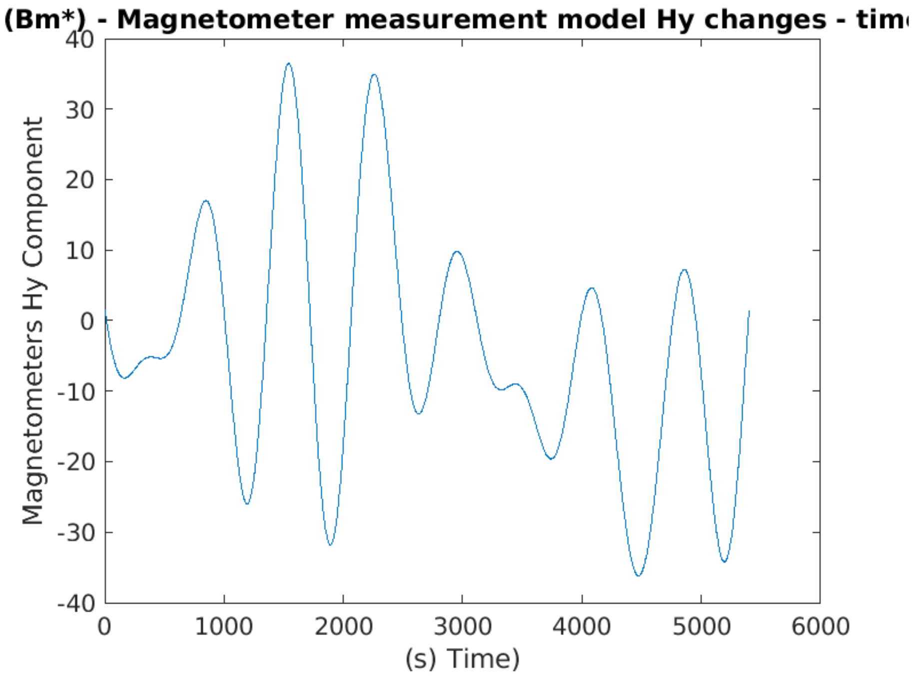


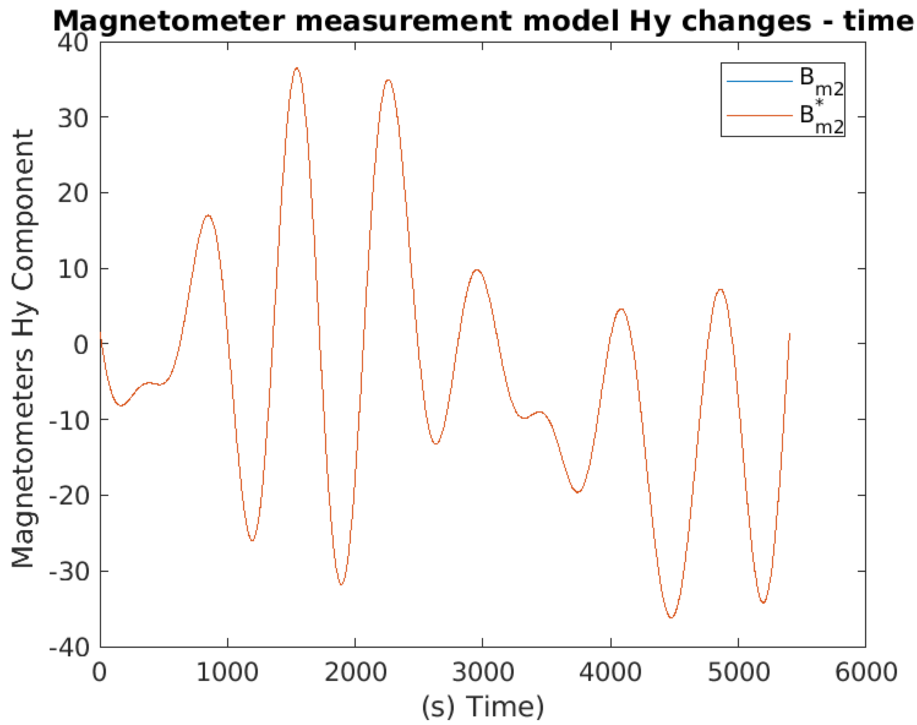
Bm*) - Magnetometer measurement model Hx changes - time
Magnetometers Hx Component
(s) Time)

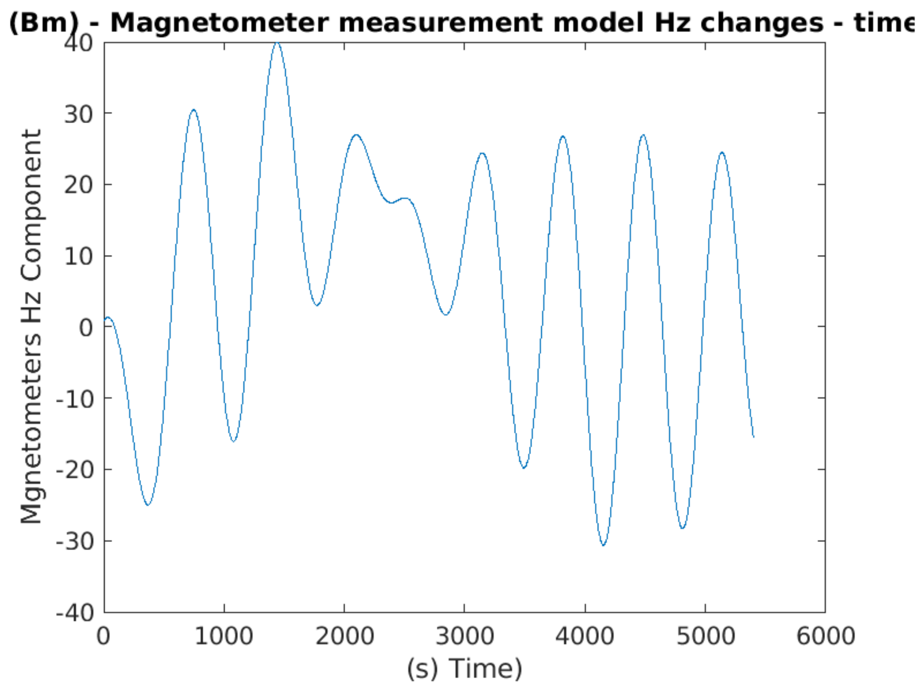


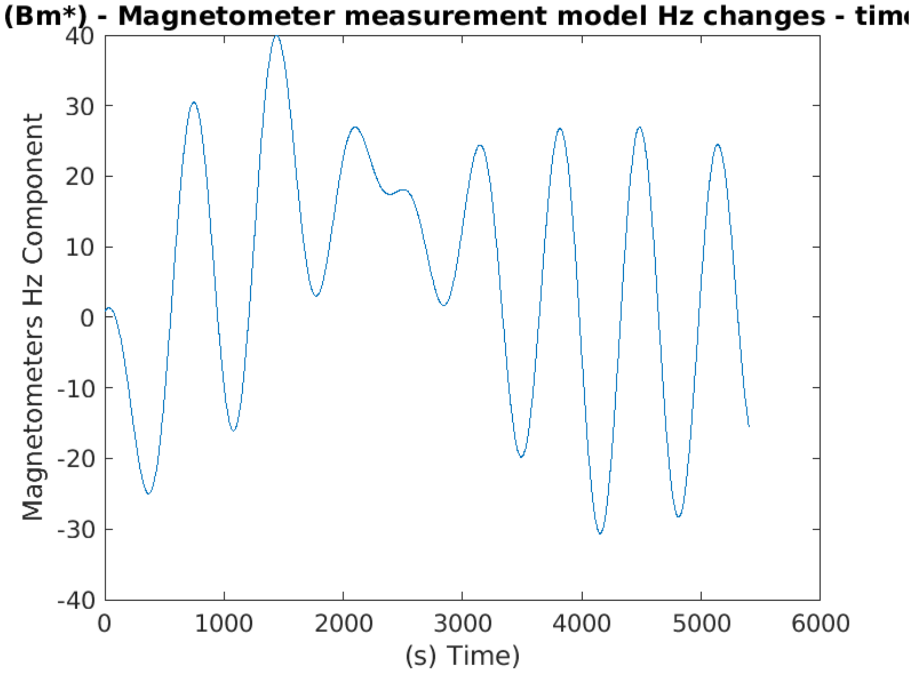
Magnetometer Measurement Model Hx changes - time
Magnetometers Hx Component
(s) Time)
B_{m1}
B^*_{m1}

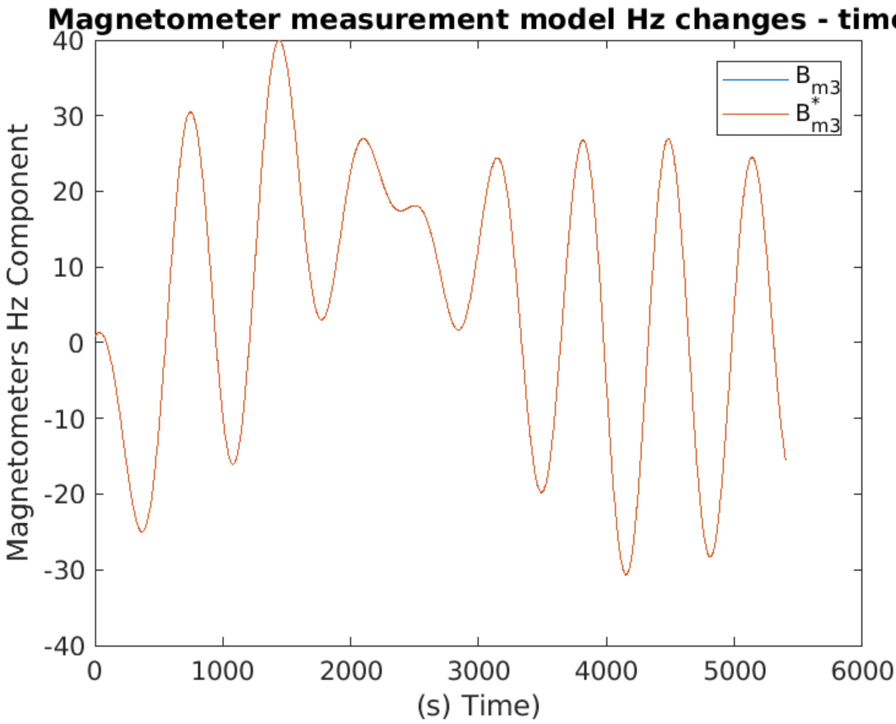

(Bm) - Magnetometer measurement model Hy changes - time
Magnetometers Hy Component
(s) Time)
40
30
20
10
0
-10
-20
-30
-40
0
1000
2000
3000
4000
5000
6000


(Bm*) - Magnetometer measurement model Hy changes - time
Magnetometers Hy Component
(s) Time)
40
30
20
10
0
-10
-20
-30
-40
0
1000
2000
3000
4000
5000
6000


Magnetometer measurement model Hy changes - time
Magnetometers Hy Component
(s) Time)
B_{m2}
B^*_{m2}
40
30
20
10
0
-10
-20
-30
-40
0
1000
2000
3000
4000
5000
6000


(Bm) - Magnetometer measurement model Hz changes - time
Mgnetometers Hz Component
(s) Time)
40
30
20
10
0
-10
-20
-30
-40
0
1000
2000
3000
4000
5000
6000


(Bm*) - Magnetometer measurement model Hz changes - time
Magnetometers Hz Component
(s) Time)
40
30
20
10
0
-10
-20
-30
-40
0
1000
2000
3000
4000
5000
6000


Magnetometer measurement model Hz changes - time
Magnetometers Hz Component
(s) Time)
B_{m3}
B^*_{m3}
40
30
20
10
0
-10
-20
-30
-40
0
1000
2000
3000
4000
5000
6000