Acoustic field in a pipe with harmonic forcing at the bottom

This script demonstrates the use of StabFem for a linear acoustics problem

Problem : find the velocity potential ϕ such as :

- $\Delta \phi + k^2 \phi = 0 \; (\text{with } k = \omega c_0$ the acoustic wavenuber)
- $u_z = \partial_z \phi = 1$ along Γ_{in}
- $\partial_R \phi + R^{-1} \phi + ik\phi = 0$ (Sommerfeld condition) on Γ_{out}

Variational formulation :

$$\forall \phi^*, \int \int_\Omega \left(\nabla \phi \cdot \nabla \phi^* + k^2 \phi \phi^* \right) dV + \int_{\Gamma_{out}} (R^{-1} + ik) \phi \phi^* dV = \int_{\Gamma_{in}} \phi^* dS$$

Contents

initialisation

```
clear all
close all
run('../../SOURCES_MATLAB/SF_Start.m');
set(groot, 'defaultAxesTickLabelInterpreter','latex');
set(groot, 'defaultLegendInterpreter','latex');
```

Chapter 1 : building of a mesh

```
ffmesh = SF_Mesh('Mesh_1.edp')
```

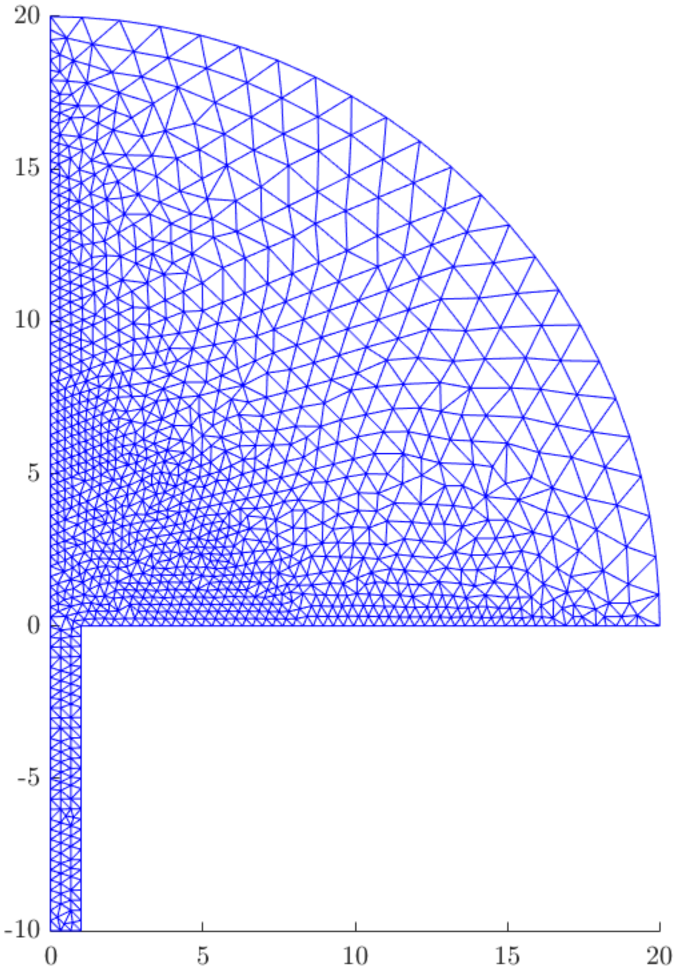
```
        ### INITIAL MESH CREATED WITH np = 1337 points
```

```
ffmesh = 

    DataDescription: '(Auxiliary file with information on initial mesh)'
           datatype: 'Mesh'
           meshtype: '2D'
                 np: 1337
               Ndof: 11619
           deltamin: 0.295564000000000
           deltamax: 1.488820000000000
             deltaA: 0.407319000000000
             deltaB: 0.355871000000000
             deltaC: 0.332579000000000
             deltaD: 0.379764000000000
        problemtype: 'AcousticAxi'
               ZERO: 0
             points: [3x1337 double]
             bounds: [3x204 double]
                tri: [4x2468 double]
                nbe: 204
                 nt: 2468
             labels: [1 2 3 4 5]
           filename: './WORK/mesh.msh'
                seg: []
     meshgeneration: 0
```

plot the mesh :

```
SF_Plot(ffmesh);
```



Chapter 2 : Resolution of an acoustically forced problem (and mesh adaptation)

```
Forced = SF_LinearForced(ffmesh,1,'BC','SOMMERFELD');
ffmesh = SF_Adapt(ffmesh,Forced,'Hmax',1); % Adaptation du maillage

Forced = SF_LinearForced(ffmesh,1,'BC','SOMMERFELD')
```

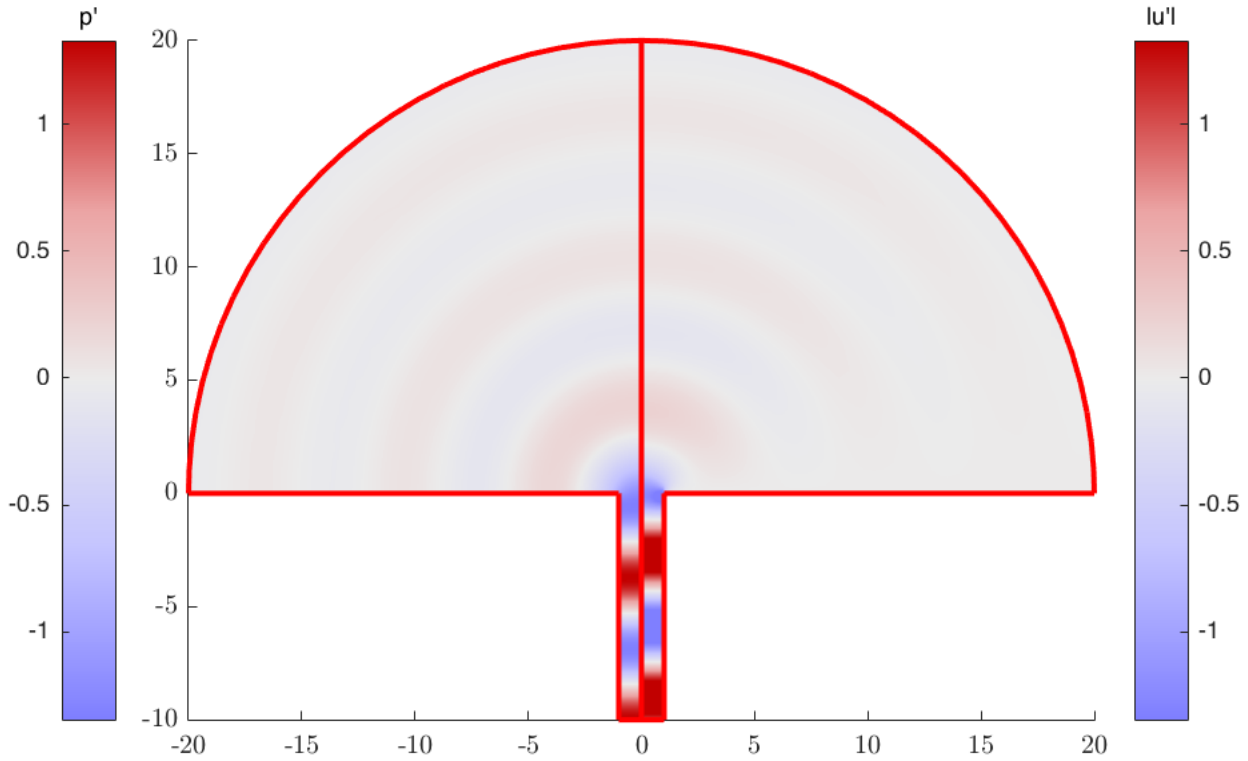
```
 ### ENTERING SF_ADAPT
rm: ./WORK/Eigenmode*: No such file or directory

Forced = 

               mesh: [1x1 struct]
           filename: './WORK/Field_Impedance_Re_Omega1.txt'
    DataDescription: 'FORCED LINEAR RESPONSE for an axisymmetric acoustic '
           datatype: 'ForcedFlow'
    datastoragemode: 'CxP2'
             Lambda: 0.000000000000000 + 1.000000000000000i
                  u: [1277x1 double]
                  p: [1277x1 double]
                  Z: -0.021116600000000 + 0.023592700000000i
              Xaxis: [501x1 double]
              Paxis: [501x1 double]
              Uaxis: [501x1 double]
```

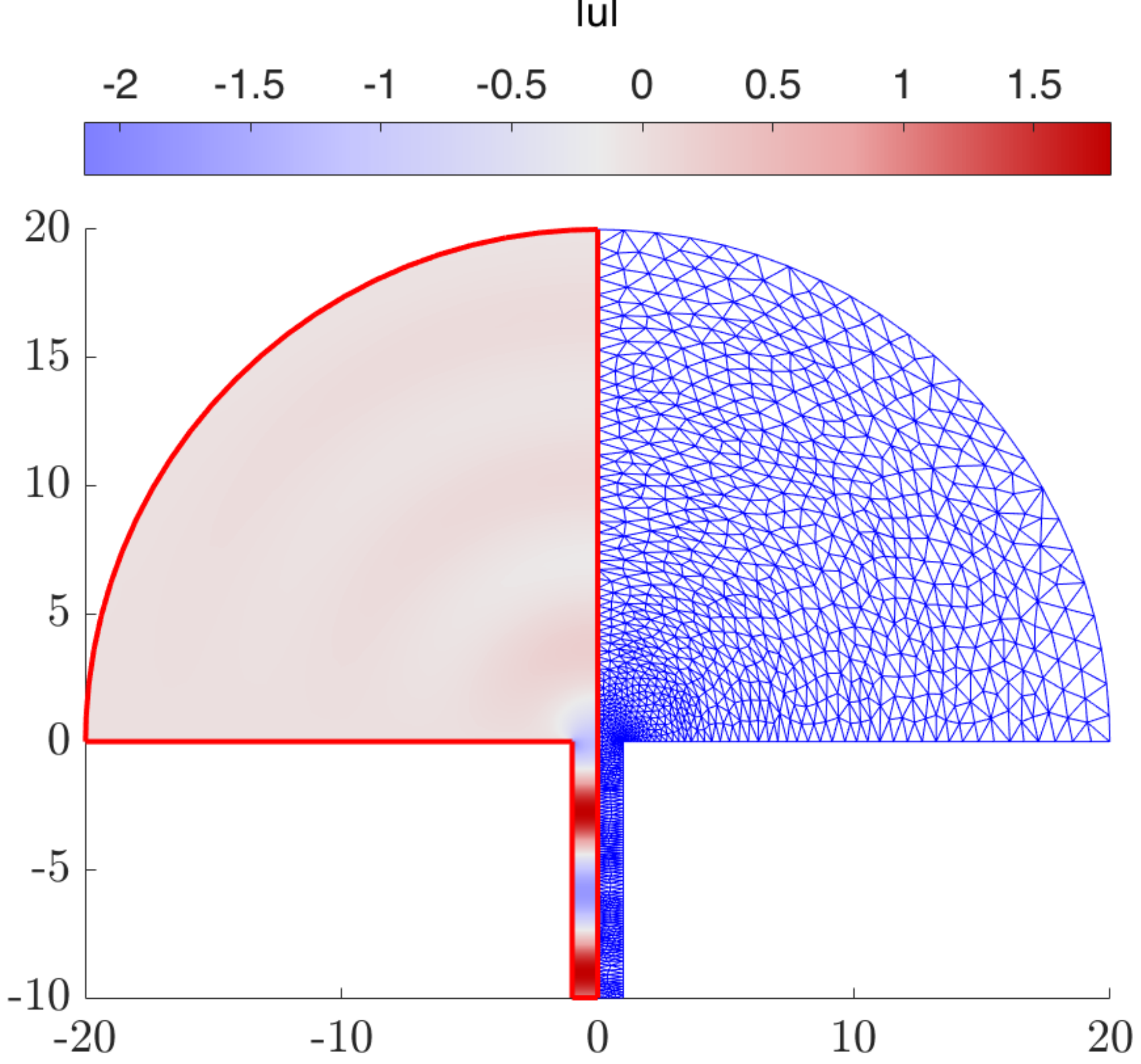
plot the structure

```
figure();
SF_Plot(Forced,'u','boundary','on','colormap','redblue','cbtitle','|u''|');
hold on;
SF_Plot(Forced,'p','boundary','on','colormap','redblue','symmetry','YM','cbtitle','p''','colorbar','westoutside');
```



plot the structure along with the mesh

```
figure('DefaultAxesFontSize',18);
SF_Plot(Forced,'mesh');
hold on;SF_Plot(Forced,'u','mesh','off','boundary','on','colormap','redblue',...
                'colorbar','northoutside','cbtitle','|u|','symmetry','YM'); % symmetry = XM
 means mirror about X-axis
```

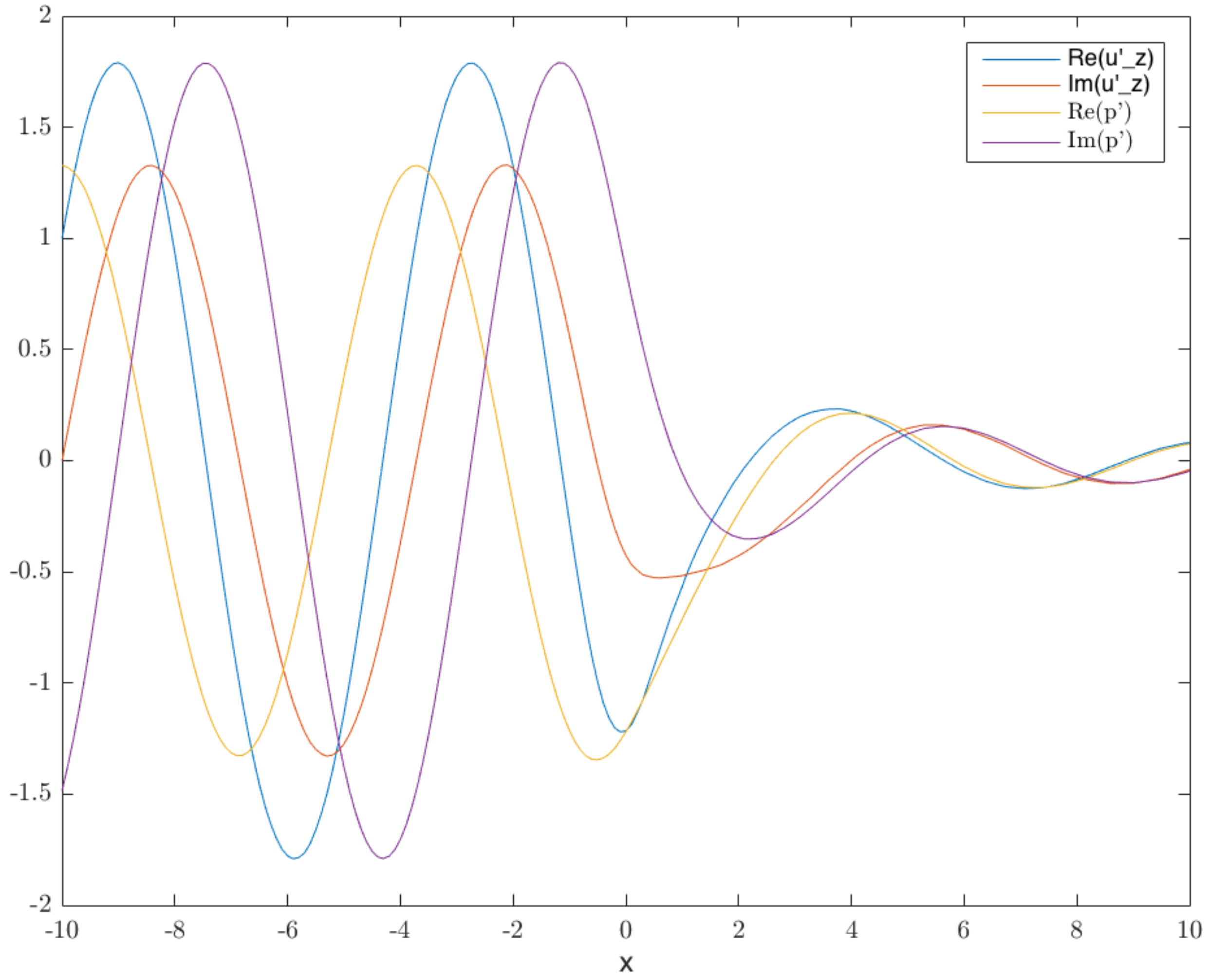


Extract p and u along the symmetry axis

```
Xaxis = [-10 :.1 :10];
Uyaxis = SF_ExtractData(Forced,'u',0,Xaxis);
Paxis = SF_ExtractData(Forced,'p',0,Xaxis);
```

plot p and u along the symmetry axis

```
figure();
plot(Xaxis,real(Uyaxis),Xaxis,imag(Uyaxis)); hold on;plot(Xaxis,real(Paxis),Xaxis,imag(Paxi
s));
xlabel('x');
legend('Re(u''_z)','Im(u''_z)','Re(p'')','Im(p'')');
pause(0.1);
```



Chapter 3 : loop over k to compute the impedance $Z(k)$ (using SOMMERFELD)

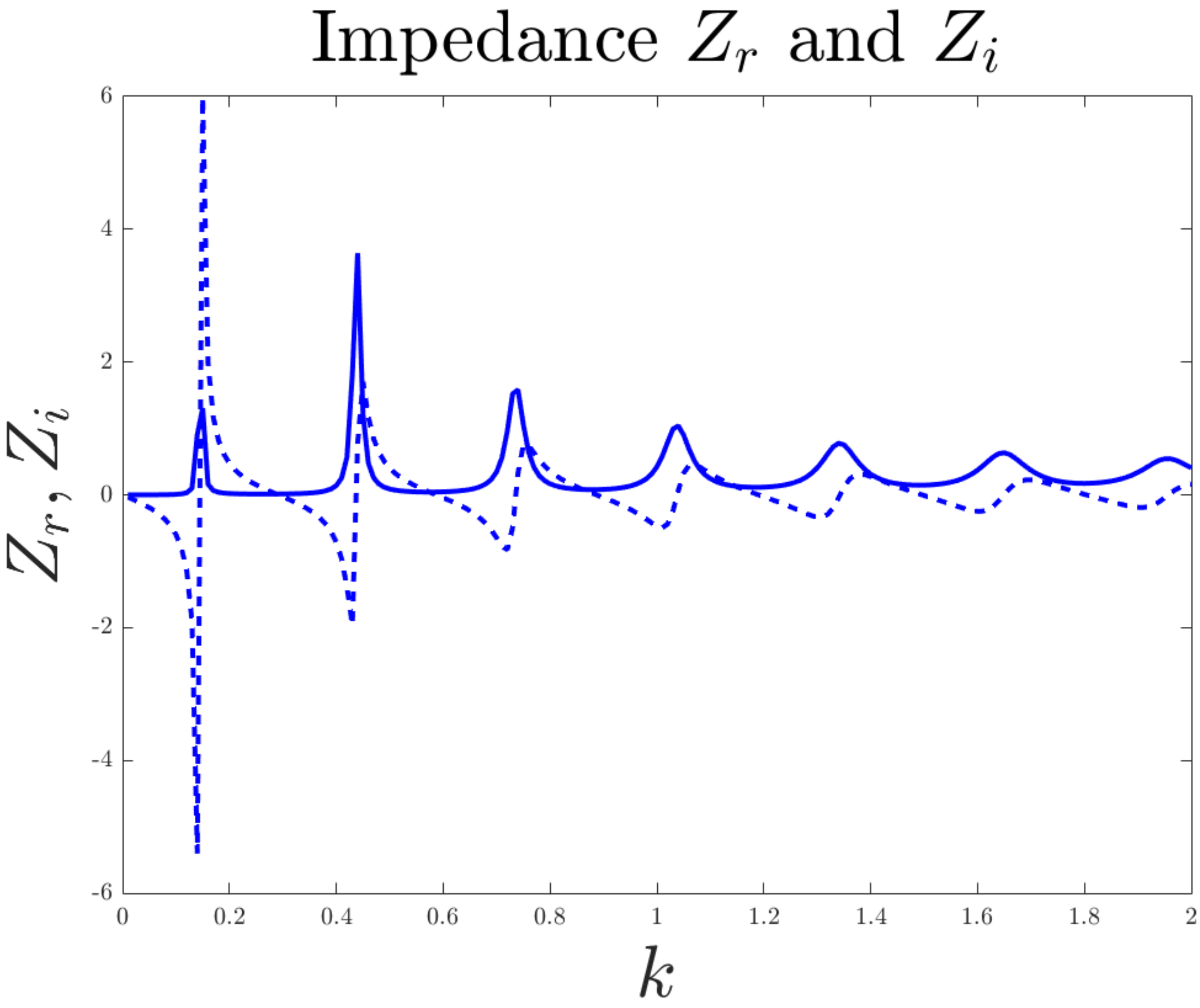
```
IMP = SF_LinearForced(ffmesh,[0.01:.01:2],'BC','SOMMERFELD','plot','no')
```

```
IMP = 

               mesh: [1x1 struct]
           filename: './WORK/Impedances_Re.txt'
    DataDescription: 'Impedance of a axisymmetric acoustic flow'
           datatype: 'ForcedLinear'
                ind: [200x1 double]
              omega: [200x1 double]
                  Z: [200x1 double]
                  R: [200x1 double]
```

Plot $Z(k)$

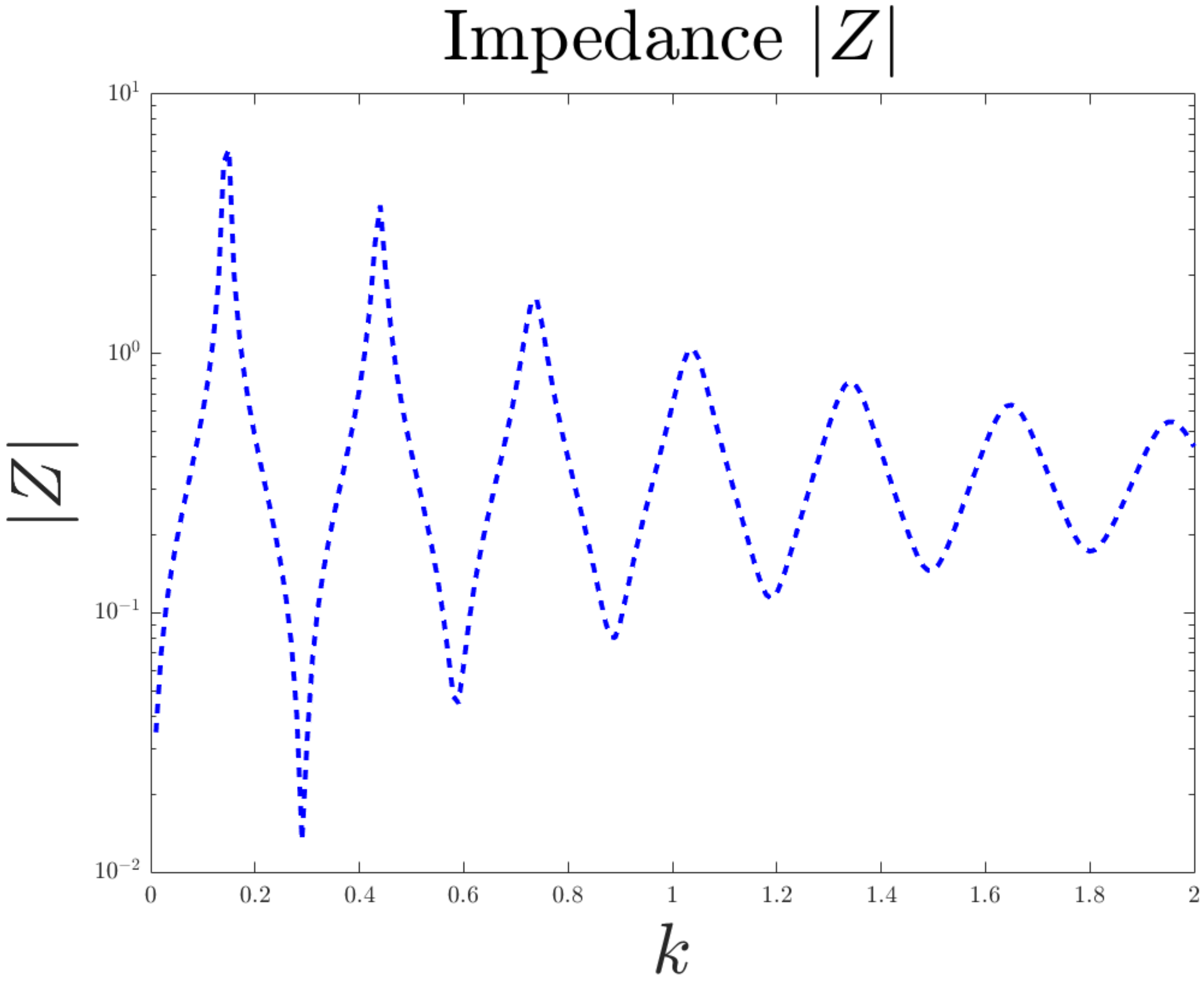
```
figure;
plot(IMP.omega,real(IMP.Z),'b',IMP.omega,imag(IMP.Z),'b--','DisplayName','Sommerfeld');
title(['Impedance $Z_r$ and $Z_i$'],'Interpreter','latex','FontSize', 30)
xlabel('$k$','Interpreter','latex','FontSize', 30);
ylabel('$Z_r,Z_i$','Interpreter','latex','FontSize', 30);
set(findall(gca, 'Type', 'Line'),'LineWidth',2);
pause(0.1);
```



plot in semilog

```
figure;
semilogy(IMP.omega,abs(IMP.Z),'b--','DisplayName','CM');
xlabel('b'); ylabel('|Z|');
xlabel('$k$','Interpreter','latex','FontSize', 30);
ylabel('$|Z|$','Interpreter','latex','FontSize', 30);
title(['Impedance $|Z|$'],'Interpreter','latex','FontSize', 30)
leg.FontSize = 20;
set(findall(gca, 'Type', 'Line'),'LineWidth',2);

pause(0.1);
```

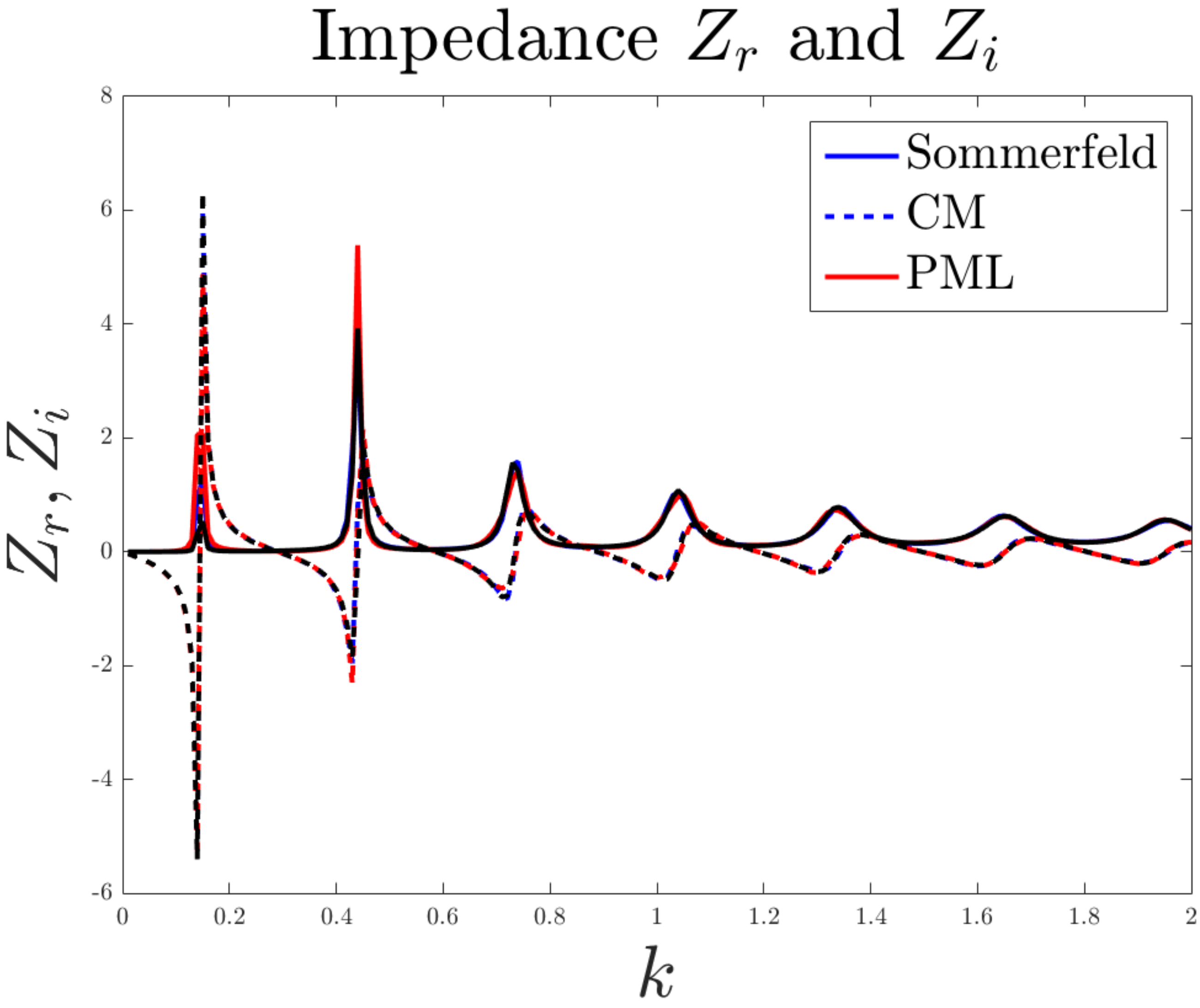


Chapter 4 : trying better kind of boundary conditions : PML, CM

```
IMPPML = SF_LinearForced(ffmesh,[0.01:.01:2],'BC','PML','plot','no');
IMPCM = SF_LinearForced(ffmesh,[0.01:.01:2],'BC','CM','plot','no');
IMP = SF_LinearForced(ffmesh,[0.01:.01:2],'BC','SOMMERFELD','plot','no');
```

trace de Z(k) parties reelles et imaginaires

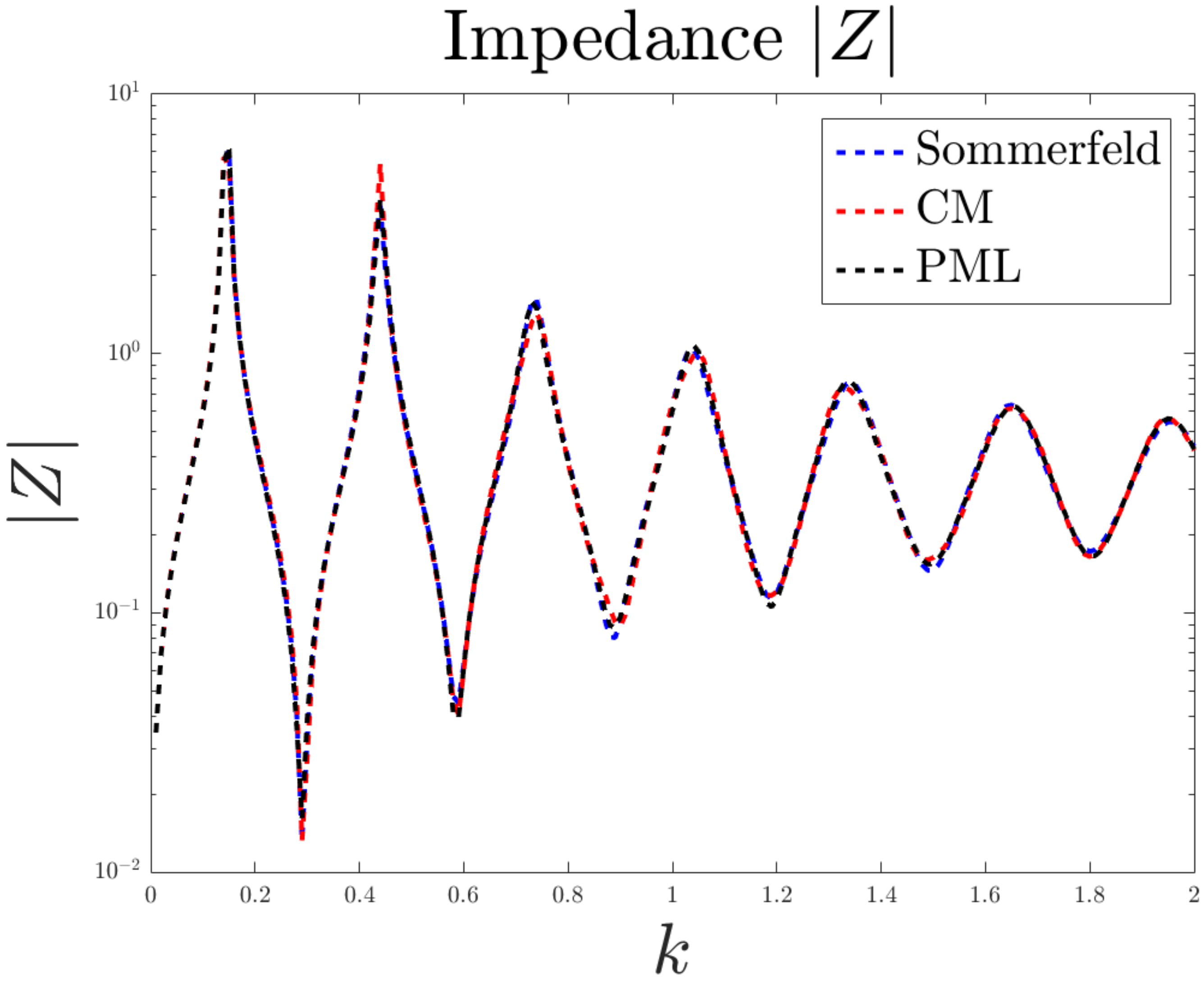
```
figure;
plot(IMP.omega,real(IMP.Z),'b',IMP.omega,imag(IMP.Z),'b--','DisplayName','Sommerfeld');
hold on;
plot(IMPCM.omega,real(IMPCM.Z),'r',IMPCM.omega,imag(IMPCM.Z),'r--','DisplayName','CM');
plot(IMPPML.omega,real(IMPPML.Z),'k',IMPPML.omega,imag(IMPPML.Z),'k--','DisplayName','PML')
;
title(['Impedance $Z_r$ and $Z_i$'],'Interpreter','latex','FontSize', 30)
xlabel('$k$','Interpreter','latex','FontSize', 30);
ylabel('$Z_r,Z_i$','Interpreter','latex','FontSize', 30);
leg=legend('Sommerfeld','CM','PML');
leg.FontSize = 20;
set(findall(gca, 'Type', 'Line'),'LineWidth',2);
pause(0.1);
```



trace de `Z(k)` en semilog

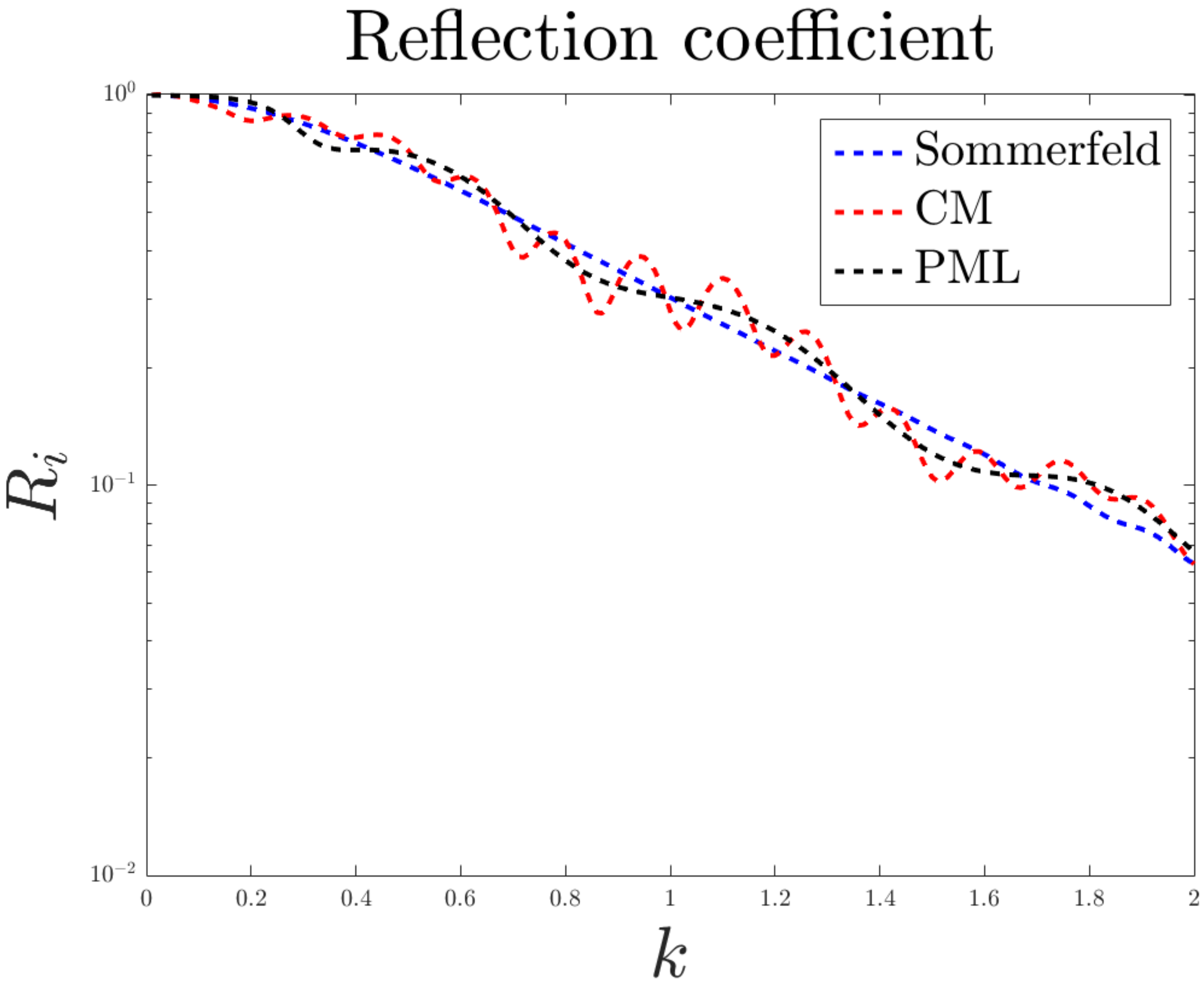
```
figure;
semilogy(IMP.omega,abs(IMP.Z),'b--','DisplayName','CM');
hold on;
semilogy(IMPCM.omega,abs(IMPCM.Z),'r--','DisplayName','CM');
semilogy(IMPPML.omega,abs(IMPPML.Z),'k--','DisplayName','CM');
xlabel('b'); ylabel('|Z|');
xlabel('$k$','Interpreter','latex','FontSize', 30);
ylabel('$|Z|$','Interpreter','latex','FontSize', 30);
title(['Impedance $|Z|$'],'Interpreter','latex','FontSize', 30)
leg=legend('Sommerfeld','CM','PML');
leg.FontSize = 20;
set(findall(gca, 'Type', 'Line'),'LineWidth',2);

pause(0.1);
```



plot reflection coefficient

```
figure;
semilogy(IMP.omega,IMP.R,'b--','DisplayName','Sommerfeld');
hold on;
semilogy(IMPCM.omega,IMPCM.R,'r--','DisplayName','CM');
semilogy(IMPPML.omega,IMPPML.R,'k--','DisplayName','PML');
xlabel('$k$','Interpreter','latex','FontSize', 30);
ylabel('$R_i$','Interpreter','latex','FontSize', 30);
title(['Reflection coefficient'],'Interpreter','latex','FontSize', 30)
leg = legend('Sommerfeld','CM','PML');
leg.FontSize = 20;
set(findall(gca, 'Type', 'Line'),'LineWidth',2);
%
% k = [0.01:0.01:2.0];
% Z0 = 1/(2*pi);
% R = 1;
% L = 10;
% ZL = Z0*(k.^2*R^2/4 + 1i*k*0.35*R);
% Zin = Z0*(ZL.*cos(k*L)+1i*Z0*sin(k*L))./(1i*ZL.*sin(k*L)+Z0*cos(k*L))
% plot(k,-real(Zin),'k',k, -imag(Zin), 'k--');
% hold on;
% plot(IMP.k,real(IMP.Z),'b',IMP.k,imag(IMP.Z),'b--','DisplayName','Sommerfeld');
%
% plot(k,real(Zin),'k',IMPPML.k,real(IMPPML.Z),'b');
% plot(k,-imag(Zin),'k',IMPCM.k,imag(IMPML.Z),'b');
```



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