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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Problem Setup %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all
close all

% Physical constants
eps0 = 8.8541878e-12;
mu0  = 4e-7 * pi;
c0   = 299792458;

% Cell size
h = 0.0025;

% Waveguide dimensions
Lx = 0.040;
Ly = 0.0225;
Lz = 0.160;

% Number of cells in each direction
Nx = round(Lx / h);
Ny = round(Ly / h);
Nz = round(Lz / h);

% Length of time steps
Dt = h / (c0 * sqrt(3)); % Courant condition?

% Insignal data
t_max = 16e-9;
Nt     = ceil(t_max / Dt);
t      = (1:Nt)' * Dt;

f_min = 4e9;
f_max = 7e9;
f_mid = (f_max + f_min) / 2;
BWr   = (f_max - f_mid) / f_mid;
f      = ((0:Nt-1)' - floor(Nt/2)) / Nt / Dt;
s      = gauspuls(t-0.2e-8, f_mid, BWr, -12);

% Allocate field matrices
Ex = zeros(Nx,      Ny + 1, Nz + 1);
Ey = zeros(Nx + 1, Ny,      Nz + 1);
Ez = zeros(Nx + 1, Ny + 1, Nz      );

Hx = zeros(Nx + 1, Ny,      Nz      );
Hy = zeros(Nx      , Ny + 1, Nz      );
Hz = zeros(Nx      , Ny,      Nz + 1);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Initiation of boundary conditions %

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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
disp(sprintf('Initiate boundary conditions...'))
NumModesTE = 7; % 01 10 11 20 21 30 31
NumModesTM = 3; % 11 21 31
NumModes    = NumModesTE + NumModesTM;

disp(sprintf('  Compute TE modes'))
[ExTE, EyTE, K2TE] = ComputeTEModes(NumModesTE, Nx, Ny, h, h);
disp(sprintf('  Compute TM modes'))
[ExTM, EyTM, K2TM] = ComputeTMModes(NumModesTM, Nx, Ny, h, h);

ModaleX = [ExTE ExTM];
ModaleY = [EyTE EyTM];
ModaleK2 = [K2TE K2TM];
ModalNm = sum(ModaleX.^2) + sum(ModaleY.^2); % Normalizing constants

clear ExTE EyTE ExTM EyTM

% Compute Impulse response for the propagating mode
IR    = zeros(Nt, NumModes); % Impulse response
s1R   = zeros(Nt, NumModes); % Reflected signal at z = Dz
s1    = zeros(Nt, NumModes); % Total signal at z = 0
s2T   = zeros(Nt, NumModes); % Transmitted signal at z = Lz - Dz
s2    = zeros(Nt, NumModes); % Total signal at z = Lz

for k = 1:NumModes
    disp(sprintf('  Computing Impulse response for Mode %d', k))
    IR(:,k) = ComputeIR(Dt, h, Nt, ModaleK2(k));
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Main Loop. %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
disp(sprintf('Start time stepping...'))
% Set initial source boundary conditions
sEy = Ey(2:Nx, :, 2);
sEx = Ex(:, 2:Ny, 2);
sEy(:) = s(1) * ModaleY(:,1);
sEx(:) = s(1) * ModaleX(:,1);
Ey(2:Nx, :, 1) = sEy;
Ex(:, 2:Ny, 1) = sEx;
s1(1,1) = s(1);

CH = Dt / (h * mu0);
CE = Dt / (h * eps0);

ks = 400;
for k = 2:Nt

    % if k > 250 & k < 600
    %     figure(99)
    %     mesh(0:Nz, 0:Nx, squeeze(0.5*Ey(:,6,:))), axis equal, axis([0 Nz 0 Nx
-6 6])
    %     caxis([-6 6]), view(145,30)

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% b = 6cm , a = w = 4cm, d = 3cm

a = 4e-2; b = 6e-2; d = 3e-2; w = a;

x_grid = linspace(0, Lx, Nx+1);
y_grid = linspace(0, Ly, Ny+1);
z_grid = linspace(0, Lz, Nz+1);
% Indices that correspond to PEC boundary, including boundary wall
x_narrow = [find(x_grid <= (Lx-d)/2), find(x_grid >= w-(Lx-d)/2)];
z_narrow = find(z_grid >= b & z_grid <= a+b);

% Apply metal boundary conditions by setting E-components to zero

% Surfaces inwards towards middle
for x = [find(x_grid == 5e-3), find(x_grid == 35e-3) ]
    Ez(x, :, z_narrow) = 0;
    Ey(x, :, z_narrow) = 0;
end

% Surfaces outwards towards each port
for z = [find(z_grid == b), find(z_grid == b+a)]
    Ex([1,2,end-1,end], :, z) = 0;
    Ey([1,2,end-1,end], :, z) = 0;
end

%
% plot3([find(z_grid == b),find(z_grid == b)], [0, Nx], [0,0], "k")

%
%
%
%
% -----
% |
% -----
%
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%
%=====
% Boundary Conditions at Z = 0 %
%=====

% Extract transverse fields at z = dz %
sEy = Ey(2:Nx, :, 2);
sEx = Ex(:, 2:Ny, 2);

% Compute modal voltages %
s1R(k,:) = (sEy(:)' * ModalEy + sEx(:)' * ModalEx) ./ ModalNm;

% The reflected modal amplitude at z = Dz is the difference between the
% total modal amplitude and that of the incoming wave. The amplitude of
% the incoming wave at z = Dz is a convolution of the insignal at z = 0
% and the impulse response of the wave guide.

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s1R(k,1) = s1R(k,1) - s(1:k-1)' * IR(k-1:-1:1,1);

% Port Amplitude: sum of insignal and convolution of the reflected
% signal at z = Dz with the impulse response
for l = 1:NumModes
    s1(k,1) = s1R(1:k-1, 1)' * IR(k-1:-1:1, 1);
end
s1(k,1) = s1(k,1) + s(k);

% Set port 1 boundary conditions %
sEy(:) = ModalEy * s1(k,:)' ;
sEx(:) = ModalEx * s1(k,:)' ;
Ey(2:Nx,:,1) = sEy;
Ex(:,2:Ny,1) = sEx;

%=====
% Boundary Conditions at Z = Lz %
%=====

% Extract transverse fields at z = Lz - Dz %
sEy = Ey(2:Nx, :, Nz);
sEx = Ex(:, 2:Ny, Nz);

% Compute modal voltage at z = Dz
s2T(k,:) = (sEy(:)' * ModalEy + sEx(:)' * ModalEx) ./ ModalNm;

% Port Amplitude
for l = 1:NumModes
    s2(k,1) = s2T(1:k-1, 1)' * IR(k-1:-1:1, 1);
end

% Set port 2 boundary conditions %
sEy(:) = ModalEy * s2(k,:)' ;
sEx(:) = ModalEx * s2(k,:)' ;
Ey(2:Nx,:,Nz+1) = sEy;
Ex(:,2:Ny,Nz+1) = sEx;

if(mod(k,100) == 0)
    disp(sprintf('  step %5d of %5d', k, Nt))
end

end;

% remove the incoming sigland from the total signal at port 1.
s1(:,1) = s1(:,1) - s;

% -----
% | ADD SCATTERING PARAMETERS AS FUNCTION OF FREQUENCY |

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% -----
%
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%
%

f_of_interest = find(f>3e9 & f<7e9);

S11 = (S1./S);
S21 = (S2./S);
S21_phase = (S2_phase - S_phase);
S11_phase = S1_phase - S_phase;

%
%
%
%
% -----
% |
% -----

% timevec = 1:Nt
function [f, mag, phase] = myfft(Dt, signal, timevec)
    Fs = 1/Dt;
    L = length(signal); % same as for s2
    ts = timevec; % time vector
    Y = fft(signal);
    P2 = abs(Y/L);
    P1 = P2(1:L/2+1);
    P1(2:end-1) = 2*P1(2:end-1);
    f = Fs/L*(0:L/2);

    mag = P1;
    phase = angle(Y);

end

Initiate boundary conditions...
    Compute TE modes
    Compute TM modes
    Computing Impulse response for Mode 1
    Computing Impulse response for Mode 2
    Computing Impulse response for Mode 3
    Computing Impulse response for Mode 4
    Computing Impulse response for Mode 5
    Computing Impulse response for Mode 6
    Computing Impulse response for Mode 7
    Computing Impulse response for Mode 8

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Computing Impulse response for Mode 9
Computing Impulse response for Mode 10
Start time stepping...
step 100 of 3324
step 200 of 3324
step 300 of 3324
step 400 of 3324
step 500 of 3324
step 600 of 3324
step 700 of 3324
step 800 of 3324
step 900 of 3324
step 1000 of 3324
step 1100 of 3324
step 1200 of 3324
step 1300 of 3324
step 1400 of 3324
step 1500 of 3324
step 1600 of 3324
step 1700 of 3324
step 1800 of 3324
step 1900 of 3324
step 2000 of 3324
step 2100 of 3324
step 2200 of 3324
step 2300 of 3324
step 2400 of 3324
step 2500 of 3324
step 2600 of 3324
step 2700 of 3324
step 2800 of 3324
step 2900 of 3324
step 3000 of 3324
step 3100 of 3324
step 3200 of 3324
step 3300 of 3324
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Unrecognized function or variable 'S1'.
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Error in opt1 (line 274)
S11 = (S1./S);
      ^^
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