Electromagnetism and the Yee Algorithm (PHY5017 Fall 2022)

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This code is built-on and modified from research work that J. Evans did in the Fall of 2020.

Version Comments

<u>Propogation:</u>

This is the same propogation code as Yee_v10, except that the gaussian is fed in as a pulse over time as defined in part 3 of the project. This version propogates the wave in the same manner as v10 did, but the wave is made up of a superpostion of waves caused by the pulse.

<u>Reflection:</u>

The left boundary gives a bounce back with noise. The right boundary gives a more exotic combination of a bounce back and reflection that is really quite beautiful. I believe the difference between the two sides has to do with the fact that we have different boundaries on the left and right. On the left, we hold E(0) = 0 & H(0) = 0. However, on the right, we sometimes hold two zeros for the last two values of E and H, but not always. This was for utility to make the code work. However, the calculations obviously get messed up in exotic ways at these boundaries. Also, there is a secondary reflection at L/4 because of the Guassian function that overwrites the value at that point.

Admin

```
clearvars
sympref('FloatingPointOutput',true);
```

Section 1: Define Constants and Courant Number

Given Constants

```
e0 = 8.86e-12; %permittivity of free space (F/m)

mu0 = 4e-7 .* pi; % permeability of free space (H/m)

er = 1; %permittivity in medium (set to 1 for free space)

mur = 1; %permeability in medium (set to 1 for free space)

e = er .* e0; % e = epsilon (Units F/m)

mu = mur .* mu0; % (Units: H/m)

c = 1./(sqrt(e0*mu0));
```

Set Courant number (S)

Set $S = \frac{c\Delta t}{\Delta z}$

Then $\Delta t = S\frac{\Delta z}{c}$

```
S = 1; %Courant Number of 1/2 corresponds to the magic time step

c = 3e8; % speed of light in (meters / second)

dz = 5e-3; %space increment in meters as defined in the project part 3 parameters

dt = S .* (dz./c) ;
```

Section 2: Set up the Wave

Gaussian Pulse in Time "Wave Packet"

```
sigma = 8 .* dt;  %as defined in Project Part 3

ts = 20 .* dt;

E0 = 1;

Es = @(t) E0 .* exp(-((t-ts)^2)./(sigma^2));

Z=(dz/2):(dz):1    %for plotting and video purposes
```

```
Z = 1×200
    0.0025    0.0075    0.0125    0.0175    0.0225    0.0275    0.0325    0.0375 ···
```

Create Matrices to hold wave values

```
L = 1./dz;                %Number of Space Positions so that z(L) = 1

Tmax = 6 .* sigma;
T = Tmax ./ dt;            %Number of Time Steps so that over 99% of the Guassian pulse is compl

%Matrices to hold E and H values will be row vectors of length 2L, so that
```

```
%each position represents a half step.

E = zeros(1,L);          %Matrix of electric field values in space (@ t)
Ein = zeros(1,L);        %Temporary Placeholder for the E value input for each space step
Eout = zeros(1,L);       %Temproary placeholder for the E value output for each space step

H = zeros (1,L-1);         %Matrix of magnetic field values in space (@ t)
Hin = zeros(1,L-1);        %Temporary placeholder for the H value input for each space step
Hout = zeros (1,L-1);      %Temporary placeholder for the H value output for each space step

zs = L./4;                  %Define the space point of the Gaussian pulse
```

Guassian in Space

This is a Guassian in space for the E field, which can be introduced in lieu of a Guassian pulse in time for testing purposes

```
%   a = 1;     %height
%   b = 1/4;    %center
%   d = 8*dz;    %width
%   f=@(x)a*exp(-((x-b).^2)/(d^2));
%   E(:)=f(Z);
%
```

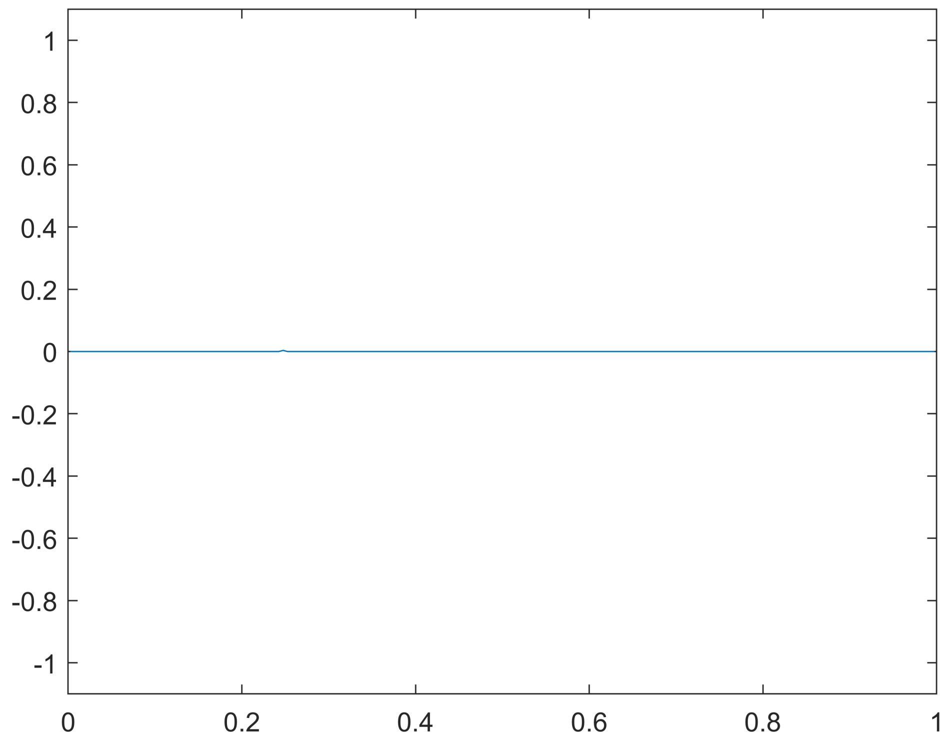
Square Wave in Space

This is a Square wave in space for the E field, which can be introduced in lieu of a Gaussian pulse in time for testing purposes

```
% E(50:150)=1;
```

Section 3: Setup Video

```
v=VideoWriter("Wave4","MPEG-4");
open(v)
plot(Z,E(:))
xlim([0 1]);
ylim([-1.1 1.1]);
Ylabel="Amplitude";
Xlabel="z";
axis manual
set(gca,"nextplot","replacechildren")
frame=getframe(gcf);
```



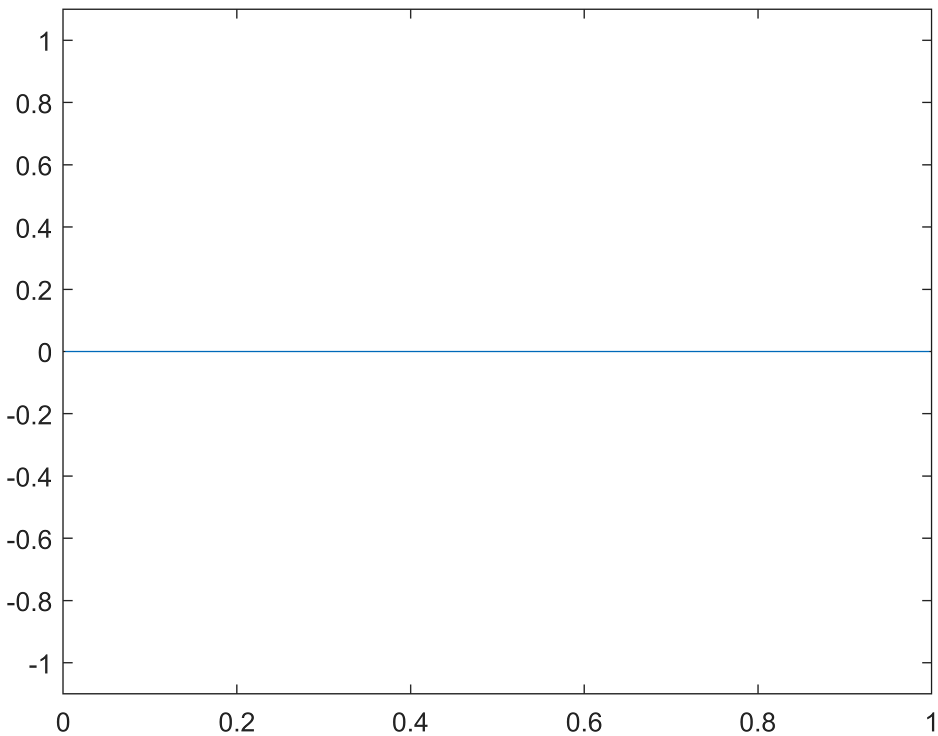

```
writeVideo(v,frame)
```

Section 5: Absorbing Boundary Conditions

This is an implementation of Part 4.6

```
for t=1:8*T                              %Iterate for T total time steps
    L = round(L);

%%%%%%%%%%%%%%%%%%%%% Calculate the E Field %%%%%%%%%%%%%%%%%%

    E2_old = E(2);                                % ABCs
    EM1_old = E(L-1);

    for k=2:(L-1)
        Hout(k) = H(k);
        Hin(k)= H(k-1);
    end

    for k=2:(L-1)
        E(k) =  E(k) - ( S ./ er )  .* ( Hout(k) - Hin(k) );    %calculate E
    end
```

```
    E2_new = E(2);                                  % ABCs
    E(1) = E2_old + (S - sqrt(er*mur)) ./ (S + sqrt(er*mur)) .* (E2_new - E(1));
    EM1_new = E(L-1);
    E(L) = EM1_old + (S - sqrt(er*mur)) ./ (S + sqrt(er*mur)) .* (EM1_new - E(L));

%%%%%%%%%%%%%%%%%%% Introduce next E pulse Value %%%%%%%%%%%%%%%%%%


    E(zs) = Es(t*dt); %Calculate the next value of the pulse at z = zs



%%%%%%%%%%%%%%%%%% Calculate H Field %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

    for k=1:(L-1)
        Eout(k) = E(k+1);
        Ein(k) = E(k);                % these values are populated with E @ t+(1/2)
    end

    for k=1:(L-1)
        H(k) = H(k) - (S ./ mur ) .* ( Eout(k) - Ein(k) );   %calculate H
    end

%%%%%%%%%%%%%%%%% Plot and Write frame to video %%%%%%%%%%%%%%%%%%%%

    plot(Z,E(:));
    frame=getframe(gcf);
    pause(0.5)
    writeVideo(v,frame)

end
```




```
close(v)
```