Team Remix Project

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Yee Algorithm

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

Version Comments

Propagation:

This is the same propagation 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 propagates the wave in the same manner as v10 did, but the wave is made up of a superpostion of waves caused by the pulse.

Reflection:

The left boundary gives a bounce back, with positive amplitude. The wave on the left side then propagates forward and reflects (with negative amplitude) off of the Gaussian pulse boundary at L/4. The right boundary gives a reflection (negative amplitude) at the same time that the left boundary gives another bounce back. We 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. Finally, there is a secondary reflection at L/4 because of the Gaussian 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 = 0.5; %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/2):1;    %for plotting and video purposes
```

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 complete

%Matrices to hold E and H values will be row vectors of length 2L, so that
%each position represents a half step.

E = zeros(1,2.*L);          %Matrix of electric field values in space (@ t)
Ein = zeros(1,2.*L);        %Temporary Placeholder for the E value input for each space step
Eout = zeros(1,2.*L);       %Temproary placeholder for the E value output for each space step

H = zeros (1,2.*L);         %Matrix of magnetic field values in space (@ t)
Hin = zeros(1,2.*L);        %Temporary placeholder for the H value input for each space step
Hout = zeros (1,2.*L);      %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

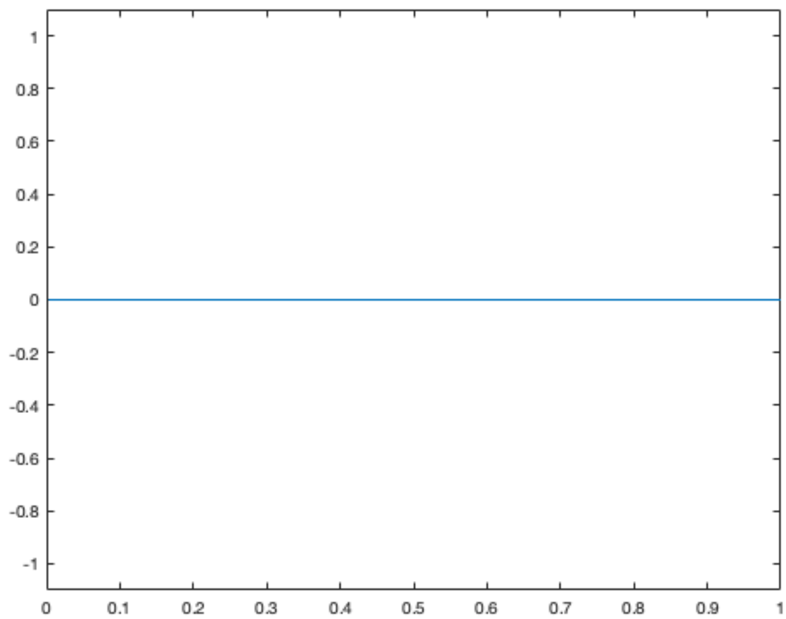
This is a Square wave in space for the E field, which can be introduced in lieu of a Gaussian pulse in time for testing purposes

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

Section 3: Setup Video

```
v=VideoWriter("Wave","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 4: Time-step the wave using the Yee Algorithm

This is an implementation of the equations in Part 2.6

```
for t=1:8*T                               %Iterate for T total time steps


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

%     E(1) = H(2);                            % ABCs
%     E(S) = H(S);

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

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

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


    E(2*zs) = Es(t*dt); %Calculate the next value of the pulse at z = zs



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

```
%     H(1) = E(1);                          % ABCs
%     H(S) = E(S-1);

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

    end

    for k=2:(2*L-1)

        H(k+1) = H(k+1) - (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)
```