W8\_THz simulation

Name: Mohammed AL Shuaili

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Using the following parameters:

## Plotting THz transmission line using the following parameter:

### The input is a sinewave with frequency of 0.1 THz.

A graph with a line

AI-generated content may be incorrect.

Figure 1 : shows the response using the exact solution.

clear

clc

R = 1200; % Resistance per unit length (Ω/m)

L = 250e-9; % Inductance per unit length (H/m)

C = 1e-10; % Capacitance per unit length (F/m)

Rs = 10;

G = 0;

l = 150e-6; % Length of the transmission line

f\_max = 100e9; % Maximum frequency (100 GHz)

w = 2\*pi\*f\_max;

s = 1i\*w;

vs\_sine = @(s) w./(s.^2 + w^2);% Laplace transform of sin(wt)

% Transfer function (exact solution)

vo = @(s) 1 ./ (cosh(l .\* sqrt((R + L.\*s) .\* (G + C.\*s))));

vo\_sine = @(s) vs\_sine(s).\*vo(s);

time =10e-12;

[y\_sine,t] = niltcv(vo\_sine,time);

% Plot the frequency response

plot(t, y\_sine)

xlabel('time (s)');

ylabel('Vo');

grid on;

## RLC,

Unit step response.

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Figure 2 illustrates the output of the transmission line (TL) using the RLC ladder method with a unit step input.

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Figure 3 :shows the output of the transmission line (TL) using the RLC ladder method with a unit step input and R\_s = 10.

## The response due to sinewave with frequency of 0.1 THz.

A graph with a line

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Figure 4 :presents the output of the transmission line (TL) using the RLC ladder method with a sinusoidal input at a frequency of 0.1 THz.

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Figure 5:shows the response of the transmission line (TL) using the RLC ladder method with a sinusoidal input at a frequency of 0.1 THz and R\_s = 10.

### The input is a pulse with a rise time from 0 to 1V of 1ps and the same fall time and it stays at 1V for 5ps using trapezoidal pulse.

A trapezoidal pulse that:

* Rises linearly from 0 V to 1 V over 1 ps,
* Stays at 1 V for 5 ps,
* Falls back to 0 V over 1 ps,  
  can be built from ramps and exponentials in the Laplace domain.

Time‐Domain Definition

Total duration: 7 ps = 1 ps (rise) + 5 ps (high) + 1 ps (fall).

a function is coded in MATLAB below to implement this pulse.

A graph with blue lines

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Figure 6: illustrates the output of the transmission line (TL) using the RLC ladder method with a trapezoidal pulse input.

A graph with blue lines

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Figure 7: illustrates the output of the transmission line (TL) using the RLC ladder method with a trapezoidal pulse input and R\_s=10.

function v = trapezoidalPulse(t)

% Define pulse parameters

T\_r = 1e-12; % Rise time (1 ps)

T\_p = 5e-12; % High-level duration (5 ps)

T\_total = 2\*T\_r + T\_p; % Total pulse duration (7 ps)

% Piecewise definition of the pulse

if t < 0

v = 0;

elseif t < T\_r

% Linear rise: from 0 to 1 V over T\_r

v = t / T\_r;

elseif t < T\_r + T\_p

% Constant high level at 1 V

v = 1;

elseif t < T\_total

% Linear fall: from 1 V back to 0 over T\_r

v = (T\_total - t) / T\_r;

else

v = 0;

end

end

%RLC input as pulse

clear

clc

len=150e-6;

N = 200; % Number of sections in the transmission line

dz=len/N;

L = 250e-9\*dz; % Inductance

C = 1e-10\*dz; % Capacitance

R = 1200\*dz; % Resistance per section

Rs = 0; % Source resistance

vs\_pulse = @(t) trapezoidalPulse(t);

y0 = zeros(2 \* N, 1);

tspan = linspace(0,10e-12,10e4);

% Solve using ode45

[t, y\_pulse] = ode45(@(t, y) fline\_noR(t, y, N, L, C, R, Rs, vs\_pulse), tspan, y0);

% Plot voltage at the end of the transmission line (VN)

figure(1);

plot(t, y\_pulse(:,N\*2));

xlabel('Time (s)');

ylabel('Voltage (V)');

title('RLC with Trapezoidal Pulse input');

grid on

## FDTD

In the FDTD model, resistance R is not included. To compare it with the exact solution and the RLC method, the model must be adapted to account for R= 1200. Previously, in the original code, we performed the following steps: Given , we calculated the lumped inductance (L) and capacitance (C) elements using the following approach.

(1)

where, is the speed of propagation so,

(2)

How to include R, compute as in the exact solution using the given values for R, L and C:

We find with the provided R, L, and C values. Since the lumped elements L and C in the model are purely a means to replicate the behaviour of a transmission line, recalculating them based on the adjusted will generate new values that effectively account for the resistance R.

## FDTD improvised with 100 sections.

Unit step response

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Figure 8 : shows the unit step response using FDTD and 1000000-time steps.

With 10000000 time steps and 100 sections

A graph of a graph showing a number of blue lines

AI-generated content may be incorrect.

Figure 9: shows the unit step response with 10^7-time steps and 100 sections

## The response due to sinewave with frequency of 0.1 THz.

A graph showing a line

AI-generated content may be incorrect.

Figure 10: the response due to sinewave at 0.1 THz and 100 segments .

clear

clc

L\_total = 150e-6; % Total length of the line (m)

R = 1200;

l = 250e-9;

c = 1e-10;

Zc = sqrt((R+l)/(c)); % Characteristic impedance (Ohms)

v = 2e8; % Speed of propagation (m/s)

% Compute inductance and capacitance

C = 1 / (v \* Zc);

L = Zc/v;

NDZ = 100; % Number of spatial steps

dz = L\_total / NDZ; % Spatial step delta z

dt = 1e-17; % Time step delta t

t\_max = 10e-12;

t\_steps = round(t\_max / dt); % Number of time steps

% allocate voltage and current arrays

V = zeros(NDZ+1, t\_steps);

time = (0:t\_steps-1)\*dt;

Vs = sin(2\*pi\*100e9.\*time);

V(1,:)=Vs.\*ones(1,t\_steps);

I = zeros(NDZ, t\_steps);

% FDTD Loop for Time Stepping

for n = 1:t\_steps-1

%V(1,n+1) = V(1,n);

V(1, n+1) = sin(2\*pi\*100e9 \* time(n+1));

for k = 1:NDZ

if k>1

V(k,n+1) = V(k,n) + dt/(dz \*C)\* (I(k-1,n) - I(k,n)); % Update voltag

dV\_k = V(k-1,n) - V(k,n); % Voltage difference between points

I(k-1,n+1) = I(k-1,n) + dt/(dz \*L) \* dV\_k;

end

end

V(NDZ,n+1) =V(NDZ,n)+dt\*(I(NDZ-1,n)/(C\*dz));

end

y\_FDTD = V(NDZ,:);

% Plot the results for the voltage at the load

figure(1)

plot((0:t\_steps-1)\*dt/1e-12, V(NDZ,:));

xlabel('Time (ps)');

ylabel('V Load (Volts)');

%title('FDTD Simulation of Transmission Line with unit step input');

title('FDTD Simulation of Transmission Line with 100 GHz Sine Wave Input');

grid on;

## The input is a pulse with a rise time from 0 to 1V of 1ps and the same fall time and it stays at 1V for 5ps using trapezoidal pulse (using the same function that was coded for the RLC method)

A graph of a graph

AI-generated content may be incorrect.

Figure 11: illustrates FDTD simulation of a TL with a pulse input using 100 sections and 10^6 time steps.

clear

clc

L\_total = 150e-6; % Total length of the line (m)

R = 1200;

l = 250e-9;

c = 1e-10;

Zc = sqrt((R+l)/(c)); % Characteristic impedance (Ohms)

v = 2e8; % Speed of propagation (m/s)

% Compute inductance and capacitance

C = 1 / (v \* Zc);

L = Zc/v;

NDZ = 100; % Number of spatial steps

dz = L\_total / NDZ; % Spatial step delta z

dt = 1e-17; % Time step delta t

t\_max = 10e-12;

t\_steps = round(t\_max / dt); % Number of time steps

% allocate voltage and current arrays

V = zeros(NDZ+1, t\_steps);

time = (0:t\_steps-1)\*dt;

%Vs = sin(2\*pi\*100e9.\*time);

%Vs = 1;

%V(1,:)=Vs.\*ones(1,t\_steps);

V(1,1) = trapezoidalPulse(time(1));

I = zeros(NDZ, t\_steps);

% FDTD Loop for Time Stepping

for n = 1:t\_steps-1

%V(1,n+1) = V(1,n);

%V(1, n+1) = sin(2\*pi\*100e9 \* time(n+1));

V(1,n+1) = trapezoidalPulse(time(n+1));

for k = 1:NDZ

if k>1

V(k,n+1) = V(k,n) + dt/(dz \*C)\* (I(k-1,n) - I(k,n)); % Update voltag

dV\_k = V(k-1,n) - V(k,n); % Voltage difference between points

I(k-1,n+1) = I(k-1,n) + dt/(dz \*L) \* dV\_k;

end

end

V(NDZ,n+1) =V(NDZ,n)+dt\*(I(NDZ-1,n)/(C\*dz));

end

y\_FDTD = V(NDZ,:);

% Plot the results for the voltage at the load

figure(1)

plot((0:t\_steps-1)\*dt/1e-12, V(NDZ,:));

xlabel('Time (ps)');

ylabel('V Load (Volts)');

%title('FDTD Simulation of Transmission Line with unit step input');

%title('FDTD Simulation of Transmission Line with 100 GHz Sine Wave Input');

title('FDTD Simulation of Transmission Line with Trapezoidal Pulse Input');

grid on;