

W8_THz simulation

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Using the following parameters:

Plotting THz transmission line using the following parameter:

$$C = 1 \times 10^{-10} F, \quad L = 250 \times 10^{-9} H, \quad R = 1200 \text{ ohms}, \quad l = 150 \times 10^{-6} m$$

The input is a sinewave with frequency of 0.1 THz.

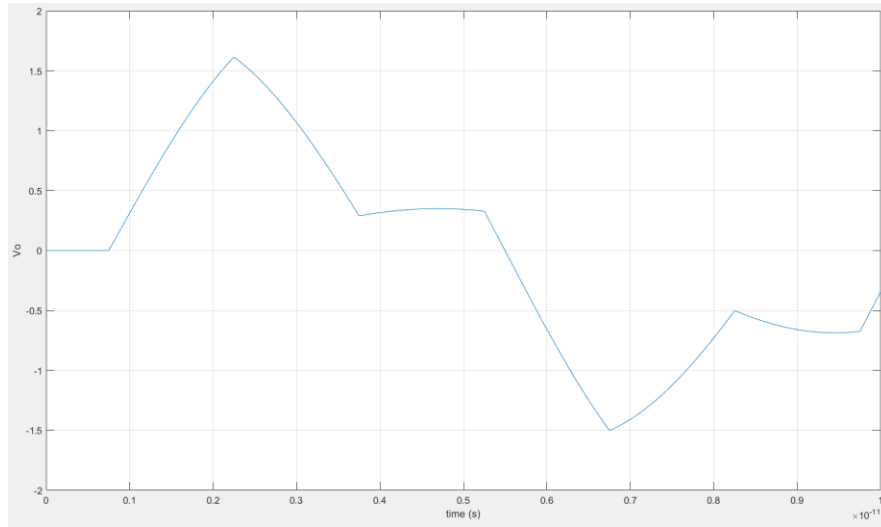


Figure 1 : shows the response using the exact solution.

```
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.

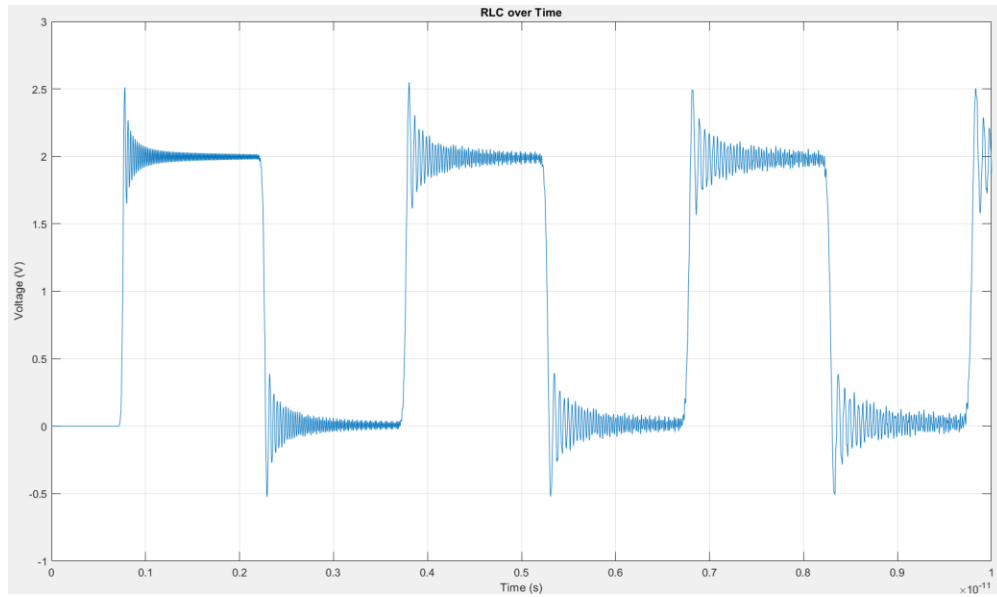


Figure 2 illustrates the output of the transmission line (TL) using the RLC ladder method with a unit step input.

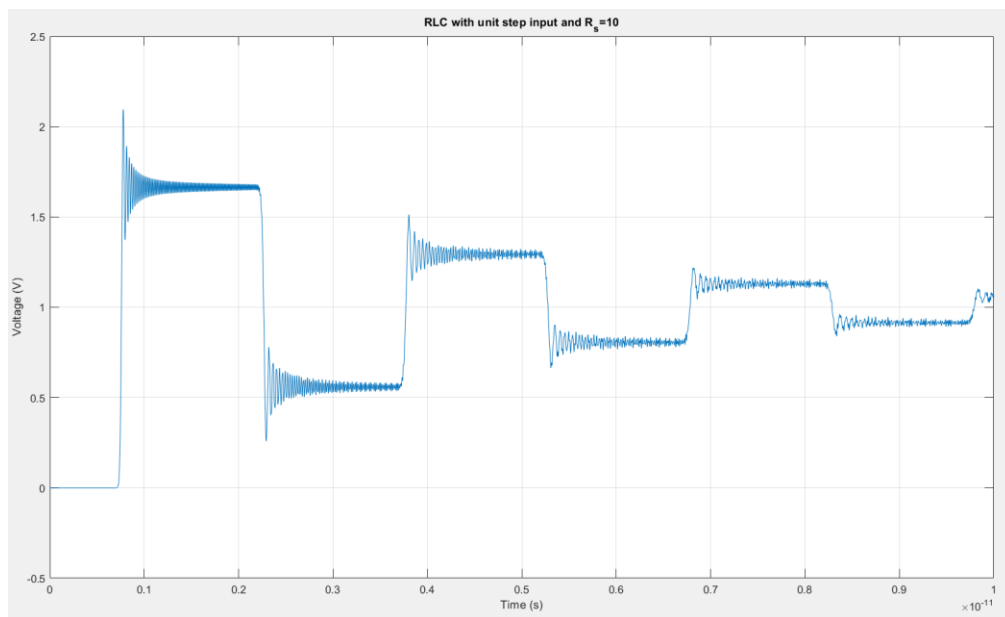


Figure 3 :shows the output of the transmission line (TL) using the RLC ladder method with a unit step input and $R_s = 10$.

The response due to sinewave with frequency of 0.1 THz.

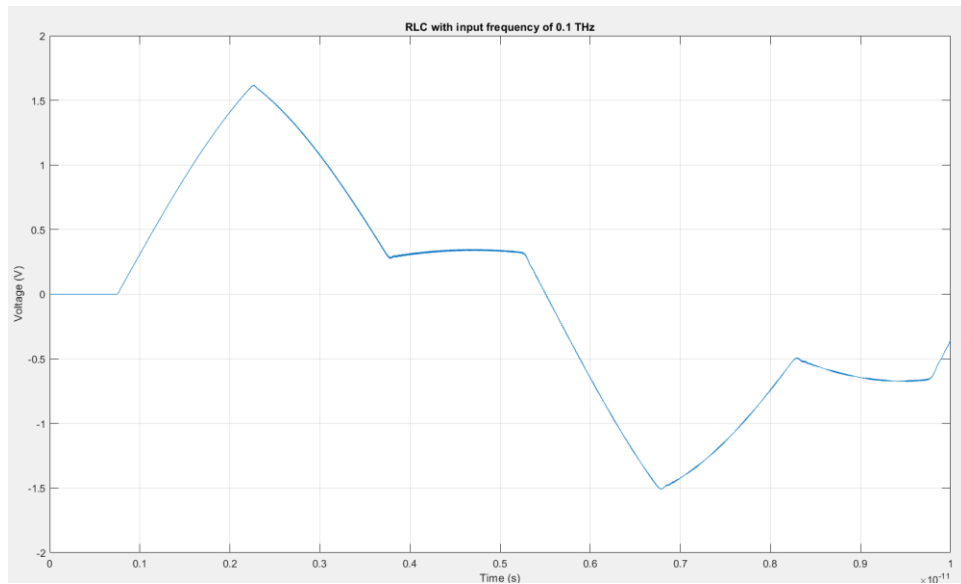


Figure 4 :presents the output of the transmission line (TL) using the RLC ladder method with a sinusoidal input at a frequency of 0.1 THz.

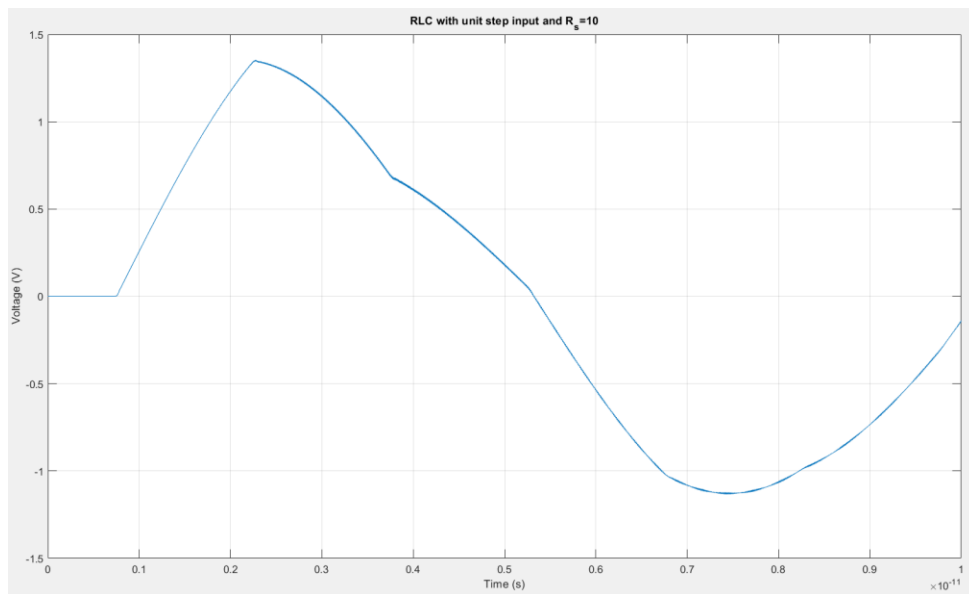


Figure 5:shows the response of the transmission line (TL) using the RLC ladder method with a sinusoidal input at a frequency of 0.1 THz and $R_s = 10$.

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

$$v_{pulse}(t) = \begin{cases} 0, & t < 0 \\ \text{linear rise}, & 0 \leq t < 1ps \\ 1, & 1ps \leq t < 6ps \\ \text{linear fall}, & 6ps \leq t < 7ps \\ 0, & t \geq 7ps. \end{cases}$$

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

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

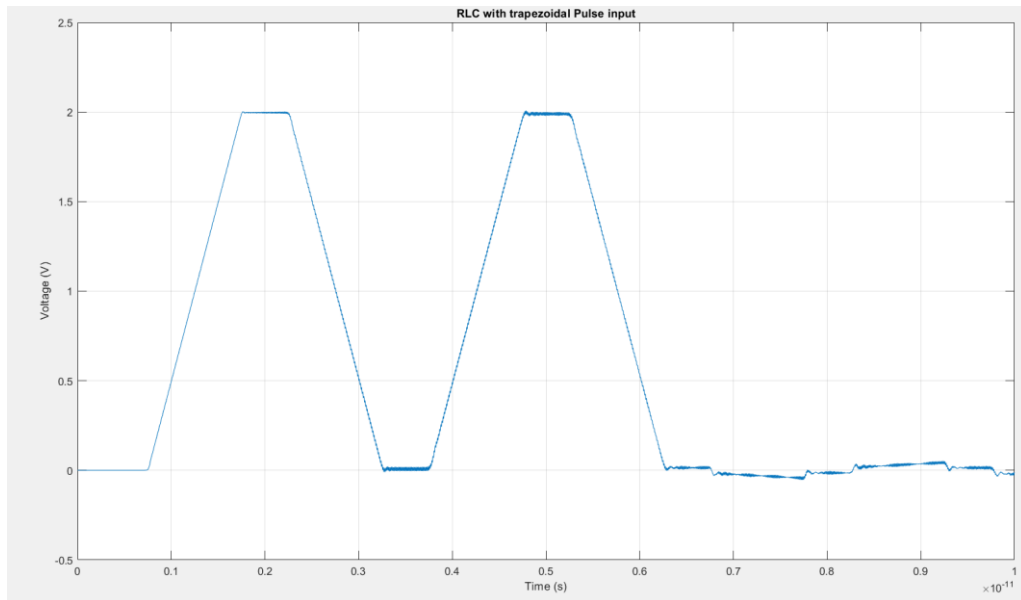


Figure 6: illustrates the output of the transmission line (TL) using the RLC ladder method with a trapezoidal pulse input.

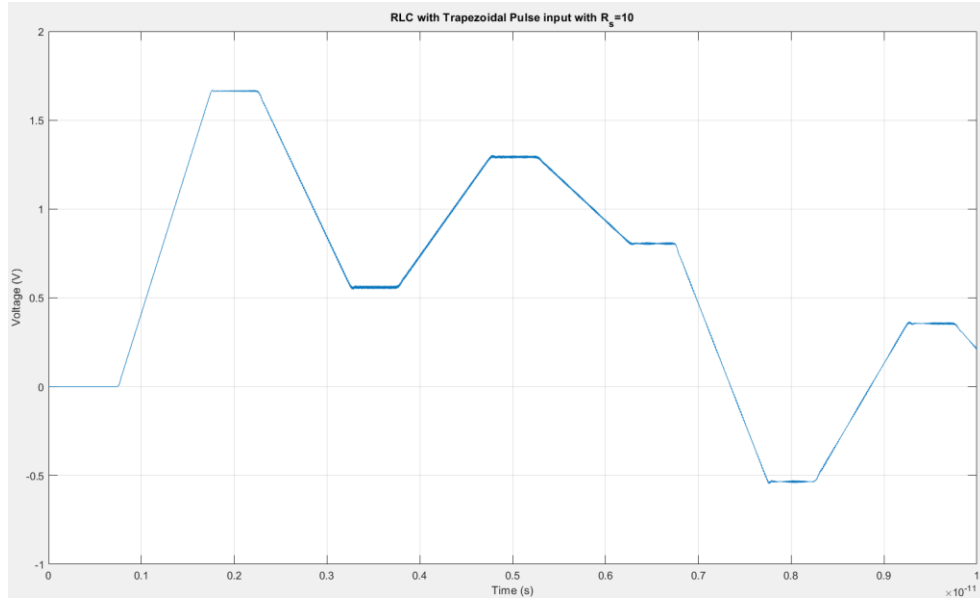


Figure 7: illustrates the output of the transmission line (TL) using the RLC ladder method with a trapezoidal pulse input and $R_s=10$.

```
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
```

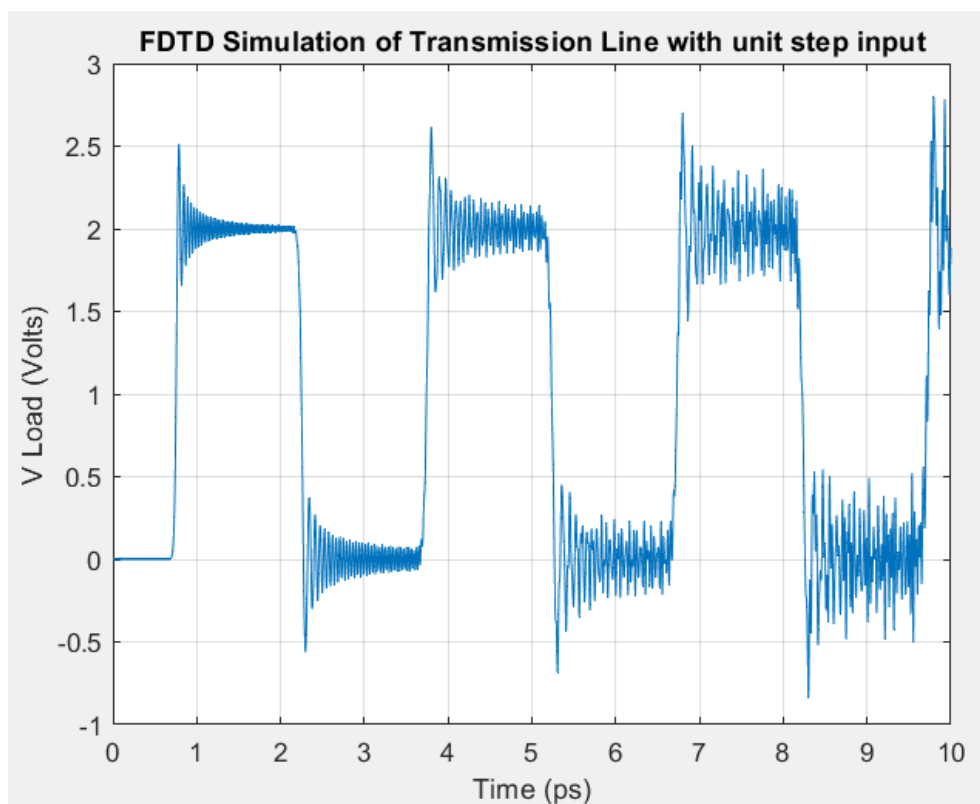
```
%RLC input as pulse
clear
clc
len=150e-6;
N = 200; % Number of sections in the transmission line
dz=len/N;
L = 250e-9*dz; % Inductance
C = 1e-10*dz; % Capacitance
R = 1200*dz; % Resistance per section
Rs = 0; % Source resistance
vs_pulse = @(t) trapezoidalPulse(t);
y0 = zeros(2 * N, 1);
```

```

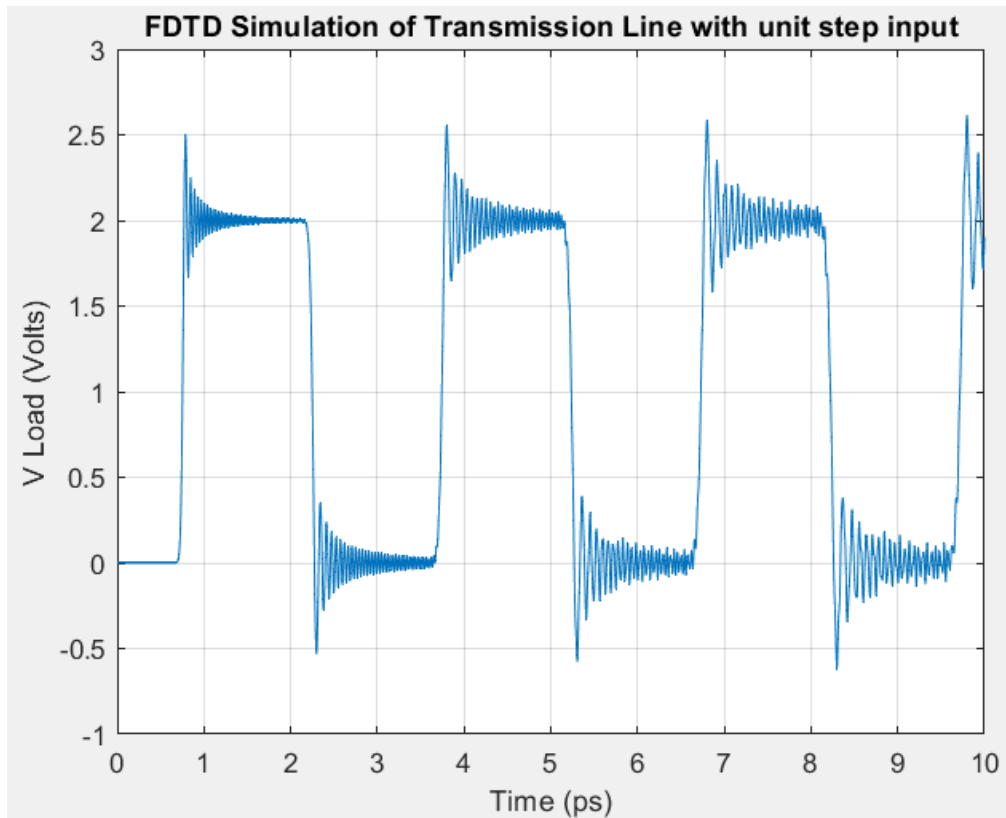
tspan = linspace(0,10e-12,10e4);
% Solve using ode45
[t, y_pulse] = ode45(@(t, y) fline_noR(t, y, N, L, C, R, Rs, vs_pulse), tspan, y0);
% Plot voltage at the end of the transmission line (VN)
figure(1);
plot(t, y_pulse(:,N*2));
xlabel('Time (s)');
ylabel('Voltage (V)');
title('RLC with Trapezoidal Pulse input');
grid on

```

FDTD improvised with 100 sections.



With 10000000 time steps and 100 sections



```

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 = 50; % Number of spatial steps
dz = L_total / NDZ; % Spatial step delta z
dt = 1e-16; % 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);
    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 voltage
            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
end

```



```

        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;

```