EE692 Applied EM- FDTD Method (Spring 2012)
Computer Project 2- 1D Transmission Line Circuit

Overview

We have discussed applying the finite-difference time-domain (FDTD) method to 1D lossless transmission line circuits. For this project, we will model the 1D lossless transmission line circuit shown in Figure 1. The transmission line has characteristic impedance Z_C = 50 Ω, phase velocity v_p = 2×10^8 m/s, and length l = 80 cm. The source voltage $v_S(t)$ will be a time-delayed, unit-amplitude, differentiated Gaussian pulse $v_{S,DFG}(t) = \tau_p \sqrt{e} \frac{\partial}{\partial t}\left[e^{-0.5\left(\frac{t-\tau_d}{\tau_p}\right)^2}\right] = -\frac{\sqrt{e}\ t-\tau_d}{\tau_p} e^{-0.5\left(\frac{t-\tau_d}{\tau_p}\right)^2}$ (V)

where τ_d is the time delay and τ_p is the characteristic time of the pulse.

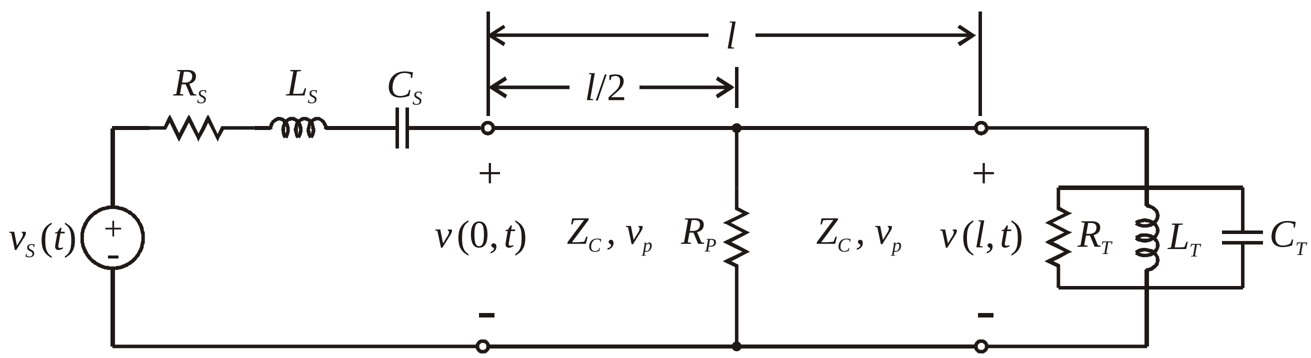

Figure 1 1D Transmission Line Circuit

Tasks

You may use the programming language(s) and/or mathematics package(s) of your choice for the numerical calculations and plotting of results.

1) Analytically calculate the Fourier transform $V_{S,DFG}(f)$ of $v_{S,DFG}(t)$. Determine the frequency f_{pk} at which the spectrum of the differentiated Gaussian pulse is at its maximum, i.e., $|V_{S,DFG}(f_{pk})| = |V_{S,DFG}(f)|_{\max}$. What is $|V_{S,DFG}(f)|_{\max}$? Select τ_p so that f_{pk} = 1.1 GHz. Select the time delay so that $\tau_d = T/4$ where $T = l/v_p$ is the one-way transit time of the transmission line. With these values, plot $v_{S,DFG}(t/T)$ for $0 \le t/T \le 1$. What is the normalized (by the maximum value) value of $v_{S,DFG}(t=0)$ (unitless and decibels)? With these values, plot $|V_{S,DFG}(f/f_{pk})|$ (normalized by $|V_{S,DFG}(f_{pk})|$) for $0 \le f/f_{pk} \le 5$. What is the normalized (by the maximum value) value of $|V_{S,DFG}(f = 5f_{pk})|$ (unitless and decibels)? In a table, list τ_p, τ_d, T, normalized $v_{S,DFG}(t=0)$ (unitless and decibels), f_{pk}, $|V_{S,DFG}(f = f_{pk})|$, and normalized $|V_{S,DFG}(f = 5f_{pk})|$ (unitless and decibels).

2) Assuming a maximum frequency of interest $f_{\max} = 5\, f_{pk}$, select a spatial step size $\Delta z \approx 0.1\,\lambda_{\min}$, where $\lambda_{\min}$ is the wavelength on the transmission line at $f_{\max}$, so that R_P (see Figure 1) is precisely located at $z = l/2$. (Hint: Is the resistor located at a current or voltage node?) Draw a figure or figures detailing the overall spatial mesh set-up (with corresponding variables and indices as implemented in your FDTD code) and close-ups of the source, parallel resistive load R_P, and terminating parallel RLC load (R_T, L_T, & C_T). Using a Courant stability factor $S = 0.5$, calculate Δt. In a table, list $f_{\max}$, $\lambda_{\min}$, Δz, $\Delta z/\lambda_{\min}$, and Δt.

3) Write an FDTD program that will model the 1D lossless transmission line circuit shown in Figure 1. Include code/program listing(s) in the report as an appendice(s). Clearly identify and define important variables in a comment block at the beginning of the code/program. Make copious use of comment statements to explain what code/program blocks are doing. In an appendix, list the various update equations used for the currents and voltages in the circuit both in general form and with coefficients calculated out for specific component values.

4) Assume the transmission line circuit has a source resistance $R_S = 50\ \Omega$, $L_S = 0$, and $C_T \rightarrow \infty$ (i.e., no source inductance or capacitance), a load resistance $R_P = 50\ \Omega$, and a terminating parallel RLC load values $R_T = 150\ \Omega$, $L_T \rightarrow \infty$, and $C_T = 0$ (i.e., no inductance or capacitance). Using transmission line theory, what is the expected magnitude V_{init} of the initial pulse launched onto the transmission line? What is the expected magnitude $V_{\text{refl,RP}}$ of the initial pulse reflected from R_P? What is the expected magnitude $V_{\text{tran,RP}}$ of the initial pulse transmitted through R_P? What is the expected magnitude $V_{\text{refl,RT}}$ of the initial pulse reflected from R_T? [Hint: find reflection and transmission coefficients for various loads.] List V_{init}, $V_{\text{refl,RP}}$, $V_{\text{tran,RP}}$, and $V_{\text{refl,RT}}$ in a table.

5) Run your program using the values in part 4). Plot $v_S\,(t/T)$ (dashed line) and $v(z = 0, t/T)$ (solid line) for $0 \leq t/T \leq 4$. On the plot, label the initial and first reflection voltage peaks/zero-crossings and corresponding normalized times. Then, on separate graphs, plot $v(z, t/T = 0.5)$, $v(z, t/T = 1)$, and $v(z, t/T = 1.5)$ for $0 \leq z \leq l$. (Hint: what time index n values correspond to these times?) On the plots, label voltage peaks/zero-crossings and corresponding normalized times. Compare these results with those predicted in part 4).

6) Run your program with $R_S = 30\ \Omega$, $C_S = 5$ pF, $L_S = 2.0$ nF, $R_P = 50\ \Omega$, $R_T = 150\ \Omega$, $L_T = 25$ nH, and $C_T = 1.0$ pF. Plot $v_S(t/T)$ (dashed line) and $v(0, t/T)$ (solid line) for $0 \leq t/T \leq 6$. On a separate graphs, plot the load voltage $v(l, t/T)$, source capacitor voltage $v_{CS}(t/T)$, and terminating inductor current $i_{LP}(t/T)$ for $0 \leq t/T \leq 6$.

Report

Write a report covering your results. The report should be as short as possible, while remaining complete in its description of your work. General format: Cover page, Introduction, Body- break down by assigned tasks, Conclusions/Summary, & Appendice(s). Use 12 point Times New Roman font with 1.25/1.5 line spacing. The report must be totally produced on a computer using, among other software, a word processor, an equation editor, and a data plotting package.

Due Friday February 24, 2012.