

# **Time-Domain Analysis of Transmission Line Circuits**

(Part 4)

**Dr. José Ernesto Rayas Sánchez**

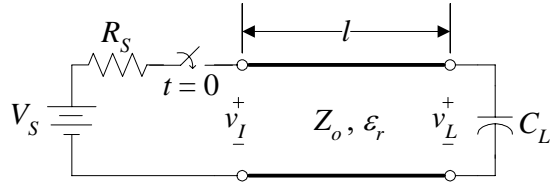
1

## Outline

---

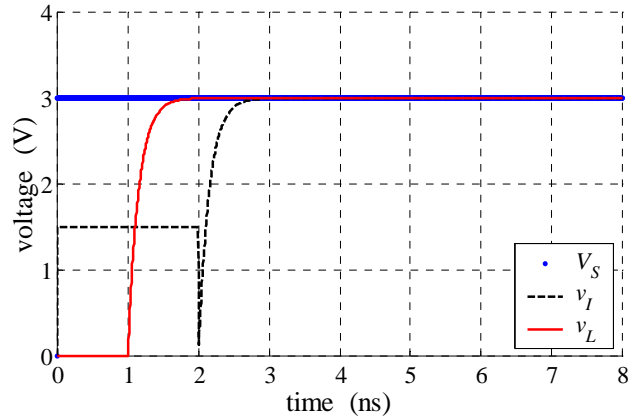
- Reducing undesired transients in TLs with capacitive loads
- Effects of transition times on TL with resistive loads
- Effects of transition times on TL with reactive loads

Case 1: TL with  $C_L$ ,  $\Gamma_S = 0$



$V_S = 3\text{V}$ ;  $Z_o = 50\Omega$ ;  
 $\epsilon_e = 3$ ;  $l = 17.321\text{cm}$ ;  
 $C_L = 3\text{pF}$

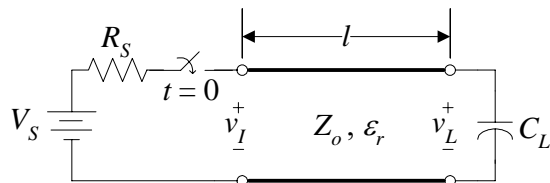
$R_S = 50\Omega$



Dr. J.E. Rayas Sánchez

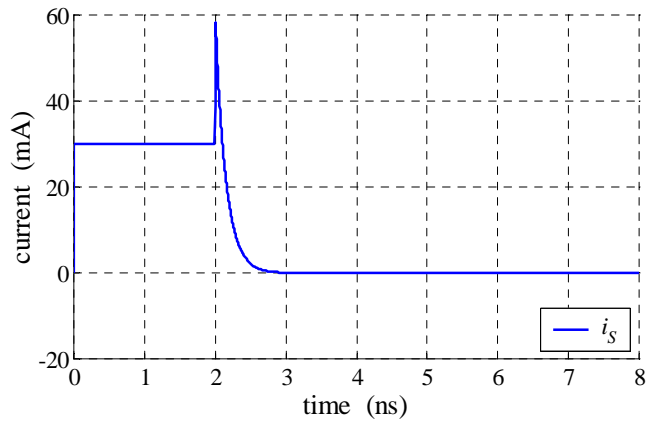
3

Case 1: TL with  $C_L$ ,  $\Gamma_S = 0$



$V_S = 3\text{V}$ ;  $Z_o = 50\Omega$ ;  
 $\epsilon_e = 3$ ;  $l = 17.321\text{cm}$ ;  
 $C_L = 3\text{pF}$

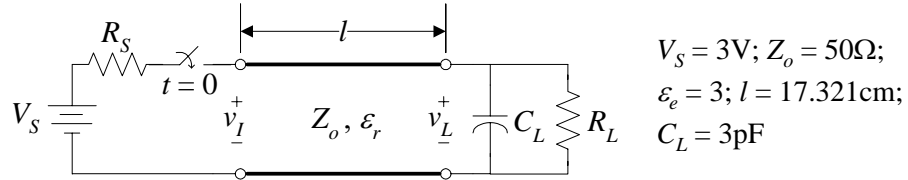
$R_S = 50\Omega$



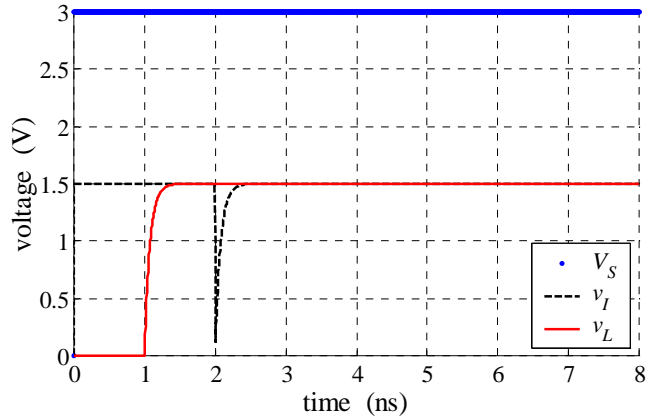
Dr. J.E. Rayas Sánchez

4

### Case 1: TL with $C_L$ and $R_L$ , $\Gamma_S = 0$



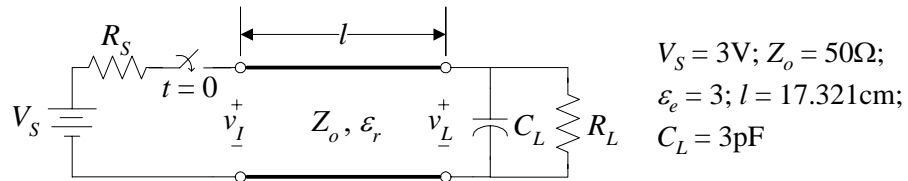
$R_S = 50\Omega$   
 $R_L = 50\Omega$



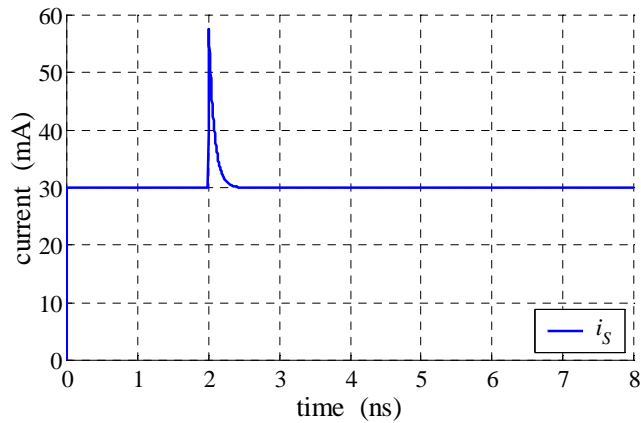
Dr. J.E. Rayas Sánchez

5

### Case 1: TL with $C_L$ and $R_L$ , $\Gamma_S = 0$



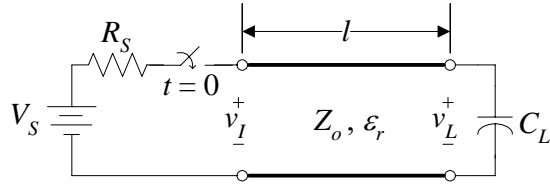
$R_S = 50\Omega$   
 $R_L = 50\Omega$



Dr. J.E. Rayas Sánchez

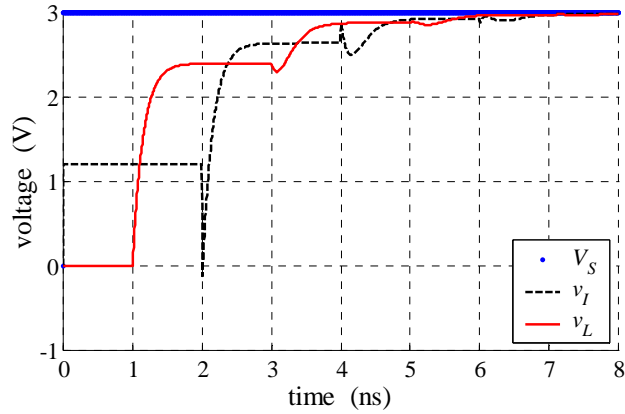
6

### Case 2: TL with $C_L, \Gamma_S > 0$



$V_S = 3\text{V}; Z_o = 50\Omega;$   
 $\epsilon_e = 3; l = 17.321\text{cm};$   
 $C_L = 3\text{pF}$

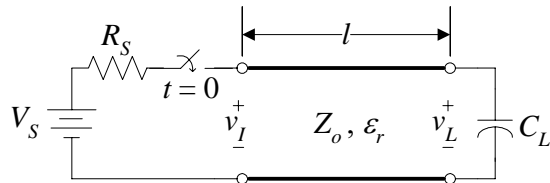
$R_S = 75\Omega$



Dr. J.E. Rayas Sánchez

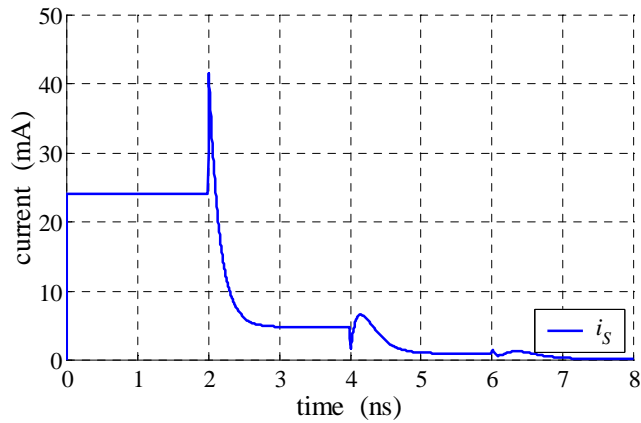
7

### Case 2: TL with $C_L, \Gamma_S > 0$



$V_S = 3\text{V}; Z_o = 50\Omega;$   
 $\epsilon_e = 3; l = 17.321\text{cm};$   
 $C_L = 3\text{pF}$

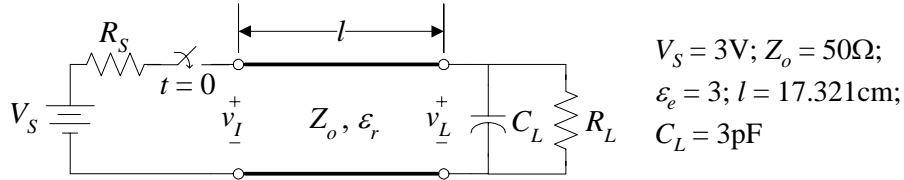
$R_S = 75\Omega$



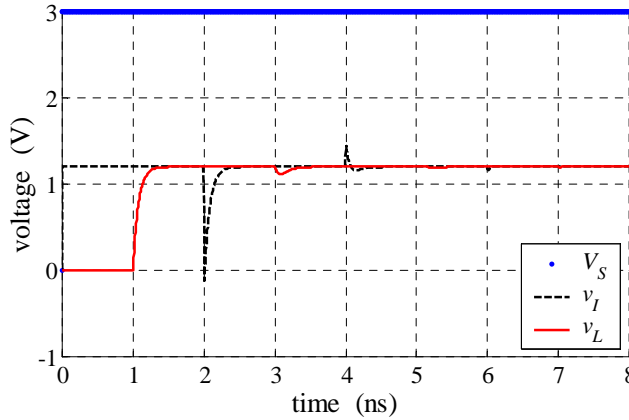
Dr. J.E. Rayas Sánchez

8

### Case 2: TL with $C_L$ and $R_L$ , $\Gamma_S > 0$



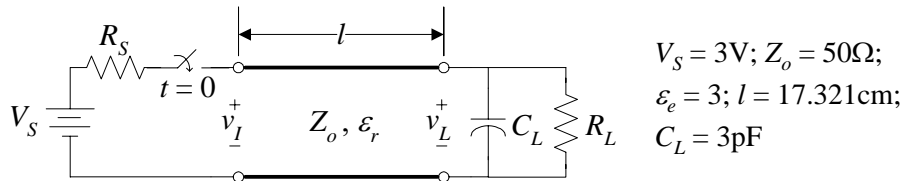
$R_S = 75\Omega$   
 $R_L = 50\Omega$



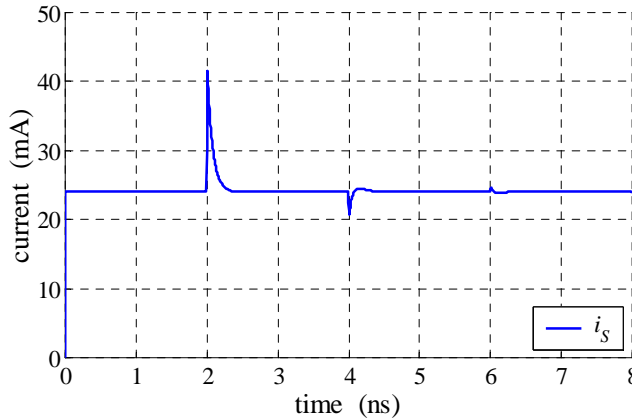
Dr. J.E. Rayas Sánchez

9

### Case 2: TL with $C_L$ and $R_L$ , $\Gamma_S > 0$



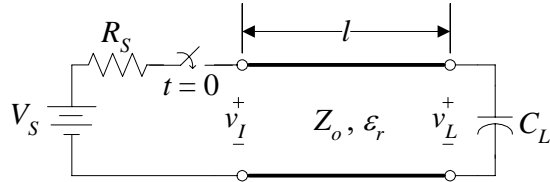
$R_S = 75\Omega$   
 $R_L = 50\Omega$



Dr. J.E. Rayas Sánchez

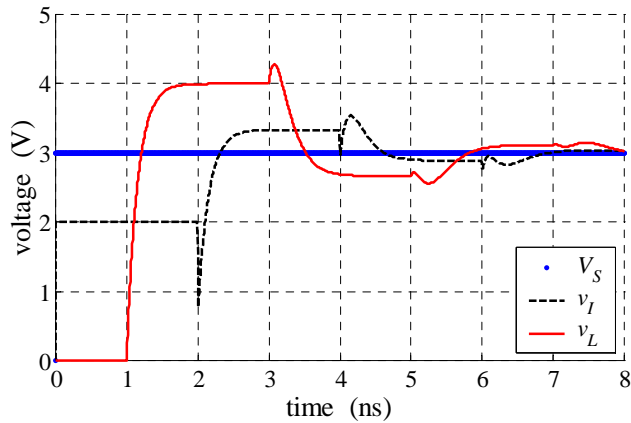
10

### Case 3: TL with $C_L$ , $\Gamma_S < 0$



$V_S = 3\text{V}$ ;  $Z_o = 50\Omega$ ;  
 $\epsilon_e = 3$ ;  $l = 17.321\text{cm}$ ;  
 $C_L = 3\text{pF}$

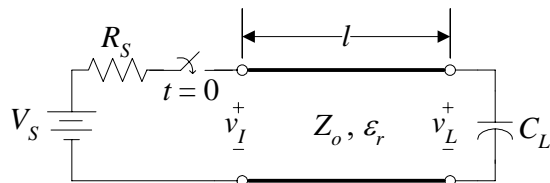
$R_S = 25\Omega$



Dr. J.E. Rayas Sánchez

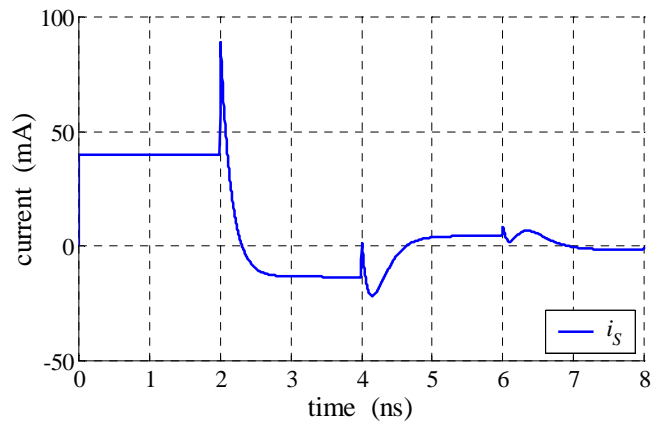
11

### Case 3: TL with $C_L$ , $\Gamma_S < 0$



$V_S = 3\text{V}$ ;  $Z_o = 50\Omega$ ;  
 $\epsilon_e = 3$ ;  $l = 17.321\text{cm}$ ;  
 $C_L = 3\text{pF}$

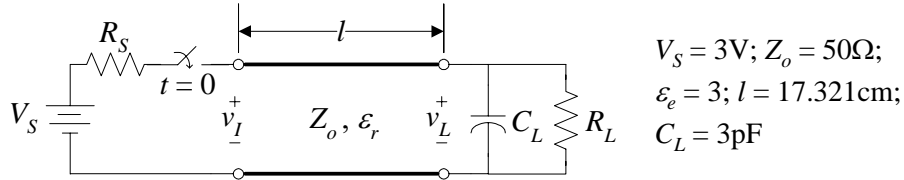
$R_S = 25\Omega$



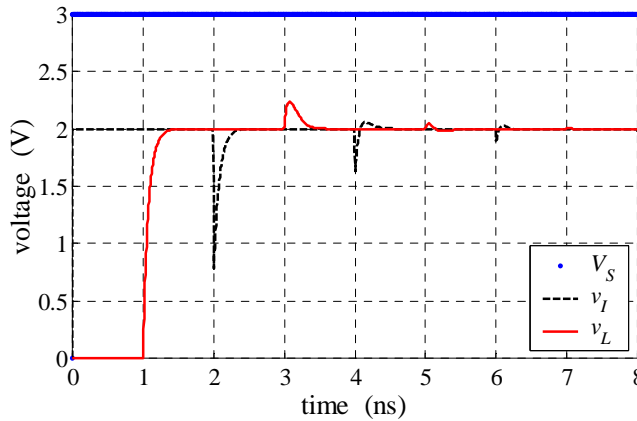
Dr. J.E. Rayas Sánchez

12

### Case 3: TL with $C_L$ and $R_L$ , $\Gamma_S < 0$



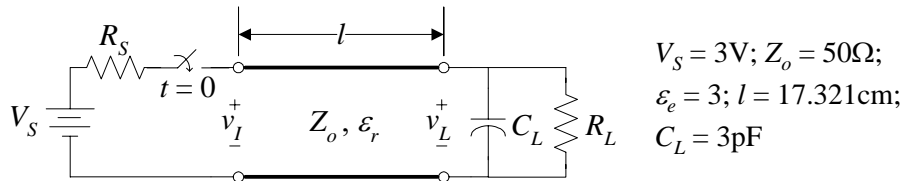
$R_S = 25\Omega$   
 $R_L = 50\Omega$



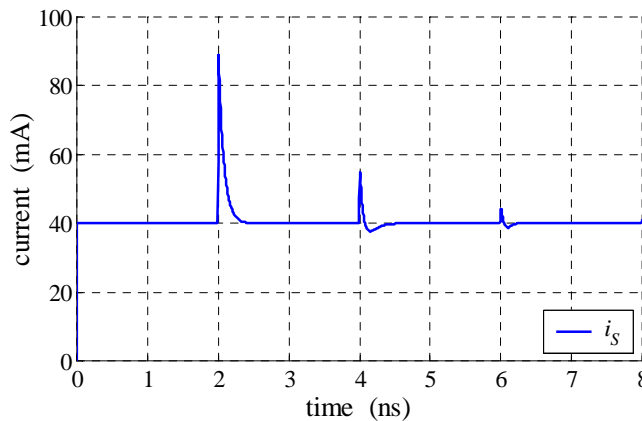
Dr. J.E. Rayas Sánchez

13

### Case 3: TL with $C_L$ and $R_L$ , $\Gamma_S < 0$



$R_S = 25\Omega$   
 $R_L = 50\Omega$



Dr. J.E. Rayas Sánchez

14

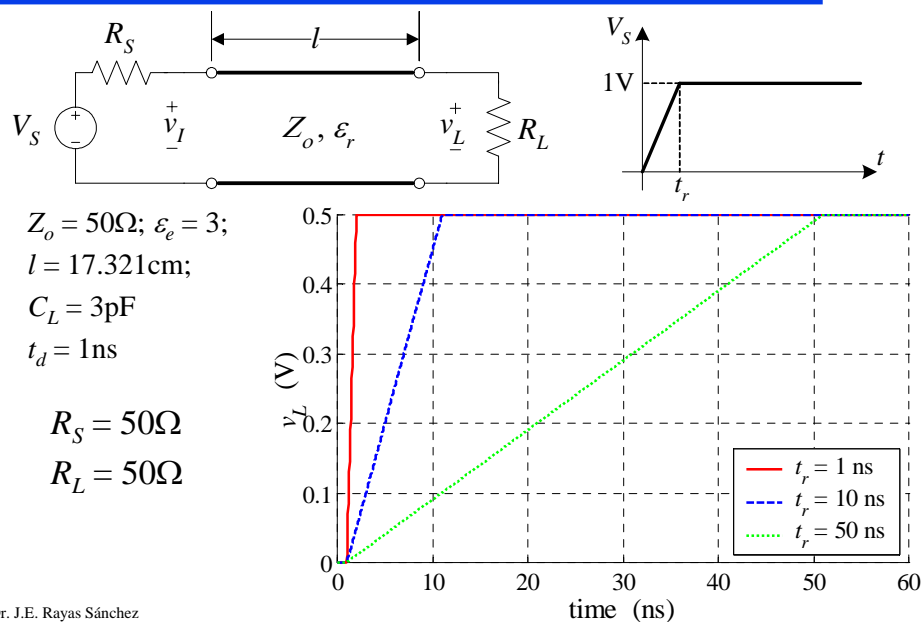
## Conclusions on Capacitive Terminations

- It is confirmed that lossless TLs with capacitive loads behave as underdriven lines if  $R_S > Z_o$
- It is confirmed that lossless TLs with capacitive loads behave as overdriven lines if  $R_S < Z_o$
- Undesired transients at the load in lossless TLs with capacitive loads are eliminated if the source is matched
- Undesired transients at the load in lossless TLs with capacitive loads and unmatched source are significantly reduced if a matched resistive load is connected in parallel with the load capacitor (at the expense of more current from the source)

Dr. J.E. Rayas Sánchez

15

## Effects of $t_r$ on TLs with Resistive Terminations

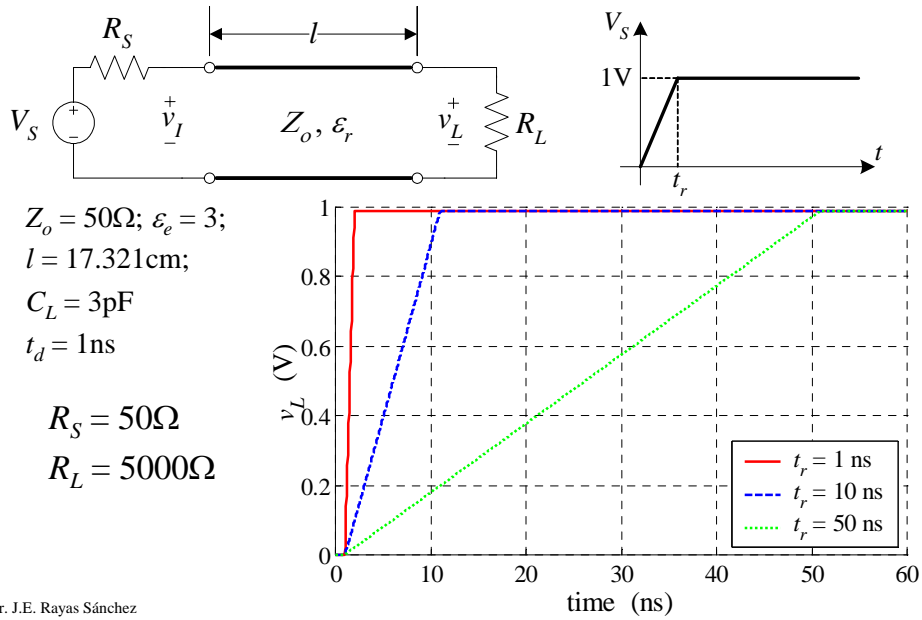


Dr. J.E. Rayas Sánchez

16



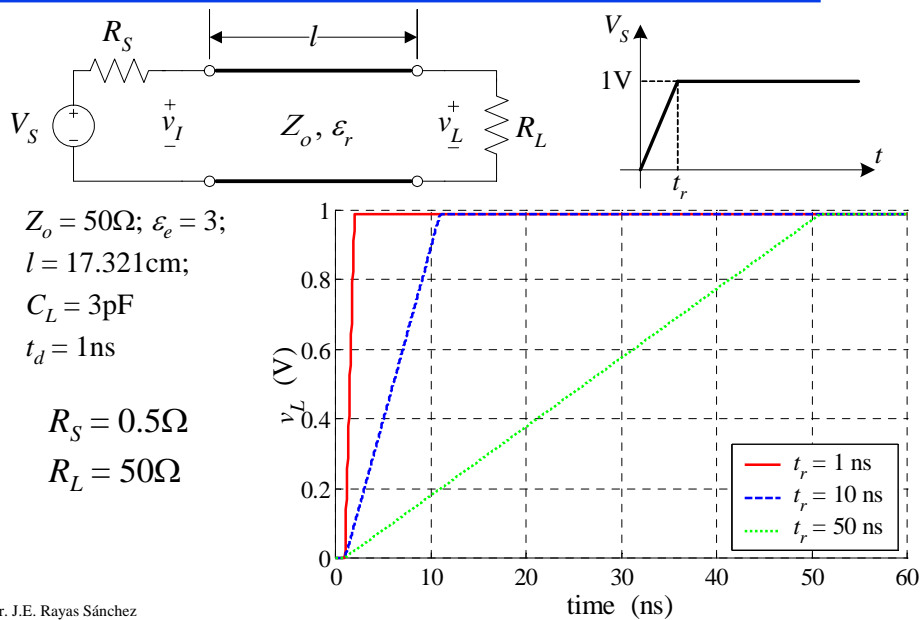
## Effects of $t_r$ on TLs with Resistive Terminations



Dr. J.E. Rayas Sánchez

17

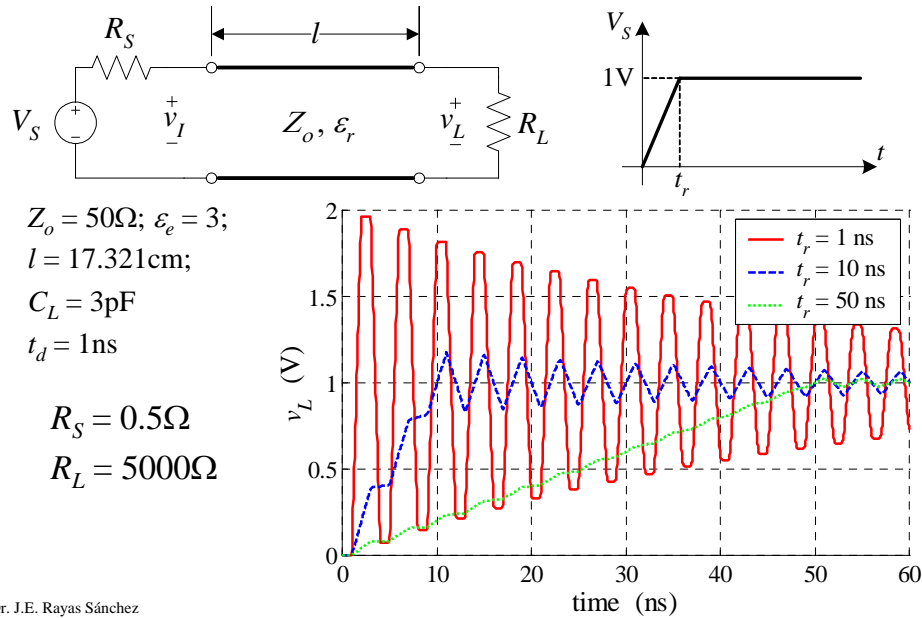
## Effects of $t_r$ on TLs with Resistive Terminations



Dr. J.E. Rayas Sánchez

18

## Effects of $t_r$ on TLs with Resistive Terminations



Dr. J.E. Rayas Sánchez

19

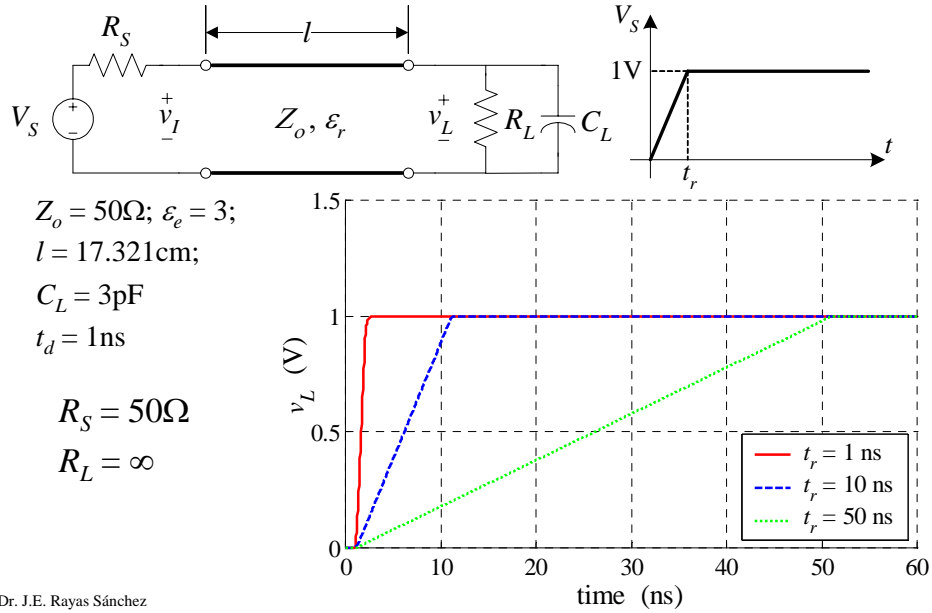
## Effects of $t_r$ on TL with Resistive Termination

- Undesired transients due to fast transition times in lossless TLs with resistive terminations are eliminated if the source, the load, or both, are matched
- If both the source and the load are unmatched, it is confirmed that a significant amount of undesired transients appear when the flight time is larger than 10% of the transition time

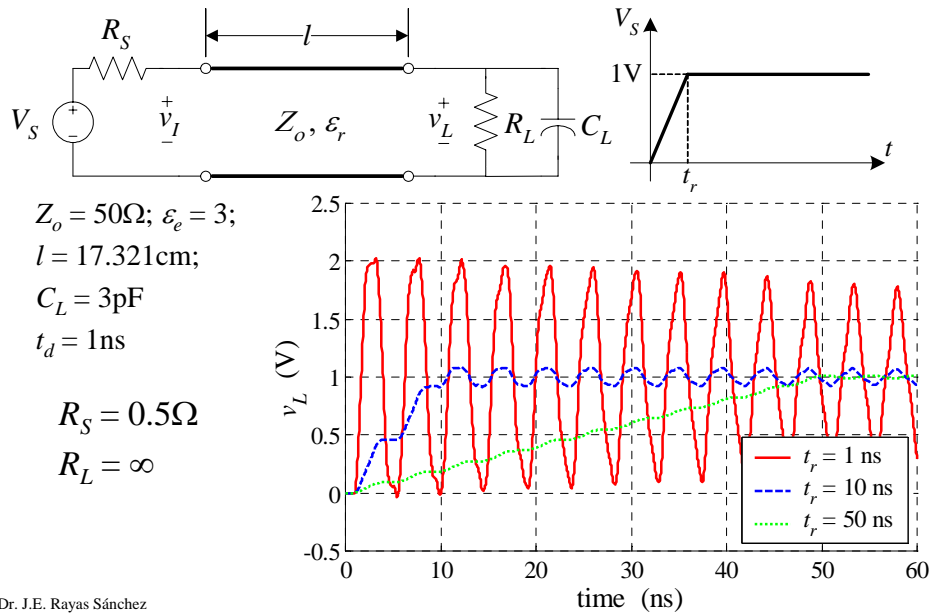
Dr. J.E. Rayas Sánchez

20

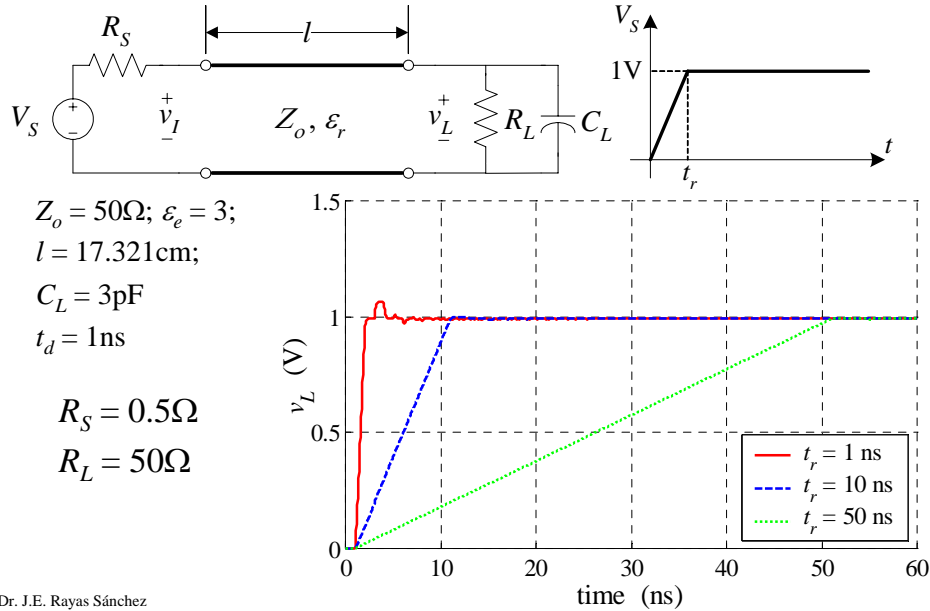
## Effects of $t_r$ on TLs with Capacitive Load



## Effects of $t_r$ on TLs with Capacitive Load



## Effects of $t_r$ on TLs with Capacitive Load



## Conclusions on Capacitive Terminations and $t_r$

- Undesired transients due to fast transition times in lossless TLs with capacitive loads are eliminated if the source is matched
- Undesired transients due to fast transition times in lossless TLs with capacitive loads and unmatched source are significantly reduced if a matched resistive load is connected in parallel with the load capacitor (at the expense of more current from the source)