Radiation and Propagation (RP-2B)

Exercises

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Theme 1: Basic concepts

1) Find the power (dBm) of a 65 dBμV signal in a 75Ω system

2) A 50 Ω load sinks 4 W of power. Give this power in dBW and dBm. Find the rms voltage on the resistor given in dBV and dBμV.

3) A 10 dBW signal flows into a 6 dB attenuator. Compute the input and output power in dBm and the power dissipated inside the attenuator, also in dBm.

4) A 0.8 mV signal is measured at the terminals of an antenna. This antenna is connected to a receiver by means of a 45 m lossy transmission line. A 0.1 mV signal is measured at the transmission line output. Gives the voltages in dBμV and the transmission line attenuation in dB and dB/m. Take into account a perfectly matched 75 Ω transmission system.

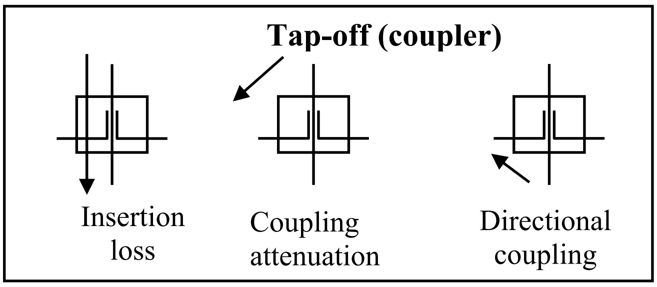
5) A -40 dBm signal is measured at the output of a 75Ω antenna, that is connected to a receiver by means of 25 m and 0.5 dB/m cable. ¿What is the minimum gain (in dB) of the input amplifier of the receiver if the minimum rms signal that is required at the input of the demodulator (amplifier output) is 10 mV_{ef}? (the reference impedance of the transmission system is 75Ω)

6) When the input signal at 50Ω amplifier is V_{in}=50 mV the output signal is V_{out}=1V. Find the amplifier gain in dB. If the maximum output power that this amplifier is allowed to deliver to a 50Ω load is 500 mW, what is the maximum rms voltage that can be measured at its input?

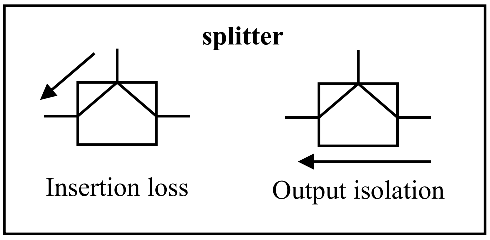
7) A rms signal of 12 mV is injected into a 40 m transmission line of characteristic impedance Z_o=50Ω. If the output rms voltage is 0.2 mV, what is the transmission line attenuation in dB/100m?

8) The maximum power that can be dissipated inside a 6 dB attenuator is 10 mW. What is the maximum power allowed at the attenuator input?

9) A 75Ω TV signal distribution network includes a two output signal coupler, perfectly matched, with 15 dB of coupling attenuation. What is the minimum insertion loss (lossless device) that can be achieved (insertion loss= main input to main output signal ratio)? The directional attenuation is 30 dB. A 95 dBμV signal is injected into the coupler through the main input, while a 80 dBμV coming from a reflection (double image effect) is injected into the coupler through its main output. What is the ratio between the main signal and the interference measured at any of the two coupled outputs?



10) A 75Ω TV signal distribution network uses a perfectly matched two way power splitter with a 4 dB insertion loss. A 95 dBμV signal is injected into its input. What is the power available at each of the two output terminals, in dBm?



11) Through a Y=0.01(2-j3) S admittance flows a rms current $I=0.8e^{-j23.5^\circ}$A. Find the power sunk into this admittance, the voltage fasor and the phase difference between voltage and current at its terminals ($\phi_V - \phi_I$).

12) A rms voltage V=0.45j V_{ef} is measured at the terminals of a Z=50+j50 Ω impedance. The system works in a sinusoidal steady state at a frequency f=10MHz. If the instantaneous voltage at t=10s is 0V, find the time delay (in μs) from t=10s to the instant when the current is null. Find the peak-tp-peak current in mA.

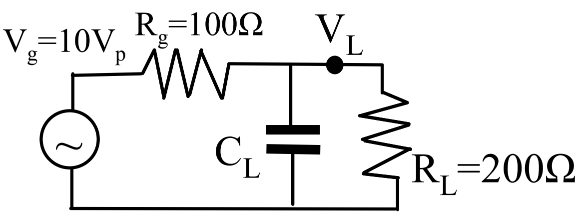
13) A voltage source, with internal impedance Z_g=10+j20 Ω and rms open circuit voltage V_g=7 V, is connected to a load impedance Z_L=25-j10 Ω. Find the source available (maximum) power, the power delivered to the load and the power mismatch coefficient.

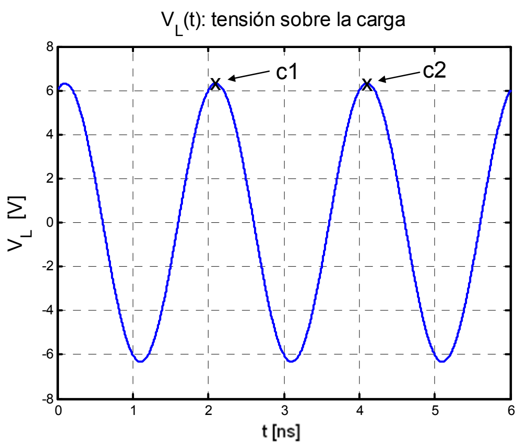
14) A voltage source, with internal impedance Z_g=50 Ω and available (maximum) power 1mW, is connected to a load impedance Z_L=40+j40 Ω.

a. Find the power delivered to the load and the power mismatch coefficient.
b. What complex impedance Z_x must be connected in series with the load Z_L to have the generator deliver its maximum power? In this case, find the power delivered to the original load Z_L=40+j40 Ω and the new power mismatch coefficient related to the original Z_L.
c. Find the power that would be delivered to Z_L, and the new power mismatch coefficient, in the case that Z_x is imaginary (with null real part) and only the reactive part of the load Z_L is cancelled out.

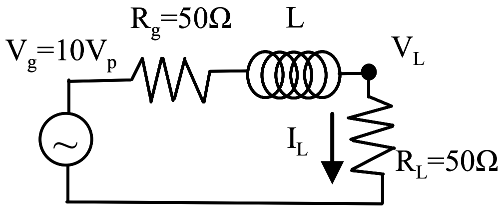
15) The voltage $V_L(t)$ applied to the load of the circuit in the figure below is measured with an oscilloscope. The markers are used to find two consecutive voltage maimums: c1 (t_1=2.102 ns, V_1=6.325 V) and c2 (t_2=4.102 ns, V_2=6.325 V). Find:

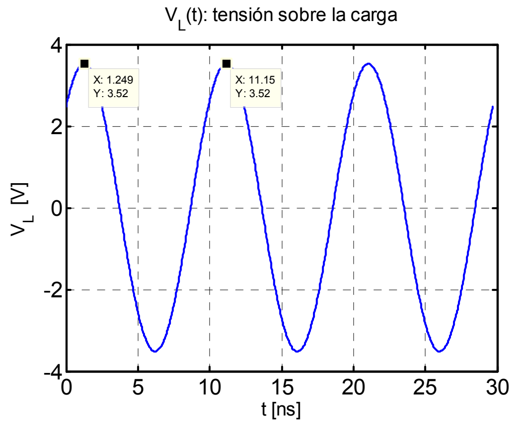
a. The working frequency
b. the power [mW] delivered to the load R_L
c. The phase difference (deg) between $v_g(t)$ and $v_L(t)$ if $v_g(t) = V_g \cos \omega t$. Write the full expression for $v_L(t)$.
d. The value of the capacitor C_L [pF]





16) $V_L(t)$ is the instantaneous voltage measured on the resistor R_L in the circuit below. The oscilloscope markers are used to find two consecutive voltage maximums as given in the plot (t_1=1,249 ns, V_1=3,52 V, t_2=11,15 ns, V_2=3,52 V

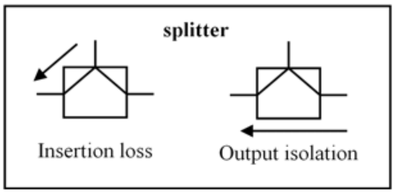




a) Write the complex expression of the current that flows through the load R_L given as $I_L = |I_L| e^{j\varphi_L}$.

b) Find the value of the inductance L in μH

17).- An output power P_{out}= -12 dBm is measured at each one of the outputs of a 75 Ω, symmetric, non ideal (lossy) and perfectly matched TV power splitter, with 4 dB insertion loss. Find the power dissipated inside the splitter (**in dBm**).



SOLUTIONS Theme 1

1) $P = -43{,}75\,dBm$

2) 6dBW ; 36dBm ; 23dBV ; 143 dBµV

3) $P_e = 40$ dBm; $P_o = 34$ dBm; $P_{at} = 38.7$ dBm

4) 0.8mV → 58dBµV ; 0.1mV → 40 dBµV ; A=18dB → 0.4dB/m

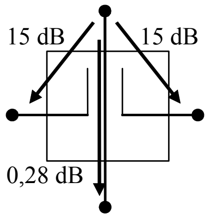
5) G=23,74 dB

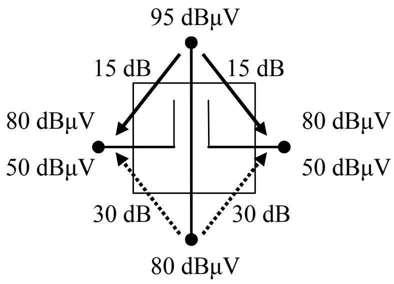
6) G=26 dB, $V_{eMAX} = 250$ mV

7) A=88,9 dB/100m

8) $P_{eMAX} = 11{,}25$ dBm

9) Mínimum insertion loss: $L_p = 0.284$ dB. Ratio to interference: 30 dB





10) $P_{out} = $ -17.75 dBm

11) $Y = 0.01(2 - j3)S$; $I = 0{,}8\, e^{-j23{,}5*\pi/180}$; $Z = \dfrac{1}{Y} = \dfrac{100}{13}(2 + j3)\,\Omega$

$$P = |I|^2 \operatorname{Re}[Z] = 9.84W \;; V = \frac{I}{Y} = 22{,}18\angle 32{,}81^\circ\, V \;;\; \phi_V - \phi_I = 32{,}81 - (-23{,}5) = 56{,}31^\circ$$

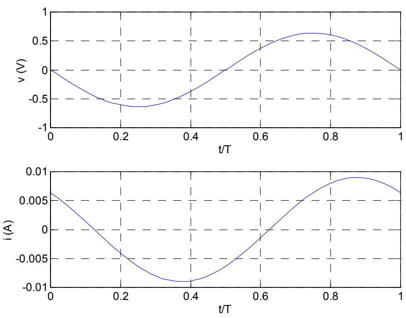
12)

$$v(t) = -0.45\sqrt{2}\sin\left(2\pi\frac{t}{T}\right);$$

$$i(t) = 0.009\cos\left(2\pi\frac{t}{T} + \pi/4\right);$$

T=1/f=0,1µs.

$$i(t_1) = 0 \;\rightarrow\; t_1 = \frac{T}{8} = 0{,}0125\,\mu s(+nT)$$



13) Source available (maximum) power: $P_{av} = 1{,}225\; W$.
Power delivered to the load: P_L =0.924 W. Mismatch coefficient: c_a=0.755

14)
a. P_L=0.825 mW; c_a=0.825
b. Z_x=10-j40 Ω; P_L=0.8 mW; c_a=0.8
c. Z_x=-j40 Ω; P_L=0.988 mW; c_a=0.988

15)
a. f=500 MHz
b. $P_L = 100$ mW
c. $\Delta\phi =$ -18.36º; $v_L(t) = 6.325\cos(\omega t - 0.32)$. d. $C_L = 1.59\,pF$

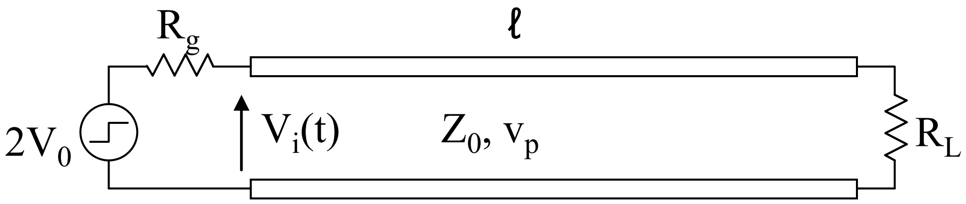
16)
a. $|I_L| = 70\; mA$ (peak value),y φ_L=-0,79 rad
b. L=0,159 μH

17) -14.9 dBm

THEME 2. TRANSMISSION LINES

A: TRANSIENT RESPONSE IN THE TRANSMISSION LINE

1) A step voltage generator with open circuit amplitude $2V_0$ and internal impedance $R_g=Z_0$ is connected to a transmission line, with characteristic impedance Z_0, speed propagation v_p and length ℓ. Find the voltage transient at the line input, $V_i(t)$, in the range $0<t<6T$, where $T=\ell/v_p$, for the following cases a) $R_L=0$, b) $R_L=\infty$ and c) $R_L=Z_0$.

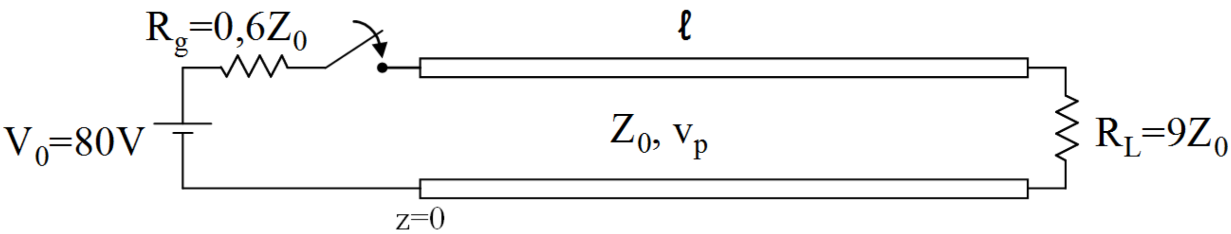


2) In the circuit below the switch connects the generator to the transmission line at t=0.

a) Draw the space-time (Gantt) diagram, including the value of the reflection coefficient at both line ends and the value of the successive voltage waves that appear in the circuit.

b) Find the value of the voltage at the middle of the line ($z=\ell/2$) and at the line input (z=0) in the range $0<t<5T$, where $T=\ell/v_p$

c) Find the voltage in the line at the instant t=3T/2: v(z,3T/2).

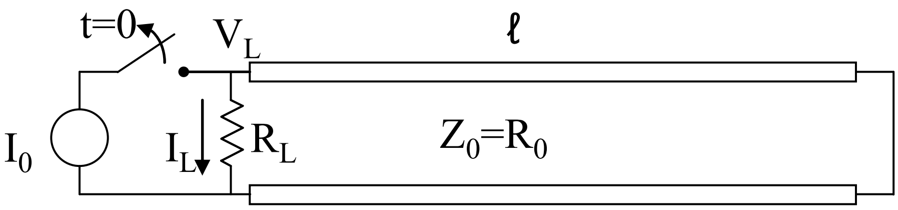


3) A transmission line of length ℓ, in open circuit at both ends, is charged with a steady DC voltage V_0. At t=0 the line is short-circuited in one of its ends. Plot the voltage and current evolution as a function of time.

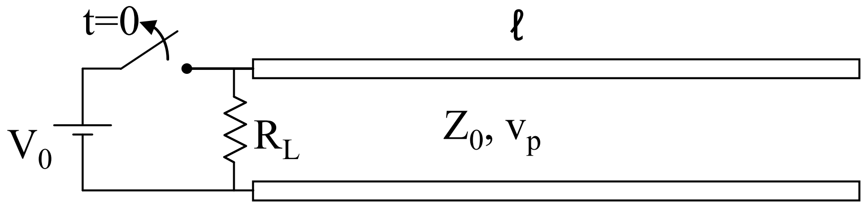
4) A transmission line of length ℓ, in open circuit at both ends, is charged with a steady DC voltage V_0. At t=0 the line is connected to a resistor $R=Z_0$. If the length of the line is 3 m and its wave propagation speed is $0.5c_0$, what is the time length of the voltage pulse that appears at the resistor terminals?

5) A DC voltage generator V_0 with internal impedance R_g is connected at t=0 to a resistive load R_L by means of a section of transmission line with characteristic wave impedance Z_0 and length ℓ. Plot the space-time (Gantt) diagram and find the steady sate voltage in the transmission line ($t\to\infty$).

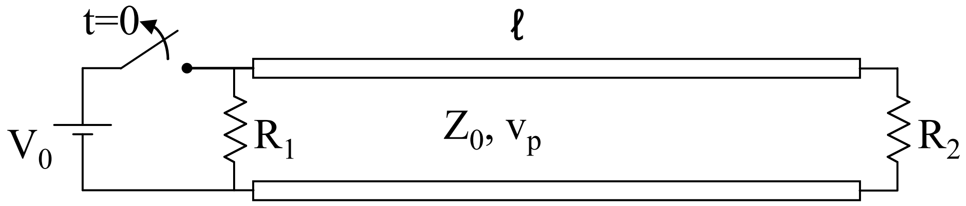
6) In the circuit below the switch is opened at t=0. Plot the voltage and current evolution over the load R_L in the range $0<t<6T$, where $T=\ell/v_p$, for the following cases a) $R_0<R_L$ b) $R_0=R_L$ and c) $R_0>R_L$.



7) In the figure below the switch is closed since t= -∞ and it is opened at t=0. Plot the voltage evolution over the load R_L in the range $0<t<6T$, where $T=\ell/v_p$, for the following cases a) $R_0<R_L$ b) $R_0=R_L$ and c) $R_0>R_L$.

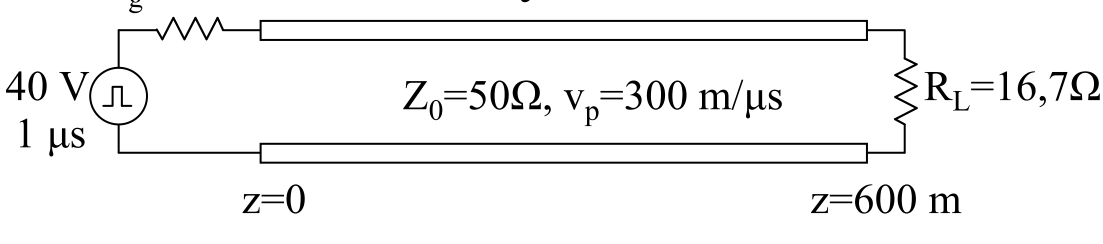


8) In the circuit below the switch is closed since t=-∞ and opens at t=0. if $R_1=Z_0$, Draw the voltage evolution over R_2 as a function of V_0, Z_0 y ρ_2.

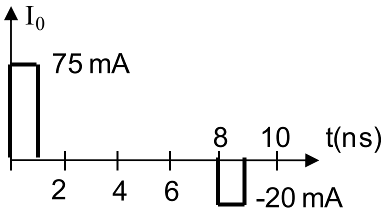


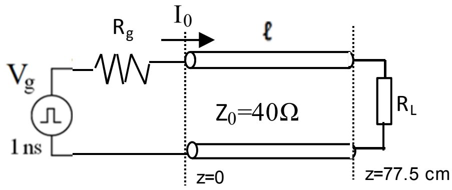
9) A transmission line has short-circuited end. A 10 ns and 10 V voltage square pulse is injected through the other end at t=0. If $Z_0=50\,\Omega$, $c=3\cdot10^8$ m/s and $\ell=9$ m, draw the space-time (Gantt) diagram and plot the voltage and current evolution in the transmission line for the following instants: t=30, t=35 y t=40 ns.

10) The generator in the figure below produces a single 1 μs open circuit 40 V pulse. Draw the voltage and current evolution at the line input (z=0) and at the middle of the line (z= 300 m) for the time interval 0<t<15µs.



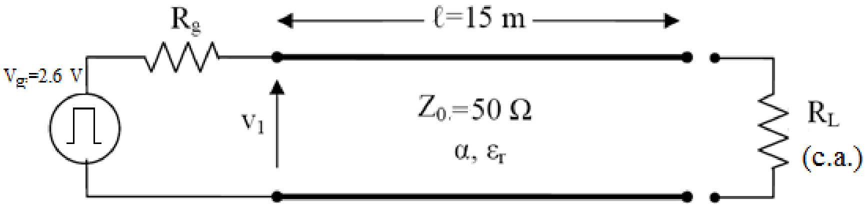
11) In the circuit below the generator produces at t=0 a single 1 ns pulse with an open circuit amplitude $V_g = 4.5\ V$. The graphic below shows the current I_0 at the input of an ideal transmission line of length $\ell = 77.5\ cm$ and loaded with a resistor R_L. If the wave impedance of the liine is $Z_0 = 40\Omega$ find:

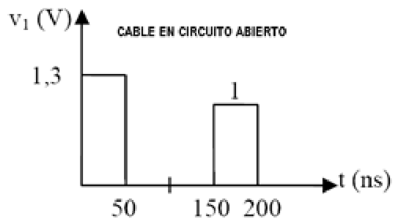




a) The value of the generator internal impedance R_g (**<u>Ohm</u>**)
b) The capacity per unit length of the transmission line C, (**pF/m**.)
c) The value of the load resistor R_L (**<u>Ohm</u>**)

12) The figure below shows a rectangular pulse generator with an open circuit amplitude V_g= 2.6 V and length T_0 =50 ns, that is connected to a low loss cable of characteristic impedance $Z_0 = 50\Omega$, similar to the set-up given in the laboratory. The figure below shows the voltage at the cable input $v_1(t)$ in the case that the transmission line is terminated with and open circuit$(R_L = \infty)$.Find**:**





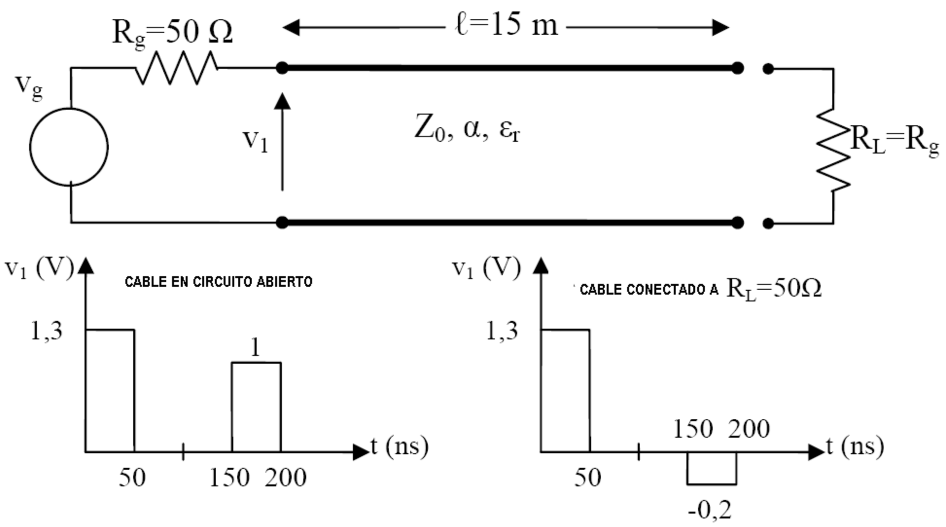
a) The cable dielectric constant ε_r and its capacity per unit of length C (i**<u>n pF/m</u>**).
b) The value of the generator internal impedance R_g i**<u>n Ohms</u>**
c) The cable attenuation i**<u>n dB/100m</u>**

13) The figure below shows a rectangular pulse generator that is connected to a low los cable. the voltage measured at the cable input $v_1(t)$ for two different load conditions are given in the plots below. The left hand plot is related to the case of the line ended in open circuit $(R_L = \infty)$ and the right hand plot is the case where the end of the line is terminated with a resistor equal to the generator internal resistance $(R_L = R_g = 50\Omega)$

a) Find the dielectric constant of the cable

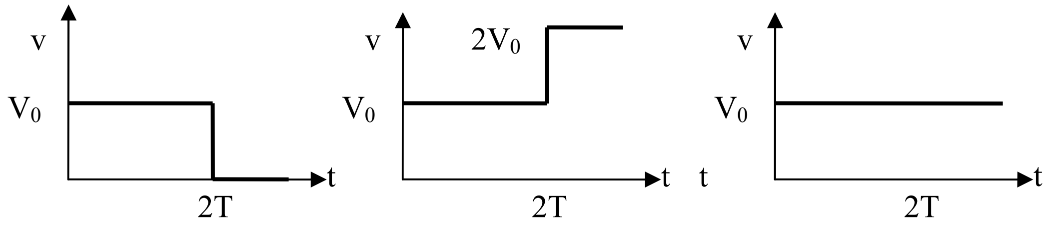
b) For the two differnet load conditions $(R_L = \infty \; y \; R_L = R_g = 50\Omega)$ find the expression of the amplitud of the second pulse (the one that appears in the range 150 to 200 ns) as a function of the amplitude of the first pulse, the cable characteristics and the reflection coefficients at the load and generator.

c) Find the following cable parameters: characteristic impedance $Z_0(\Omega)$, attenuation per unit of length A(dB/m), capacity per unit of length C(pF/m) and inductance per unit of lengt L $(\mu H/m)$..



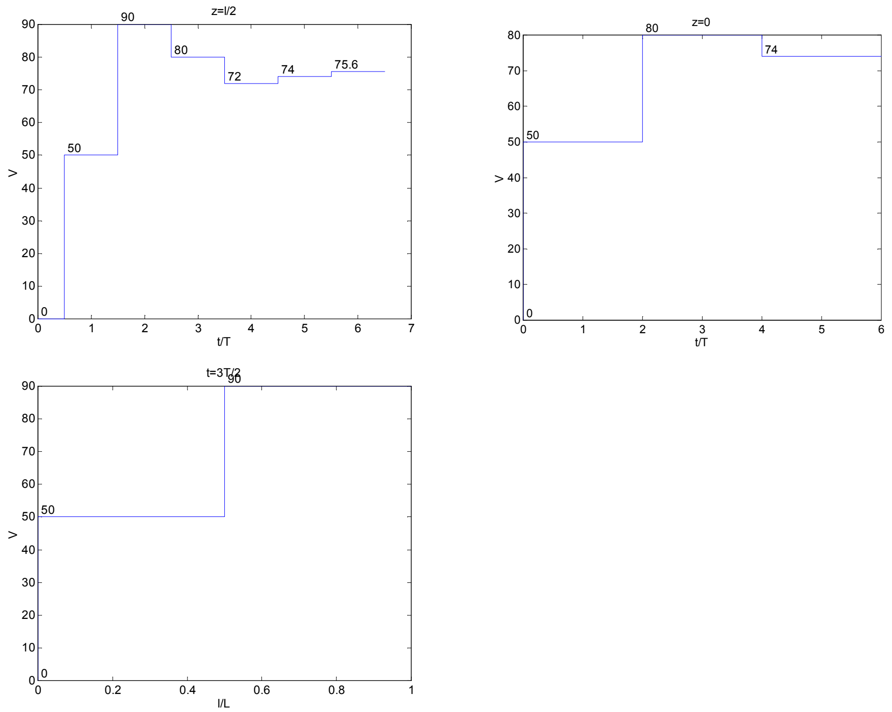
SOLUTIONS Theme 2.A Transients in the transmission line

1)

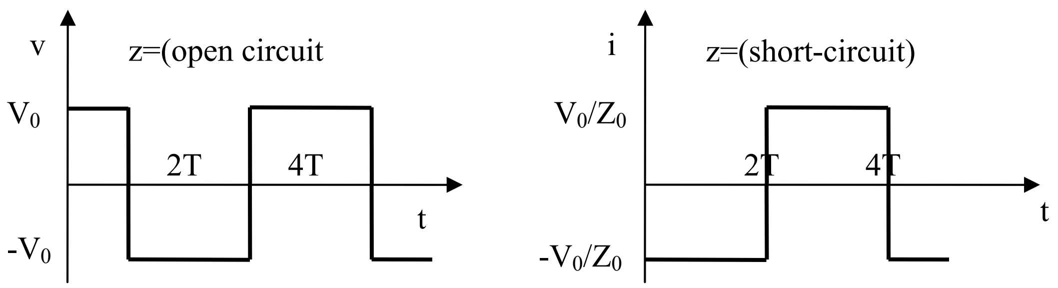


$R_L=0$ $R_L=\infty$ $R_L=Z_0$

2)



3)

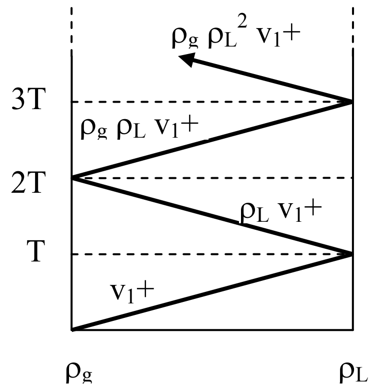


4) Length of the voltage pulse: 2T

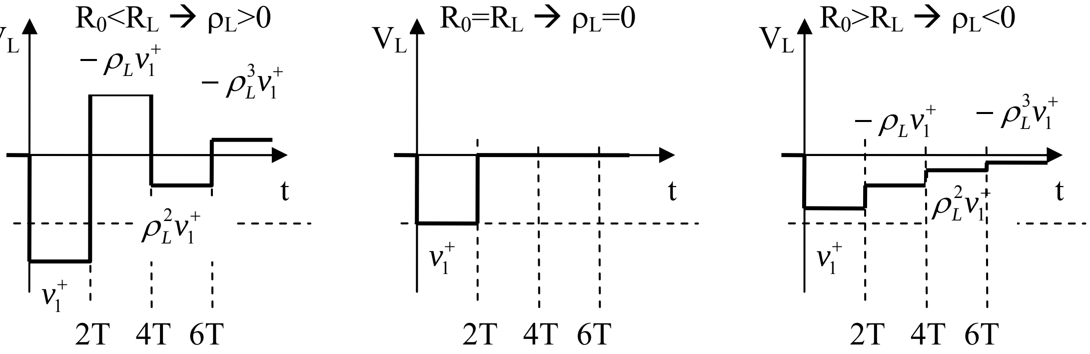
5)

$$v_1^+ = V_0 \frac{Z_0}{Z_0 + R_g}, \quad \rho_g = \frac{R_g - Z_0}{R_g + Z_0}, \quad \rho_L = \frac{R_L - Z_0}{R_L + Z_0}$$

$$V(\infty) = v_1^+(1 + \rho_L + \rho_g\rho_L + \rho_g\rho_L^2 + \cdots) = V_0 \frac{R_L}{R_L + R_g}$$



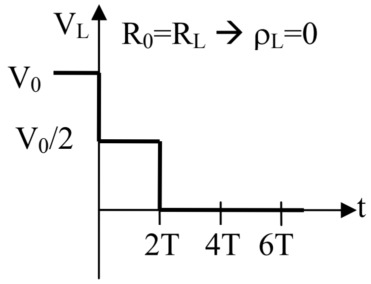
6) $v_1^+ = -I_0 \dfrac{R_L Z_0}{R_L + Z_0} = -I_0 Z_0 \dfrac{1}{2}(1+\rho_L) \quad ; \quad \rho_L = \dfrac{R_L - Z_0}{R_L + Z_0}$



$I_L=V_L/R_L$ for each instant. The evolution of the current ans voltage are the same.

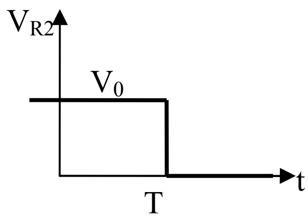
7) $v_1^+ = -V_0 \dfrac{Z_0}{R_L + Z_0} = -V_0 \dfrac{1}{2}(1-\rho_L) \quad ; \quad \rho_L = \dfrac{R_L - Z_0}{R_L + Z_0}$

Time	Total voltage over R_L
<0	V_0
0 → 2T	$V_0 + v_1^+$
2T → 4T	$V_0 + v_1^+(2+\rho_L)$
4T → 6T	$V_0 + v_1^+(2+2\rho_L+\rho_L^2)$
6T → 8T	$V_0 + v_1^+(2+2\rho_L+2\rho_L^2+\rho_L^3)$

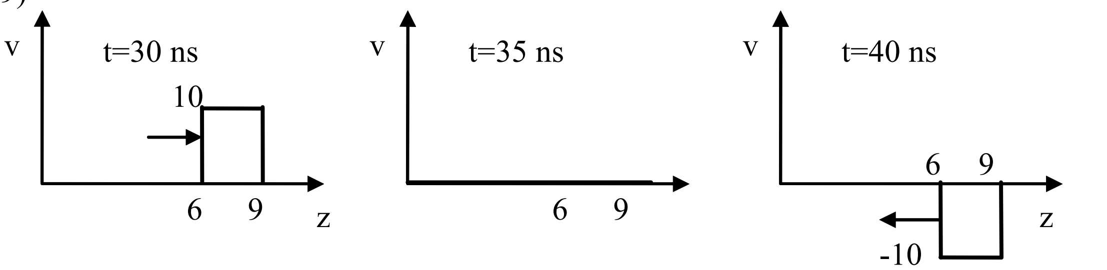


[$R_0<R_L$ i $R_0>R_L$: see table]

8)



9)



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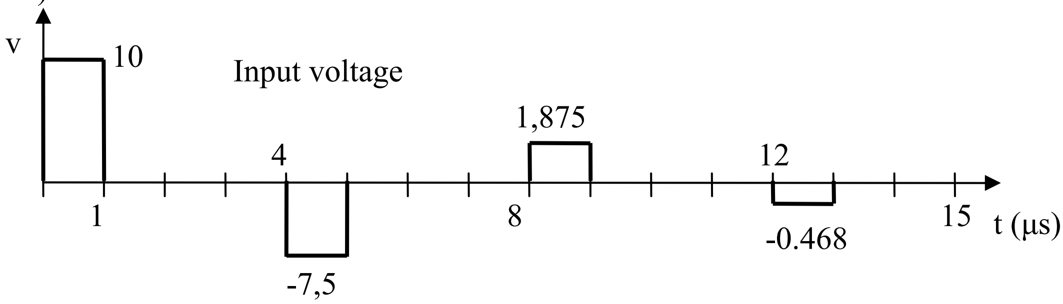

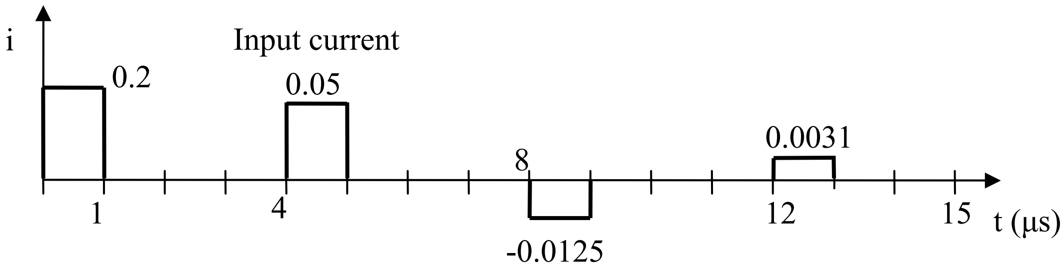

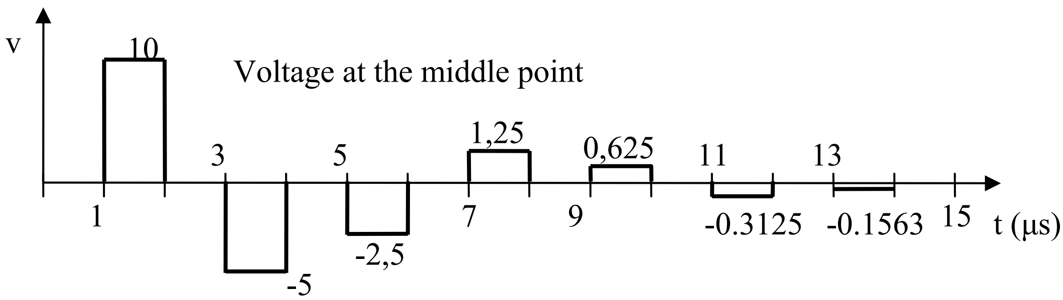

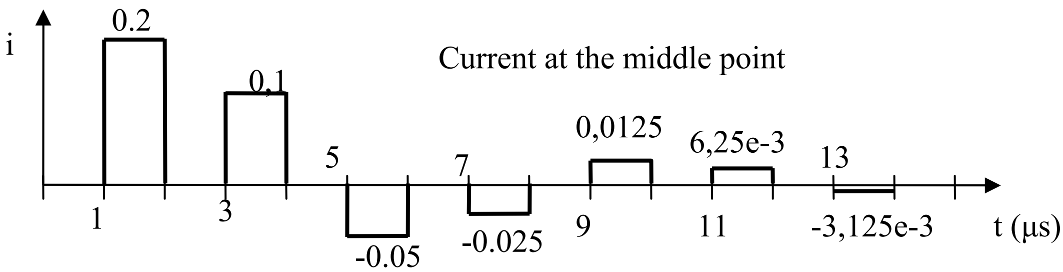

11) a) $R_g = 20\ \Omega$, b) 130 pF/m c) $R_L = 60\ \Omega$

12) a) $\varepsilon_r = 2{,}25$ y L=250 nH/m C=100pF/m b) α =7,596 dB/100m c) $R_g = 50\ \Omega$

13)

a) $\varepsilon_r = 2{,}25$

b) $$\left.\begin{aligned} V_1^{ca} &= V_1^+ e^{-2\alpha\ell}(1+\rho) \\ V_1^{RL} &= V_1^+ e^{-2\alpha\ell}\rho(1+\rho) \end{aligned}\right\}$$ where $\rho = \rho_g = \rho_L$

c) $Z_0 = 75\Omega$; A=0,0114 dB/m; C=66,66 pF/m; L=0,375 $\mu H/m$