Ch3. Crosstalk

2021. Quiz 3.

3. Figure 3 shows two parallel signal lines above a ground plane with the termination resistance R = 50 Ω. Both signal lines are of equal length of 100 cm. One end of the aggressor line is connected to a sinusoidal signal source of 5 V at 1 MHz. The self and mutual distributed inductances and capacitances are given in Table 1.

(a) Calculate the near-end (NE) and far-end (FE) signal voltages (in mV) due to capacitive crosstalk.
(10 marks)

(a) Calculate the NE and FE signal voltages (in mV) due to inductive crosstalk.
(10 marks)

(a) What are the resultant NE and FE signals (in mV) due to both capacitive and inductive crosstalk?
(5 marks)

Figure 3

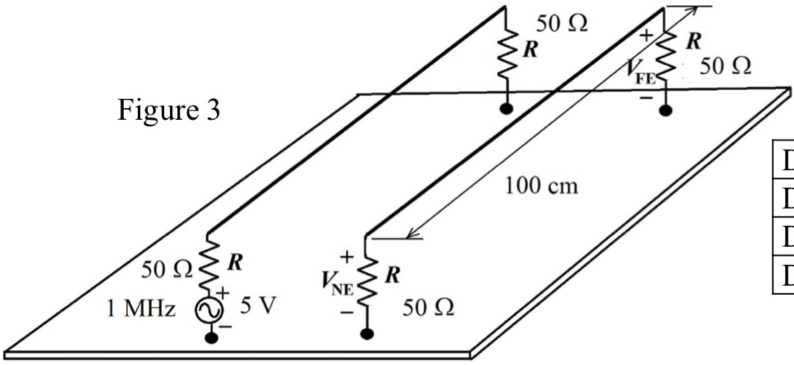

Table 1

Distributed self-capacitance	150 pF/m
Distributed mutual-capacitance	20 pF/m
Distributed self-inductance	300 nH/m
Distributed mutual-inductance	50 nH/m

(a) Capacitive crosstalk:

$$\frac{V_{NE}}{V_G} = \frac{V_{FE}}{V_G} = \frac{j\omega C_{12} R}{4 + j\omega R 4(C_{12}+C) - \omega^2 R^2 C^2 (1+\frac{2C_{12}}{C})}$$

At 1MHz, the $\lambda = \frac{3\times10^8}{10^6} = 300\,m$

the length of conductor (1m) < $\frac{\lambda}{10}$ (30m), the parallel circuit can be modeled as lumped model.

C_{12} = 20pF/m × 1m = 20pF

C = 150pF/m × 1m = 150pF

$\omega = 2\pi f = 6.28\times10^6$ rad/s

$j\omega C_{12} = j125.6\times10^{-6}$ S

$j\omega C = j942\times10^{-6}$ S

Therefore $\frac{V_{NE}}{V_G} = \frac{50\Omega \times j125.6\times10^{-6}S}{4 + j4\times50\Omega(1067.6\times10^{-6}S) - (50)^2\times(942\times10^{-6})^2(1+0.27)}$

$$= \frac{j6.28\times10^{-3}}{4 + j0.214 - 2.817\times10^{-3}}$$

$$\approx \frac{j0.00628}{4} = j0.00157$$

Hence, $V_{NE,cap} = V_{FE,cap} = 5V \times j0.00157 = 7.85mV$

(b). $L = 300\,nH/m \times 1m = 300\,nH$, $\omega L = 1.884\,\Omega$

$M_{12} = 50\,nH/m \times 1m = 50\,nH.$, $\omega M_{12} = 0.314\,\Omega$

$$\frac{V_{NE,ind}}{V_G} = -\frac{V_{FE,ind}}{V_G} = \frac{j\omega M_{12}R}{4R^2 + j4\omega RL - \omega^2(L^2 - M_{12}^2)}$$

$$= \frac{j50\,\Omega \times 0.314\,\Omega}{4 \times 50^2 + j4 \times 50 \times 1.884 - 1.884^2 + 0.314^2}$$

$$\approx \frac{j15.7}{10000 + j376.8} \approx \frac{j15.7}{10^4} = j0.00157$$

$\Rightarrow$ $V_{NE,ind} = -V_{FE,ind} = j7.85\,mV$

$V_{FE,IND} = -j7.85\,mV$

(c)

$V_{NE} = V_{NE,cap} + V_{NE,ind} = j15.7\,mV$

$V_{FE} = V_{NE,cap} + V_{FE,ind} = 0$

2018 - 2019 2. (a)

2. (a) Figure 3 on page 3 shows two parallel signal lines that share the same ground plane. The measured distributed parameters of the two signal lines are given in Table 1 on page 3. All the termination resistance R = 100 Ω. The near-end and far-end crosstalk signal voltages of the victim line are denoted as V_{NE} and V_{FE}, respectively.

(i) Calculate V_{NE} and V_{FE} due to capacitive coupling.

(4 Marks)

(ii) Repeat part (i) for inductive coupling.

(4 Marks)

(iii) Calculate resultant V_{NE} and V_{FE} due to both capacitive and inductive couplings.

(2 Marks)

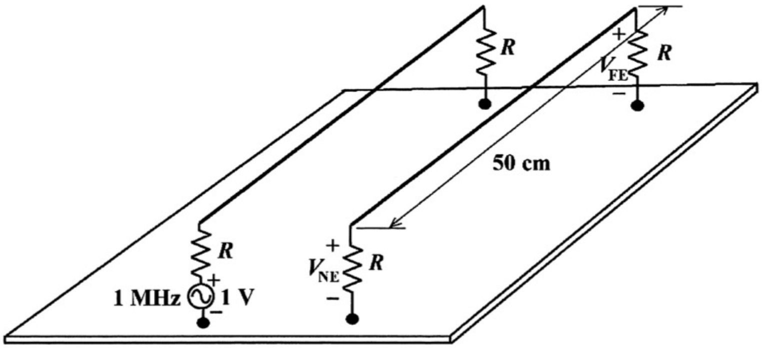

Figure 3

Table 1

Distributed self-capacitance	30 pF/m
Distributed mutual-capacitance	5 pF/m
Distributed self-inductance	50 nH/m
Distributed mutual-inductance	5 nH/m

(i) At 1MHz, the wavelength is $\frac{3\times10^8}{10^6} = 300\ (m)$

The length of conductor (0.5m) < $\frac{\lambda}{10}$ (30 m), hence, the lumped model can be applied.

$$C_{12} = 5\,pF/m \times 0.5\,m = 2.5\,pF$$

$$C = 30\,pF/m \times 0.5\,m = 15\,pF$$

$$\omega C_{12} = 2\pi \times 10^6 \times 2.5\times10^{-12} = 15.7\times10^{-6}\ S$$

$$\omega C = 2\pi\times10^6 \times 15\times10^{-12} = 94.25\times10^{-6} S$$

$$\frac{V_{NE,CAP}}{V_G} = \frac{V_{FE,CAP}}{V_G} = \frac{j\omega C_{12}R}{4 + j4\omega R(C_{12}+C) - \omega^2R^2C^2(1+\frac{2C_{12}}{C})}$$

$$= \frac{j1.57\times10^{-3}}{4 + j0.044 - 1.18\times10^{-4}}$$

$$\approx \frac{j1.57\times10^{-3}}{4} = j\,3.925\times10^{-4} \Rightarrow V_{NE,CAP} = V_{FE,CAP} = 0.3925mV$$

(ii) $M_{12} = 5\,nH/m \times 0.5\,m = 2.5\,nH$

$L = 50\,nH/m \times 0.5\,m = 25\,nH$

$\omega M_{12} = 2\pi \times 10^{6} \times 2.5 \times 10^{-9} = 1.571 \times 10^{-2}\,\Omega$

$\omega L = 2\pi \times 10^{6} \times 25 \times 10^{-9} = 0.1571\,\Omega$

$$\frac{V_{NE,IND}}{V_G} = -\frac{V_{FE,IND}}{V_G} = \frac{j\omega M_{12} R}{4R^2 + j4\omega R L - \omega^2 (L^2 - M_{12}^2)}$$

$$= \frac{j1.571}{4 \times 10^{4} + j62.84 - 0.0244}$$

$$\approx j3.925 \times 10^{-5}$$

$V_{NE,IND} = j3.925 \times 10^{-5} \times 1V = j0.03925\,mV$

$V_{FE,IND} = -V_{NE,IND} = -j0.03925\,mV$

(iii) $V_{NE} = V_{NE,CAP} + V_{NE,IND} = j0.43175\,mV$

$V_{FE} = V_{FE,CAP} + V_{FE,IND} = j0.35325\,mV$

2017-2018 2.(a)

2. (a) Figure 3 on page 3 shows two parallel microstrip lines of length L = 10 cm on a printed circuit board (PCB). The substrate material of the PCB has relative permittivity ε_r = 4.5. The measured distributed parameters of the two parallel microstrip lines are given in Table 1 on page 3. The aggressor line is driven by a 10 MHz sinusoidal signal source with a source voltage V_G = 5 V and a source resistance R_G = 1 kΩ, which is terminated by a load resistance R_L = 1 kΩ. Both the near-end and the far-end of the victim line are terminated by amplifiers with input resistance R_{NE} = R_{FE} = 1 kΩ.

(i) Compute the near-end and the far-end signal voltages due to capacitive and inductive crosstalk.

(7 Marks)

(ii) If either the near-end or far-end signal voltage due to crosstalk exceeds 20 mV, it will interfere with the operation of the amplifier. Do you expect an interference issue?

(3 Marks)

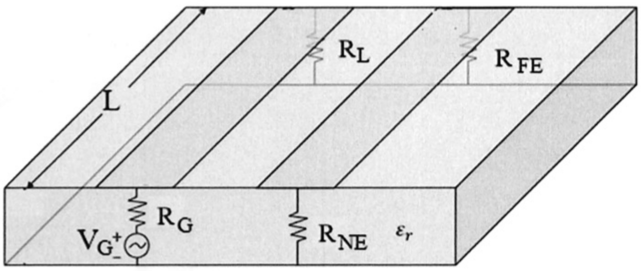

Figure 3

Table 1

Distributed self-capacitance	30 pF/m
Distributed mutual-capacitance	5 pF/m
Distributed self-inductance	50 nH/m
Distributed mutual-inductance	5 nH/m

(a) At 10 MHz, the wavelength is $\lambda = \frac{c}{f\sqrt{\varepsilon_r \mu_r}} = \frac{3\times10^8}{10^7\sqrt{4.5\times1}} = 14.14\,m$

The length of the ~~conductor~~ (0.1m) < $\frac{\lambda}{10}$ (1.414 m), the lump model can be applied.

$C_{12} = 5pF/m \times 0.1m = 0.5pF$

$M_{12} = 5nH/m \times 0.1m = 0.5nH$

$V_{NE,CAP} = \frac{I_N}{2}\cdot R_{NE} = \frac{1}{2}\times\frac{j\omega C_{12}V_G R_L}{R_G+R_L}\times R_{NE} = \frac{1}{2}\times\frac{j\times2\pi\times10^7\times0.5\times10^{-12}\times5V\times10^3}{2\times10^3}\times10^3$

$= j39.27\,mV$

$V_{FE,CAP} = V_{NE,CAP} = j39.27mV$

$V_{NE,IND} = \frac{V_N}{2} = \frac{j\omega M_{12}V_G}{2\times(R_G+R_L)} = \frac{j\times2\pi\times10^7\times0.5\times10^{-9}\times5V}{2\times2\times10^3} = j0.03927\,mV$

$V_{FE,IND} = -V_{NE,IND} = -j0.03927\,mV$

$$V_{NE} = V_{NE,CAP} + V_{NE,IND} = j(39.27 + 0.03927) \approx j39.27\,mV$$

$$V_{FE} = V_{FE,CAP} + V_{FE,IND} = j(39.27 - 0.03927) \approx j39.27\,mV$$

(ii) It exists an inteference issue. Because $|V_{NE}| = 39.27\,mV > 20\,mV$.