Prelab 2

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1) Shortly describe the relevant physical phenomena in action such as EM coupling, antennas and radiations, micro-strip line (propagation mode), fringe field and EM shielding (EMI)

→ EM coupling: EM coupling occur when an electromagnetic field in an electrical wire / circuit results in an electrical charge into another. We talk about inductive coupling (electrical inductance).
↳ EM coupling requires a change in the EM field → AC circuits

→ Antennas & Radiations: An antenna is any structure that can radiate EM energy into a medium. It must provide a time dependant current which generates an EM field. Radiation is the process of emitting energy from a source → in our case, the antenna.

→ Micro-Strip line: (prop. mode): The microstrip line consists of a dialectric layer with a metal coating in the bottom on which lye a conducting strip. This inhomogeneous structure doesn't support a pure TEM wave because of the fields within the 2 guided-wave media (Both $\vec{E}$ and $\vec{H}$ fields will have longitudinal components @ non zero frequencies) → The dominant mode is called quasi-TEM

→ Fring field: fringing effect comes due to electric field lines which makes the antenna size wider after excitation. The main cause of fringing effect is due to width and position of feed in antennas. → A voltage difference applied between these objects result in an electric field between them: thus $\vec{E}$ field exists not just directly between the conductive objects but also extends some distance away = fringing field

→ EM Shielding: EM shielding corresponds to any method used to protect a sensitive signal from external EM signals or preventing a stream from leaking out and interfering to protect a sensitive signal from external EM signals or preventing a stronger from leaking out and interfering with surrounding electronics.

↳ Prevents EMI from impacting sensitive electronics.

↳ consequence of EM coupling.

2) A microstrip transmission line is designed for a 100 Ω impedance. The substrate thickness is 0,51 mm

$\varepsilon_r = 2{,}2$ $\tan(\delta) = 0{,}001 \rightarrow \delta \simeq 10^{-3}$

@ $f = 2{,}45$ GHz → find λ, v_p, v_g, attenuation in the TL.

$$\lambda = \frac{c}{f} = \frac{3\cdot 10^8}{2{,}45\cdot 10^9} \simeq \boxed{0{,}122 = \lambda}$$

$d = h = 0{,}51$ mm

$$Z_0 = 100\,\Omega = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_r}} \ln\left(\dfrac{8d}{w} + \dfrac{w}{4d}\right) & w/d \leq 1 \\ \dfrac{120\pi}{\sqrt{\varepsilon_e}\left(\frac{w}{d} + 1{,}393 + 0{,}667 \ln\left(\frac{w}{d} + 1{,}444\right)\right)} & w/d \geq 1 \end{cases}$$

which gives

$$w = \begin{cases} \dfrac{d\, 8e^{A}}{e^{2A} - 2} & w/d < 2 \\ \dfrac{2d}{\pi}\left[B - 1 - \ln(2B-1) + \dfrac{\varepsilon_r - 1}{2\varepsilon_r}\left(\ln(B-1) + 0{,}39 - \dfrac{0{,}61}{\varepsilon_r}\right)\right] & w/d > 2 \end{cases}$$

where $A = \dfrac{Z_0}{60}\sqrt{\dfrac{\varepsilon_r + 1}{2}} + \dfrac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0{,}23 + \dfrac{0{,}11}{\varepsilon_r}\right)$

$\simeq 2{,}213$

↑ $Z_0 = 100$, $\varepsilon_r = 2{,}2$

$B = \dfrac{377\pi}{2Z_0\sqrt{\varepsilon_r}} \simeq 3{,}99$

$$\rightarrow w = \begin{cases} 0{,}457 \text{ mm} & w/d \simeq 0{,}9 < 2 \\ 0{,}469 \text{ mm} & w/d \simeq 0{,}92 \cancel{>} 2 \end{cases}$$

↳ INCONSISTENT!

So $\boxed{w = 0{,}457 \text{ mm}}$

$$v_p = \frac{c}{\sqrt{\varepsilon_e}} \rightarrow \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\frac{1}{\sqrt{1 + 12\, d/w}} \simeq 1{,}76 = \varepsilon_e$$

$$v_p = \frac{3 \cdot 10^8}{1,76} \cong \boxed{1,7 \cdot 10^8 = v_p}$$

$$\beta = k_0 \sqrt{\varepsilon_e} \rightarrow k_0 = \beta / \sqrt{\varepsilon_e}$$

$$\text{attenuation} = \alpha_d = \frac{k_0 \, \varepsilon_r \, (\varepsilon_e - 1) \tan\delta}{2\sqrt{\varepsilon_e} \, (\varepsilon_r - 1)} \, Np/m = k_0 \times 6,633 \cdot 10^{-4} \, Np/m$$

$$\alpha_d = \frac{2\pi f}{c} \times 6,663 \cdot 10^{-4} \, Np/m = 0,034037$$

$f = 2,45 \cdot 10^9$, $c = 3 \cdot 10^8$

$$\text{attenuation} = \alpha_d \cong 34\%$$

3) A μstrip line of 100 Ω impedance is printed on a substrate of 2,2 relative dielectric constant with a 0,762 mm thickness.
Ignore losses and fringing fields.
Find the shortest line that will exhibit a 5pF capacitance @ f = 2,45 GHz.
Repeat for 5nH inductance

$Z_0 = 100 \, \Omega$ $\quad \varepsilon_r = 2,2$ $\quad h = d = 0,762$ mm

$C = 5pF$ $\quad L = 5nH$

ℓ ?

As before

$$w = \begin{cases} 0,457 \text{ mm} & w/h < 2 \quad (0,6) \\ 0,469 \text{ mm} & w/h \cancel{>} 2 \quad (0,615) \end{cases}$$

So $w = 0,457$ mm $\qquad \frac{w}{h} < 1$ so

$$C = \frac{\varepsilon_r \ell}{60 c \ln\left(\frac{8h}{w} + \frac{w}{4h}\right)}$$

$$\frac{C\,60\,c\,\ln\left(\frac{8h}{w}+\frac{w}{4h}\right)}{\varepsilon_r} = l = \frac{5\cdot 10^{-12}\times 60\times 3\cdot 10^{8}\,\ln\left(\frac{8\times 0{,}762}{0{,}457}+\frac{0.457}{4\times 0{,}762}\right)}{2{,}2}$$

$C = 5pF$

$\hookrightarrow l = 0{,}10644\,m = 106{,}4\,mm$

For the inductance and for $w/h \leq 1$ we have

$$L = \frac{60l}{c}\ln\left(\frac{8h}{w}+\frac{w}{4h}\right) \Rightarrow l = \frac{Lc}{60\,\ln\left(\frac{8h}{w}+\frac{w}{4h}\right)}$$

$$l = \frac{5\cdot 10^{-9}\cdot 3\cdot 10^{8}}{60\ln\left(\frac{8\cdot 0{,}762}{0{,}457}+\frac{0{,}457}{4\times 0{,}762}\right)} = 9{,}608\,mm = l$$