PS5

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Q1)

$$\nabla E = \rho / \epsilon$$

→ Grounded shield has no charge distribution so no electric field gradient.

⇒ no EMI

$$\nabla \times E = \frac{-\delta B}{\delta t}$$ time varying $B \rightarrow E$

→ uniform EMI excite voltage on both wires.

due to turn, direction of B changes & induced V too. causing net cancellation over cable.

$$\nabla \times H = J + \frac{\delta D}{\delta t}$$

→ Getting wires closer causes the loop area to reduce an thus reduce interference.

Q2)

$$\delta = \sqrt{\frac{2}{\omega \mu \sigma}}$$

$$\left.\begin{array}{l} \sigma = 4 \ S/m \\ \quad \text{salt water} \\ \mu = 4\pi \times 10^{-7} \ H/m \\ \omega = 2\pi f = 2\pi \times 10^{4} \end{array}\right\}$$

$$\delta = \sqrt{\frac{2}{2\pi \times 10^{4} \times 4\pi \times 10^{-7} \times 4}}$$

$$\approx \underline{2.5 m}$$

Q3)

$$P = E \times H$$

Power flow $= \int (E \times H) \cdot dA$ since energy is carried

Power Flow $= \int_{\text{cross section}} (E \times H) \cdot dA$ since energy is carried $\perp$ to E & B.

$$H = \frac{I}{2\pi r}$$
$$E = \frac{Q}{2\pi \epsilon r}$$

$$P_{flow} = \int \frac{IQ}{4\pi^2 \epsilon r^2} \times r\,dr\,d\theta$$

$$= V \times I$$

after simplification

$$C = \frac{2\pi\epsilon}{\ln(r_o/r_i)} = Q/V \Rightarrow$$

Q4)

$$E_y = V/h$$

$$= \frac{\sigma}{\epsilon}$$

$e \times dy \rightarrow \sigma$ as charge is on surface primarily.

$$V/h = \frac{Q/w}{\epsilon}$$

$$Q = \frac{V\epsilon w}{h}$$

$C = \frac{\epsilon w}{h}$ Capacitance / unit l.

$Q \rightarrow$ charge per unit l.

$$\nabla \times H = J + \cancel{\frac{\delta D}{\delta t}}^{\,0}$$

$$\Rightarrow \nabla \times H = J$$
$$= I/w$$

$I \rightarrow$ current / unit l.

$$\phi = \oint B \cdot dA$$
$$= \mu_0 H\, dA = H \times \mu\, h$$ per unit l

$\phi = \oint B \cdot dA$

$= \int H \mu \, dA = H_x \mu \; h$ per unit l

$$L = \phi / I = \frac{H_x \mu \; h}{I}$$

$$Z = \sqrt{L/C} = \sqrt{\frac{\frac{H_x \mu \cancel{\omega} h}{I}}{\epsilon \cancel{\omega}/h}}$$

$$= h \sqrt{\frac{\cancel{H_x} \mu}{\epsilon \cancel{I}} \times \frac{1}{w}} = \frac{h}{w} \sqrt{\frac{\mu}{\epsilon}}$$

$$v = \frac{1}{\sqrt{\mu \epsilon}}$$

Q5) a)

$$Z_0 = \frac{1}{2\pi \sqrt{\varepsilon_r \varepsilon_0 \mu_0}} \ln\left(\frac{r_o}{r_i}\right)$$

$$\approx \frac{60}{\sqrt{\epsilon_r}} \ln\left(\frac{r_o}{r_i}\right) \approx \frac{60}{\sqrt{2.26}} \ln\left(\frac{1.48}{0.406}\right)$$

$$Z_0 \approx 39.9 \times 1.29 = 51.5\,\Omega$$

b)

$$v = \frac{c}{\sqrt{\varepsilon_r}} = \frac{3 \times 10^8}{\sqrt{2.26}} \approx 2 \times 10^8 \text{ m/s}$$

c) Maximum cable length:

1 ns pulse.

$$v \times t = 2 \times 10^8 \times 10^{-9} = 0.2 \text{m}$$

d) outer diameter = 30 mils

≈ 0.000762 m

$$Z_0 = \frac{60}{\sqrt{\epsilon_r}} \ln\left(\frac{r_0}{r_i}\right) \Rightarrow r_i = r_0 e^{-\frac{Z_0\sqrt{\epsilon_r}}{60}}$$

$$r_i = 0.000381 \times e^{-\frac{50\times\sqrt{2.26}}{60}}$$

$$\approx \underline{220\,\mu m}$$

e) $\lambda = v/f$

$$\lambda = 2r_0 = 0.00296\ m$$

$$f = v/\lambda = \frac{2\times10^{8}}{0.00296} \approx \underline{\underline{67.6\,GHz}}$$

Q4) a) 64 bytes $\longrightarrow$ 512 bits

prop. delay $= 4.6\ ns/m$

Impedance $= 100\Omega$

10Mbps , bit period $= \frac{1}{D}$ $\rightarrow$ $\underline{\underline{\frac{1}{10^7}}}$

Total frame time $= 512 \times T_b = 5.12\times10^{-5}\ s$.

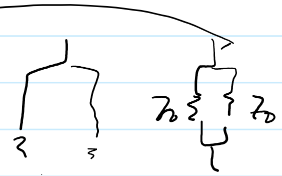
Distance $= v \times (\text{frametime})$

$$= \frac{1}{4.6\times10^{-9}} \times \text{frame time} \approx \underline{11.1\ m}$$

b)

$$R = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$Z_L = \frac{Z_0}{2} = 50\Omega$$



$$R = \frac{50-100}{150} = \underline{\underline{-\frac{1}{3}}}$$