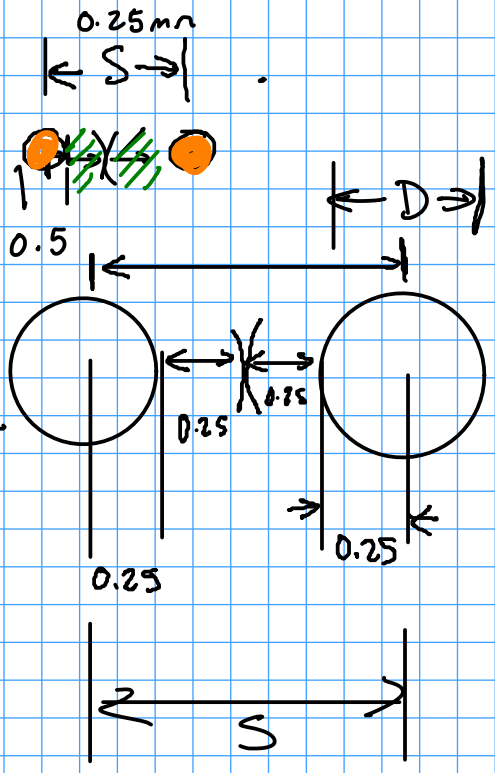
ELEX 3525 - Answers to Lecture 2 Exercises

$$Z_0 \approx \frac{120}{\sqrt{\varepsilon_r}} \ln\left(\frac{2S}{D}\right)$$

Exercise 1: What is the characteristic impedance of UTP made from 24-gauge wire with polyethylene insulation ($\varepsilon_r = 2.2$) of 0.25mm thickness?



24 ga = 0.5mm dia (D)

= 2 x radius of wire + 2 x thickness of ins.

= 2 x 0.25 + 2 x 0.25

= 0.5 + 0.5 = 1

S = 4 x 0.25 = 1mm

D = 0.5mm

$$Z_0 = \frac{120}{\sqrt{2.2}} \times \ln\left(\frac{2 \cdot 1}{0.5}\right) \approx \frac{120}{1.4} \ln(4)$$

$$\approx 100 \cdot 2 = 200$$

$$= 112\ \Omega$$

$$Z_0 \approx \frac{138}{\sqrt{\varepsilon_r}} \log_{10}\left(\frac{D}{d}\right)$$

Exercise 2: What is the characteristic impedance of a coax cable with a 0.8mm diameter center conductor, 3.5mm diameter shield and foamed polyethylene between them that has a dielectric constant of 1.5?

d = 0.8

D = 3.5

$\varepsilon_r = 1.5$

$$Z_0 = \frac{138}{\sqrt{1.5}} \log_{10}\left(\frac{3.5}{0.8}\right) \approx 100 \log_{10}(4)$$

$\log_{10}(2) = 0.3$

$\log_{10}(4) = 0.6$

$$\approx 100 \cdot 0.6 = 60$$

$$\approx 72$$

$$Z_O = \sqrt{\frac{L}{C}}$$

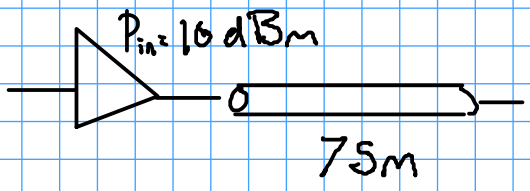
Exercise 3: What is the characteristic impedance of a lossless cable with an inductance of 94 nH per foot and capacitance of 17pF/ft?

$$Z_0 = \sqrt{\frac{94 \times 10^{-9}}{17 \times 10^{-12}}} \approx \sqrt{\frac{100}{20} \frac{\times 10^{-9}}{10^{-12}}}$$

$$\approx \sqrt{5 \times 10^{3}} = 74\ \Omega$$

Exercise 4: An 800 MHz signal is output from a CATV amplifier at a power level of 10dBm. What power level would you expect at the other end of a 75m run of co-ax whose loss is specified as 24dB/100m at 800 MHz?

$f = 800\ MHz$



24dB/100m

$$Loss = 24\ dB/100m \cdot 75m$$
$$= 18\ dB$$

$$P_{OUT} = P_{in} - Loss$$
$$= 10\ dBm - 18\ dB$$
$$= -8\ dBm$$

$$VF = \frac{1}{\sqrt{\varepsilon_r}}$$

Exercise 5: What is the velocity factor for a cable with polyethylene insulation ($\varepsilon_r = 2.2$)? How long would it take for a signal to propagate 100m? For a cable with air dielectric?

for $\varepsilon_r = 2.2$

$$VF = \frac{1}{\sqrt{2.2}} = 0.674$$

$$v = \underbrace{3 \times 10^8}_{c} \cdot 0.66 = 2 \times 10^8$$

$$t = \frac{d}{v} = \frac{100}{2 \times 10^8} = 50 \times 10^{-8} = 500 \times 10^{-9} = 500\,ns$$

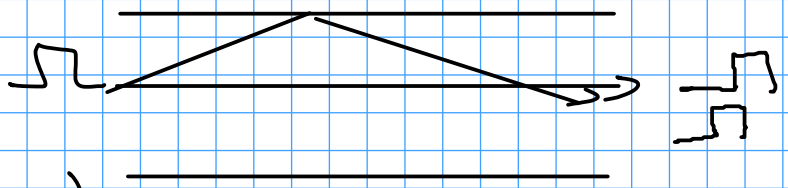
for air $VF = 1$

$$t = \frac{100}{3 \times 10^8} = 330\,ns.$$

$125\,\mu m = 125 \times 10^{-6}\,m$

$$\frac{125 \times 10^{-6}}{1 \times 10^{-3}}\,mm$$

$$\approx \frac{1}{8}$$



Exercise 6: If the optical signal wavelength is 1330nm what is the frequency?

$$c = \lambda f$$

$$f = \frac{c}{\lambda} = \frac{2 \times 10^8}{1.3 \times 10^{-6}} \text{ (assumed)}$$

$$= 1.5 \times 10^{14} = 150 \times 10^{12}$$

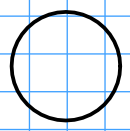
$$= 150\ THz$$

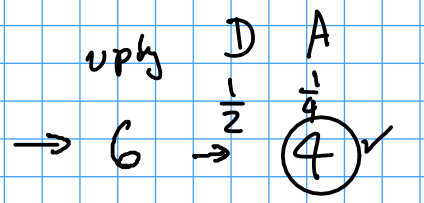
Exercise 7: How much does a cable's resistance increase when the gauge size increases by 6? By 3? Hint: a wire's resistance is ~~proportional~~ inversely to its cross-sectional area.

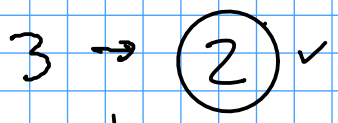
gauge ↑ 6 → diameter ↓ × $\frac{1}{2}$

gauge ↑ +3 → diameter ↓ $\frac{1}{\sqrt{2}}$

resistance ≃ gauge







$D = \frac{1}{\sqrt{2}}$

$A = \frac{1}{2}$

$D = \left(\frac{1}{2}\right)^{\left(\frac{\Delta}{6}\right)}$

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

Where P_R and P_T are the received and transmitted powers, G_T and G_R are the gains of the transmit and receive antennas, λ is the wavelength and d is the distance from transmitter to receiver.

Exercise 8: A point-to-point link uses a transmit power of 1 Watt, transmit and receive antennas with gains of 20dB and operates at 3 GHz. How much power is received by the receiver?

$P_T = 10 \log\left(\frac{1000}{1\,mW}\right)$

$= 30\ dBm$

$P_T = 1W$

$G_T = 20\ dB$

$G_R = 20\ dB$

$f = 3\ GHz$

$c = \lambda f$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 10^{-1}$ assume $d = 100\ m$

in dB(m): $P_R = P_T + G_T + G_R + 20 \log\left(\frac{\lambda}{4\pi d}\right)$

$= 30 + 20 + 20 + 20\log\left(\frac{0.1}{4\pi \cdot 100}\right)$

$= 30 + 20 + 20 - 82$

$= -12\ dBm$