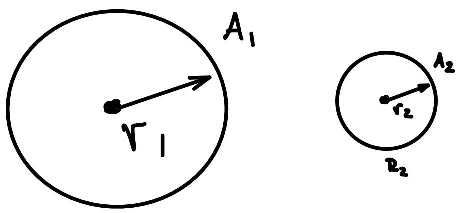
Lecture 3 - Common Transmission Media

Exercise 1: How much does a cable's resistance increase when the gauge size increases by 6? By 3? Hint: a wire's resistance is inversely proportional to its cross-sectional area.



R_1

resistance

$$\frac{R_2}{R_1} = \frac{A_1}{A_2} = \frac{\pi r_1^2}{\pi r_2^2} = \left(\frac{r_1}{r_2}\right)^2$$

radius

$$A = \pi r^2 \qquad \frac{r_2}{r_1} = \frac{1}{2} \text{ or } \frac{1}{\sqrt{2}}$$

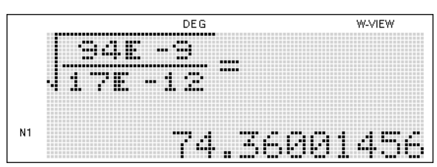
$$\frac{R_2}{R_1} = \left(\frac{2}{1}\right)^2 = 4$$

If gauge increases by 3; diameter

$$\frac{R_2}{R_1} = \left(\frac{r_1}{r_2}\right)^2 = \left(\frac{\sqrt{2}}{1}\right)^2 = 2$$

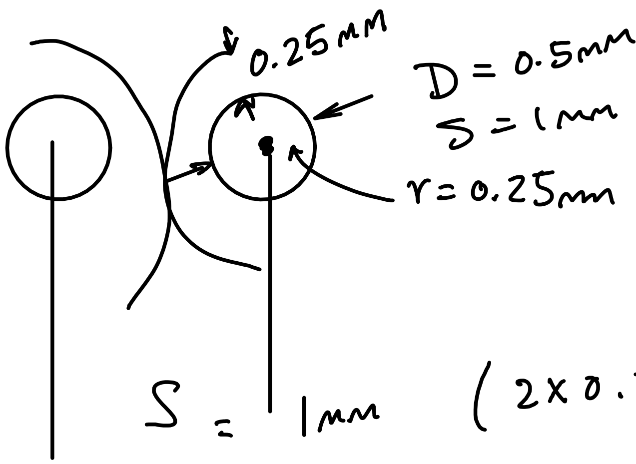
Exercise 2: What is the characteristic impedance of a lossless cable with an inductance of 94 nH per foot and capacitance of 17pF/ft?

$$Z_0 = \sqrt{\frac{L}{C}} =$$

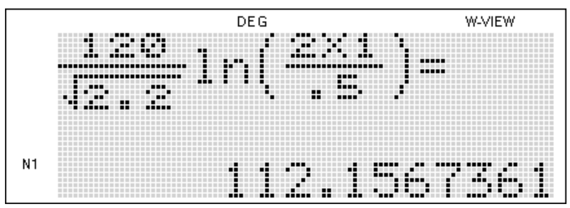


Exercise 3: What is the characteristic impedance of UTP made from 24-gauge wire with polyethylene insulation ($\varepsilon_r = 2.2$) of 0.25mm thickness?

$\varepsilon_r = 2.2$



$(2 \times 0.25 + 2 \times 0.25)$

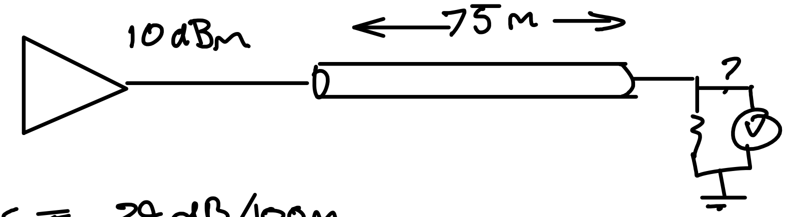


Exercise 4: What is the characteristic impedance of a co-ax cable with a 0.8mm diameter center conductor, 3.5mm diameter shield and foamed polyethylene between them that has a dielectric constant of 1.5?

45
72

$$\frac{60}{\sqrt{1.5}} \ln\left(\frac{3.5}{0.8}\right) \approx 72\ \Omega$$

Exercise 5: 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? Hint: gain $G_{dB} = 10\log_{10}(P_{out}/P_{in})$.



$P_{out} = 10 - 18 = -8\,dBm$

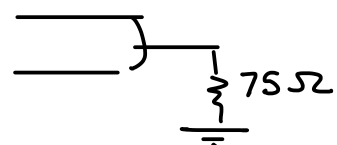
loss = 24 dB/100m

$$\text{loss} = \frac{75}{100} \cdot 24\,dB = 18\,dB.$$

Exercise 6: Assuming the transmission line in the above example is properly terminated, what are the voltage and current at the input and output of the cable? Hint: $P = V^2/R$.

assuming $Z_0 = 75$

$\therefore R = 75$



$-8\,dBm$

$$P = \frac{V^2}{R}$$

$$-8 = 10\log\left(\frac{P}{.001}\right)$$

$$= 0.001 \cdot 10^{\frac{-8}{10}} = 0.16\,mW$$

$$V = \sqrt{P \cdot R} = \sqrt{0.16\times10^{-3} \cdot 75}$$

$$= 0.11\,V$$

$$P = I^2 R$$

Exercise 7: 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?

$$VF = \frac{1}{\sqrt{\varepsilon_r}} = \frac{1}{\sqrt{2.2}} = 0.66$$

$$v = \frac{d}{t} \qquad t = \frac{d}{v} = \frac{10^2}{3 \times 10^8 \cdot 0.66}$$

$$= 0.5 \times 10^{-6}$$

$$= 500\text{ns.}$$

Exercise 8: If the optical signal wavelength is 1330nm what is the frequency? Note that the wavelength is specified in free space, not in the fiber.

$$v = \frac{1}{\sqrt{\varepsilon_r}} \cdot c$$

$$\lambda \quad f \qquad c = \lambda f \qquad c = 3 \times 10^8$$

$$m \quad \frac{1}{s} \qquad \frac{m}{s} = m \cdot \frac{1}{s}$$

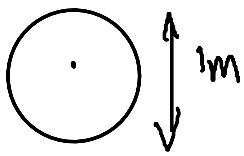
$$f = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m/s}}{1.33 \times 10^{-6}} = 2.3 \times 10^{14}$$

$(\times 10^{12})$

233 THz

$$1.33 \times 10^{-6} = 1330 \times 10^{-9}$$

Exercise 9: For some types of antennas, such as reflectors, the effective aperture is closely approximated by the physical area of the antenna. What are the approximate effective aperture and gain of a 1-m diameter Ku-band ($\approx$ 15 GHz) satellite dish?

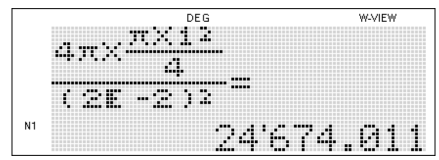


$f = 15\ \text{GHz}$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{15 \times 10^9} \simeq 2 \times 10^{-2}$

$$A_e \simeq A = \pi r^2 = \frac{\pi d^2}{4} \simeq \frac{3}{4}\ m^2$$

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \frac{\pi d^2}{4}}{(2 \times 10^{-2})^2} =$$



Exercise 10: 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 a receiver 300m away?

$P_T = 1\,W$

$G_T = G_R = 20\ dB$

$f = 3 \times 10^9\ Hz$

$d = 300m$

$G\,(dB) = 10 \log(G)$

$G = 10^{\frac{G_{dB}}{10}} = 10^{\frac{20}{10}} = 10^2$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1m$

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2 = 1 \cdot 10^2 \cdot 10^2 \left(\frac{0.1}{4\pi \cdot 300}\right)^2$$

$= 7\ \mu W$

Exercise 11: Rank each of twisted-pair, co-ax, optical fiber and free space media according to cost of the medium, cost of the interface, media size and immunity to interference.

	Cost			
	media	interface	media size	immunity to i/f
UTP	L	L	medium	
co-ax	M	↑	largest	
OF	?	↓	Small	most
wireless	Lowest	H	Smallest	least