Lecture 2

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.

increase of 6 in gauge → diameter doubles

equation is: $2^{\left(\frac{\Delta g}{6}\right)}$ ← number of "doublings" where Δg in change in gauge.

examples:
$$\begin{cases} \Delta g = 6 \rightarrow 2^{1} = 2 \\ \Delta g = 3 \rightarrow 2^{\frac{1}{2}} = \sqrt{2} \approx 1.4 \\ \Delta g = -6 \rightarrow 2^{-1} = \frac{1}{2} \end{cases}$$

$$\text{resistance} \propto \frac{1}{\text{Area}} \qquad \text{Area} \propto (\text{Diameter})^2$$

↖ "proportional to"

$$R_{new} \propto \frac{1}{(\text{Diameter})^2} = \frac{1}{\left(2^{\left(\frac{\Delta g}{6}\right)}\right)^2} = 2^{-\left(\frac{\Delta g}{3}\right)}$$

e.g.: $\Delta g = 6$ $\quad R_{new} \propto 2^{-\frac{6}{3}} = 2^{-2} = \frac{1}{4}$

$\Delta g = 3$ $\quad R_{new} \propto 2^{-\frac{3}{3}} = 2^{-1} = \frac{1}{2}$

∴ increasing gauge by 6 reduces resistance by 4X (increases by 4)

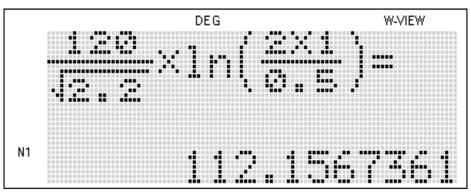
increasing gauge by 3 reduces resistance by 2X

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

$$Z_o = \sqrt{\frac{L}{C}} = \sqrt{\frac{94 \times 10^{-9}}{17 \times 10^{-12}}} \approx 74\,\Omega$$

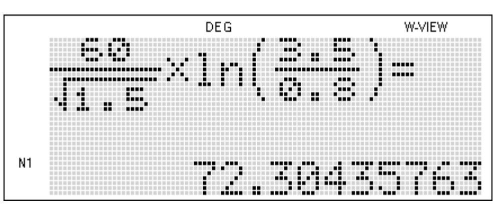
Exercise 3: What is the characteristic impedance of UTP made from 24-gauge wire with polyethylene insulation ($\varepsilon_r = 2.2$) of 0.25mm thickness?

$$Z_o = \frac{120}{\sqrt{\varepsilon_r}} \ln\left(\frac{2S}{D}\right) = \frac{120}{\sqrt{2.2}} \ln\left(\frac{2 \times 1}{0.5}\right) = 112\,\Omega$$



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?

$$Z_o = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right) = \frac{60}{\sqrt{2.2}} \ln\left(\frac{3.5}{0.8}\right) = 72\,\Omega$$



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?

$$P_{out} = P_{in} \cdot Loss \quad \underline{\text{OR}} \quad P_{out}(dB) = P_{in}(dB) - Loss(dB)$$

$$P_{in} = 10\ dBm \qquad Loss = (\text{unit lengths}) \cdot \frac{dB}{(\text{unit length})}$$

$$= \left(\frac{75}{100}\right) \cdot 24 = 18\ dB$$

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

in linear units: $10\ mW \cdot 10^{\frac{-18}{10}} \approx 10\ mW \cdot 10^{-2} = 0.1\ mW = -10\ dBm$

Exercise 6: 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?

$$v = \frac{d}{t}$$

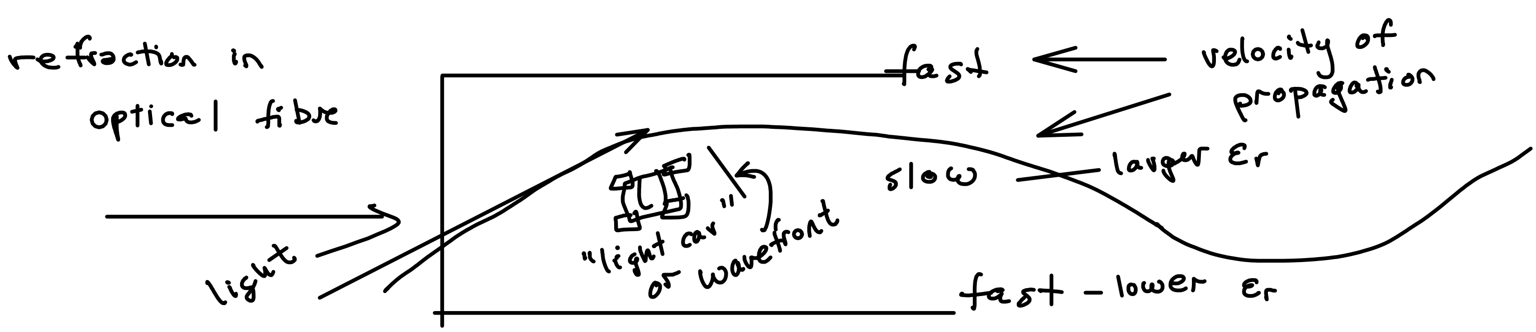
$$t =$$

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

$$v = 0.66 \times 3 \times 10^8 = 2 \times 10^8\ m/s$$

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

ε_r for air $= 1 \quad VF = 1 \qquad t = \frac{d}{v} = \frac{100}{3 \times 10^8} = 333ns.$



Exercise 7: If the optical signal wavelength is 1330nm what is the frequency?

$\lambda = 1330 \times 10^{-9}$ m

$f = ?$

$c = 3 \times 10^{8}$ m/s

$c = \lambda f$

$f = \frac{c}{\lambda}$

$= \frac{3 \times 10^{8} \text{ m/s}}{1.330 \times 10^{-6} \text{ m}}$

$= 2.3 \times 10^{14}$ Hz

$= 230 \times 10^{12}$

230 THz

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 a receiver 300m away?

$P_T = 1W$

$G_T = G_R = 10^{\frac{20}{10}} = 100$

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

$d = 300$

$P_R = P_T\, G_T\, G_R \left(\frac{\lambda}{4\pi d}\right)^2 = 1 \cdot 100 \cdot 100 \cdot \left(\frac{0.1}{4\pi \cdot 300}\right)^2$

$\approx 10^{4} \left(\frac{10^{-1}}{4 \times 10^{3}}\right)^2 = 10^{4}\left(\frac{1}{4} \times 10^{-4}\right)^2 = \frac{10^{4}}{16} \times 10^{-8}$

$= 1 \times 10^{-5}$ $\quad = 7 \times 10^{-6}$ $\quad = 7 \mu W$

Exercise 9: 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.

	U.T.P.	co-ax	F.O.	wireless
cost of medium	L	M	H	lowest (free)
cost of interface	L	L	M	H
media size	M	thickest	thinnest	?
immunity to interference	good	better	best	worst