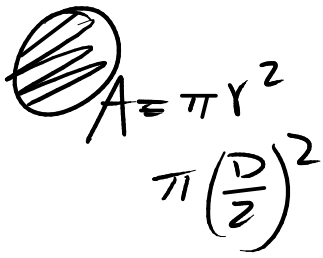
Lecture 2

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 proportional to its cross-sectional area.

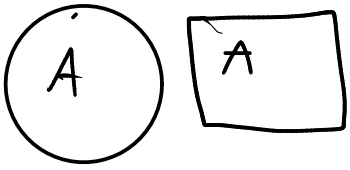


gauge ↑ 6 $(\times 6)$

D ↓ $\frac{1}{2}$ $(\times \frac{1}{2})$

A ↓ $\frac{1}{4}$ $(\times \frac{1}{4})$

R ↑ 4 $(\times 4)$



$\frac{1}{k} \cdot \frac{1}{k} \cdot \frac{1}{k} \cdot \frac{1}{k} \cdot \frac{1}{k} \cdot \frac{1}{k} = \frac{1}{2} = \frac{1}{k^6}$

$k = 2^{\frac{1}{6}}$ ← diameter factor per gauge

gauge ↑ 3 $(\times 3)$

D ↓ $\frac{1}{\sqrt{2}}$ $(\times \frac{1}{\sqrt{2}})$

A ↓ $\frac{1}{2}$ $(\times \frac{1}{2})$

R ↑ 2 $(\times 2)$

if add 3 to gauge:

$\frac{1}{k} \cdot \frac{1}{k} \cdot \frac{1}{k}$

$\frac{1}{2^{\frac{1}{6}}} \cdot \frac{1}{2^{\frac{1}{6}}} \cdot \frac{1}{2^{\frac{1}{6}}}$

$\frac{1}{2^{\frac{3}{6}}} = \frac{1}{2^{\frac{1}{2}}} = \frac{1}{\sqrt{2}}$

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

$$Z_0 = \sqrt{\frac{L}{C}} \approx \sqrt{\frac{100 \times 10^{-9}}{20 \times 10^{-12}}} \approx \sqrt{5000}$$

$$= 74\ \Omega$$

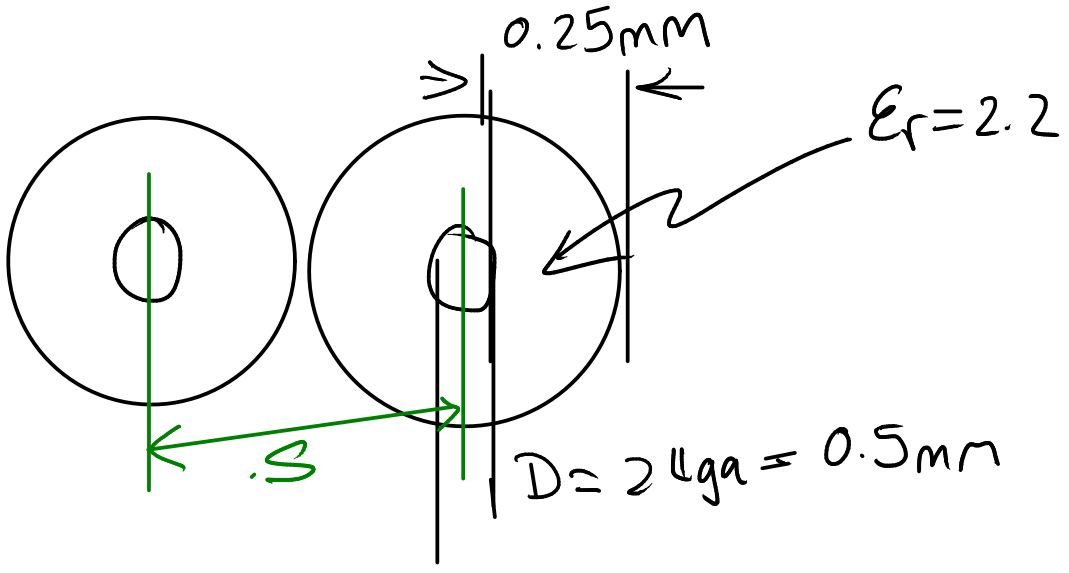
$$\approx \sqrt{50} \cdot \sqrt{100}$$

$$\approx 7 \cdot 10$$

$$= 70.$$

$$\sqrt{\frac{H/\cancel{m}}{F/\cancel{m}}}$$

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?

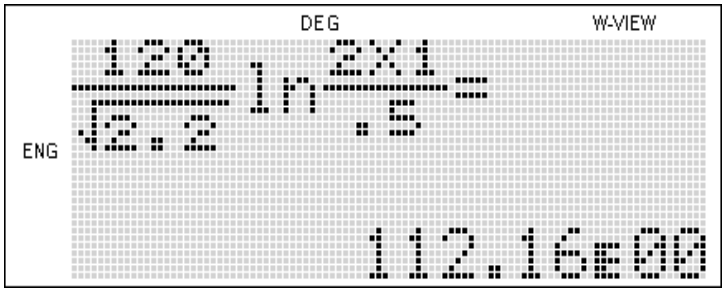


$$Z_0 = \frac{120}{\sqrt{\varepsilon_r}} \ln\left(\frac{2S}{D}\right)$$

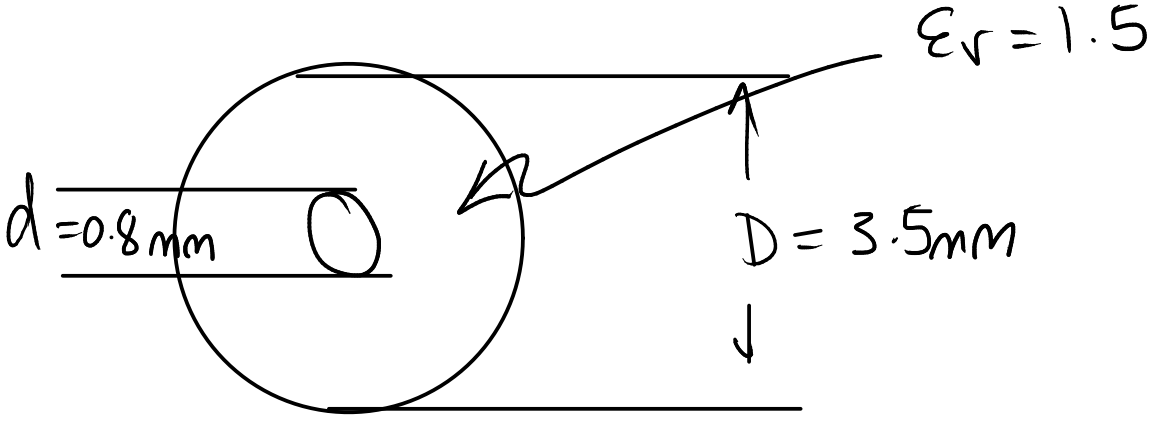
$$S = 0.25 + 0.25 + 0.25 + 0.25 = 1\,mm$$

radius dielectric

$$Z_0 = \frac{120}{\sqrt{2.2}} \ln\left(\frac{2 \cdot 1}{0.5}\right) \approx 112\ \Omega$$



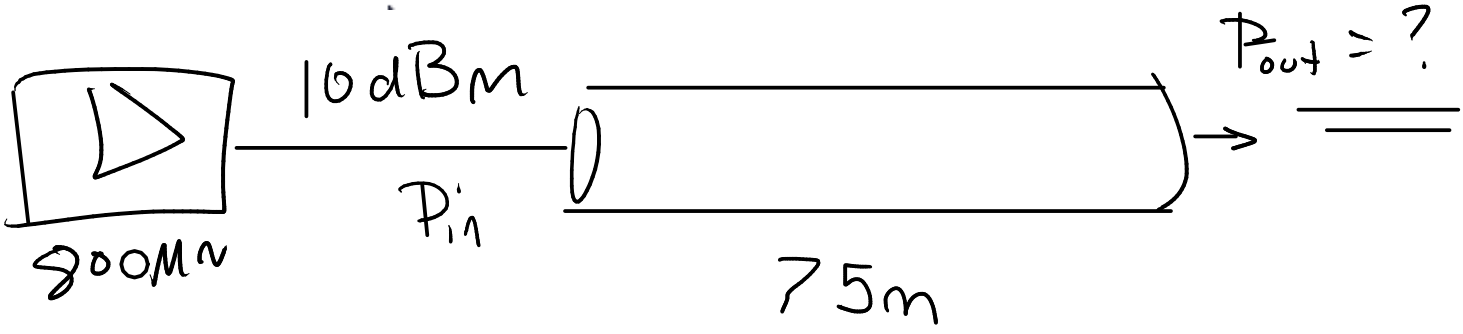
Exercise 4: What is the characteristic impedance of a co-ax cable with a 0.8mm diameter center conductor, 3.5mm diameter shield and foamed polyethylene between them that has a dielectric constant of 1.5?



$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right) = \frac{60}{\sqrt{1.5}} \ln\left(\frac{3.5}{0.8}\right)$$

$$\approx 72\ \Omega$$

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?



loss = 24 dB/100m

loss of cable = $\frac{75}{100} \cdot 24\text{dB} = 18\text{dB}$

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

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?

$$VF = \frac{1}{\sqrt{\varepsilon_r}} \approx 0.674$$

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

$$v = \frac{d}{t} \qquad t = \frac{d}{v} = \frac{100}{2 \times 10^8} = 0.5 \times 10^{-6}$$

500 ns.

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

10^9 G

10^{12} T

10^{15} P

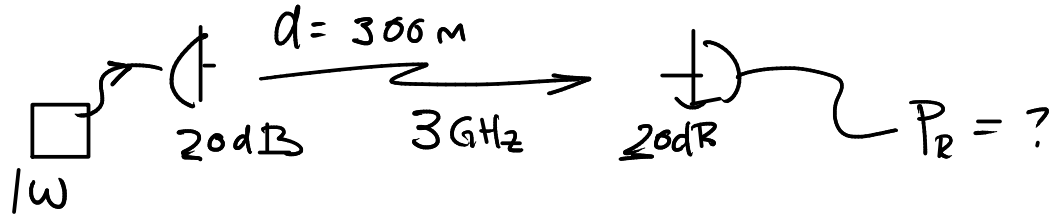
$$c = \lambda f$$

$$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{1.33 \times 10^{-6}} \approx 2.5 \times 10^{14}$$

$$250 \times 10^{12}$$

$$= 250 \text{ THz}$$

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?



$c = \lambda f$

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

$P_T = 1W$

$G_T = 20dB$

$G_T = 10^{\left(\frac{20}{10}\right)} = 10^2 = 100$

$G_R = 20dB = 100$

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

$$= 1 \cdot 100 \cdot 100 \left(\frac{0.1}{4\pi \cdot 300}\right)^2 \simeq 7 \times 10^{-6}\, W$$

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

$$= 10^{-5}$$

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

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.

	UTP	co-ax	FO	free space
cost of media	M	H	H	L
cost of interface	L	M	M	H
media dimensions	M	H	L	?
immunity to interference	M^-	M^+	H	L