Lecture 2-Transmission Lines

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 increase of 6 <u>halves</u> the diameter.

the cross-sectional area changes by $\times\frac{1}{4}$

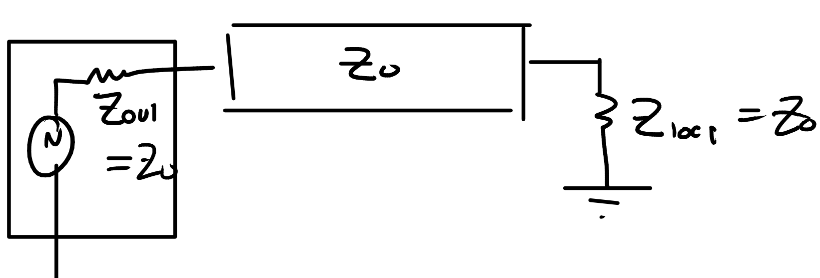
$\left(A = \pi\left(\frac{D}{2}\right)^2\right)$ and the resistance by $\times 4$.

Each increase of +1 in gauge decreases the diameter by $\times 2^{-1/6}$ $\left(\left(2^{-1/6}\right)^6 = \frac{1}{2}\right) = 0.891$

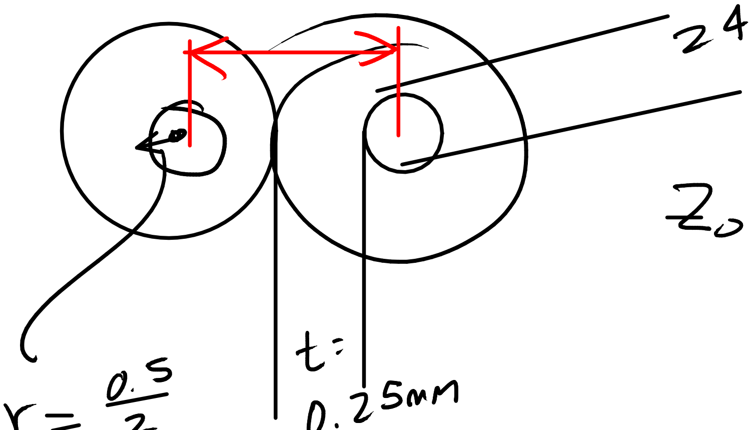
$\therefore$ +3 in gauge is $\times(0.891)^3 = \times 6.71$ in diameter & $\frac{1}{2}$ in area. $\therefore$ resistance is doubled.

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

$$Z_0 = \sqrt{\frac{L}{C}} = \sqrt{\frac{\overset{\approx 100}{94 \times 10^{-9}}}{\underset{\approx 20}{17 \times 10^{-12}}}} \approx \sqrt{5000} \simeq 75$$



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?



24 AWG = 0.5 mm

$\varepsilon_r = 2.2$

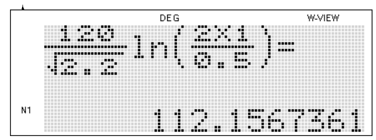
$$Z_0 = \frac{120}{\sqrt{\varepsilon_r}} \ln\left(\frac{2S}{D}\right)$$

$r = \frac{0.5}{2} = 0.25\text{mm}$

$t = 0.25\text{mm}$

$$S = 2(r + t)$$
$$S = 2(0.25 + 0.25) = 1\text{mm}$$

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



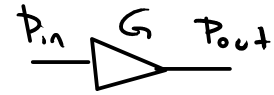
Exercise 4: What is the characteristic impedance of a co-ax cable with a 0.8mm diameter center conductor, 3.5mm diameter shield and foamed polyethylene between them that has a dielectric constant of 1.5?

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

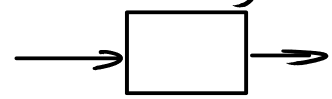
$$= 72\,\Omega$$

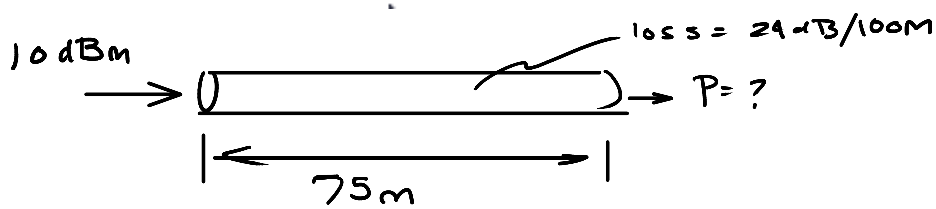
50 Ω also popular for radio application

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?



$P_{out} = P_{in} + G$ (in dB)





$$\text{loss} = \frac{75}{100} \times 24\,dB = 18\,dB \quad (\text{gain of } -18\,dB)$$

$$P_{in} = 10\,dBm \qquad P_{out} = P_{in} + \text{Gain} = 10 + (-18) = -8\,dBm$$

$$-8 = 10 \log\left(\frac{P_{out}}{1mW}\right)$$

$$P_{out} = 10^{-0.8} \cdot 1mW = \underline{\underline{0.16\,mW}}$$

$$\frac{P_{out}}{P_{in}} = 10\log\left(\frac{\frac{(V_{out})^2}{R}}{\frac{(V_{in})^2}{R}}\right) = 20\log\left(\frac{V_{out}}{V_i}\right)$$

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?

$c = 3\times10^8 \, m/s$

DEG W-VIEW

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

N1 0.67419962

$v_p = VF \cdot c \approx 2\times10^8 \, m/s$

$v = \frac{d}{t}$ $t = \frac{d}{v_p} = \frac{100}{2\times10^8} \approx 0.5\,\mu s.$

for air $\varepsilon_r \approx 1$ $\therefore t = \frac{d}{c} = \frac{100}{3\times10^8} \approx 0.33\,\mu s$

$\therefore VF \approx 1$

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

$M = 10^6$
$G = 10^9$
$T = 10^{12}$

$c = \lambda f$

$f = \frac{c}{\lambda} = \frac{3\times10^8}{1.3\times10^{-6}} = 2.3\times10^{14} \approx 2.3 \times 10^{12}$

$\approx 230 \, THz$

2.4 GHz
5 GHz
} common wireless frequencies

mmWave : 10's of GHz (max. used today)

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?

$c = \lambda f$

$P = 10 \log \left(\frac{P_2}{P_1} \right)$

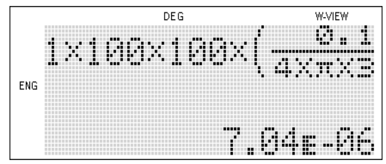
$f = 3\,GHz = 3 \times 10^9$

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

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

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

$$P_R = 1 \cdot 100 \cdot 100 \cdot \left(\frac{0.1}{4\pi \cdot 360} \right)^2 = 7 \times 10^{-6}\ W$$



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.

	cost of media	cost of i/f	media size	immunity to i/f
T.P.	ML	L	M	ML
co-ax	MH	ML	M	MH
F.O.	H	MH	S	H
free-space	L	H	?	L