(1)

ELEC 3500
Question Set-3

3-0:

Transmission Power $P_T = 100$ mW
Transmission Loss $L = 40$ dB

(a) Convert the transmission in dBm

$$P_T(\text{dBm}) = 10\log_{10}\left(\frac{P_T}{1\times10^{-3}}\right)$$
$$= 10\log_{10}\left(\frac{100\times10^{-3}}{1\times10^{-3}}\right)$$
$$= 20 \text{ dBm}$$

(b) Received Power is transmitted minus the lost power

$$\Rightarrow \quad P_R = P_T - L = 20\text{dBm} - 40\text{ dB} = -20\text{dBm}$$

3-1: Attenuation coefficient $\alpha = 0.7$ dB/km

(a) Maximum allowable loss $L = 19.6$ dB

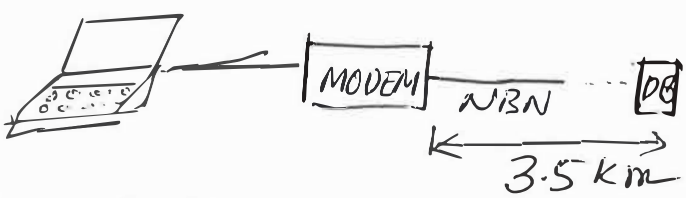
Allowable link distance $d_{link} = \frac{L}{\alpha} = \frac{19.6}{0.7} = 28$ km

(b) $P_T = 100$ mW, $P_{Rx} = -125$ dBm
$= 20$ dBm

Maximum allowable loss $L_{max} = P_T - P_R = 20 - (-125)$
$= 145$ dB

Supported link distance $d = \frac{L_{max}}{\alpha} = \frac{145}{0.7} = 207.14$ km

3-2:



$P_T = 200$ mW $= 23.01$ dBm, $L = 5$ dB/km
$P_N = 0.005$ mW

Total link loss $L_{total} = L\times d = 5\times3.5 = 17.5$ dB
$P_R = P_T - L_{total} = 23.01 - 17.5 = 5.51$ dBm

[2020, S2]

(b) Signal to noise ratio (SNR) can be calculated in following two ways

(i) $SNR(dB) = 10\log_{10}\left(\frac{P_R}{P_N}\right)$ [both power values in Watt]

$P_{RX} = 5.51$ dBm, convert into watt value

$$P_R(dBm) = 10\log_{10}\left(\frac{P_R}{1\times10^{-3}}\right)$$

Rearranging the equation

$$\Rightarrow \quad 5.51 = 10\log_{10}\left(\frac{P_R}{1\times10^{-3}}\right)$$

$$\Rightarrow \quad \log_{10}\left(\frac{P_R}{1\times10^{-3}}\right) = \frac{5.51}{10} = 0.551$$

$$\Rightarrow \quad \frac{P_R}{1\times10^{-3}} = 10^{0.551} = 3.56$$

$$\Rightarrow \quad P_R = 3.56\times10^{-3}\ \text{Watt}$$

$$P_N = 0.005\ \text{mW} = 0.005\times10^{-3}\ \text{Watt}$$

$$SNR(dB) = 10\log_{10}\left(\frac{P_R}{P_N}\right) = 10\log_{10}\left(\frac{3.56\times10^{-3}}{0.005\times10^{-3}}\right)$$

$$= 10\log_{10}(712) = 28.52\ \text{dB}$$

Second way of calculating the SNR value

$$SNR(dB) = P_R(dBm) - P_N(dBm)$$

$$P_N = 0.005\ \text{mW} \Rightarrow P_N(dBm) = 10\log_{10}\left(\frac{0.005\times10^{-3}}{1\times10^{-3}}\right)$$

$$\Rightarrow P_N(dBm) = 10\log_{10}(5\times10^{-3}) = 10\times(-2.301)$$

$$= -23.01\ \text{dBm}$$

$$SNR(dB) = 5.51 - (-23.01) = 28.52\ \text{dB}$$

(c) Maximum data transmission rate can be worked out by using the shannon's channel capacity theoram which is given by

$$C = B\log_2(1+SNR)$$

C is the transmission rate in bits/sec
B is the transmission bandwidth in Hz
SNR is the signal to noise ratio value NOT in dB

[2020, S2]

$SNR(dB) = 28.52 dB \Rightarrow SNR = 711.21$

$C = B \log_2(1+SNR) = 2\times10^6 \times \log_2(1+711.21)$

$= 18954206$ bits/sec

$= 18.954$ Mbps

Log$_2$ to Log$_{10}$ conversion

$$\log_2(A) = \frac{\log_{10}(A)}{\log_{10}(2)} = \frac{\log_{10}(A)}{0.301}$$

3-3: $B = 10$ KHz, Nyquist pulse levels, $M = 8$

No. of bits represented by the pulse; $2^m = M$ (m represents no. of bits)

$\Rightarrow 2^m = M \Rightarrow m = \log_2(M) = \log_2(8) = 3$ bits

Data rate of the channel; $R = 2Bm$

$\Rightarrow R = 2\times10\times10^3\times3 = 60$ kbps

3-4: $B = 1$ MHz, $M = 8$

$2^m = 8 \Rightarrow m = 3$ bits

$R = 2Bm = 2\times1\times10^6\times3 = 6$ Mbps

Shanon capacity for 20 dB SNR

$C = B\log_2(1+SNR)$

$SNR(dB) = 20 dB \Rightarrow SNR = 100$

$C = B\log_2(1+SNR) = 1\times10^6\times\log_2(100+1) = 6657807.3$ bits/sec

$= 6.658$ Mbps

[2020, S2]

3-5: No. of pixels/frame $n_{frame} = 1920 \times 1024 = 1966080$ pix

No. of bits/pixel $n_{pix} = 2^m = 4096 \Rightarrow m = \log_2(4096) = 12$ bits

No. of bits/video frame, $m_{frame} = 1966080 \times 12$

$= 23592960$ bit

Video source data rate, $R_{source} = 23592960 \times 30$

$\Rightarrow R_{source} = 7.0778 \times 10^8$ bits/sec

The video stream is compressed before streaming

$R_{stream} = \frac{R_{source}}{C}$; C is the compression ratio

$\Rightarrow R_{stream} = \frac{7.0778 \times 10^8}{20} = 35389000$ bps

$= 35.389$ Mbps

To workout the bandwidth, use the shannon channel capacity theoram

$$C = B \log_2 (1 + SNR)$$

$$\Rightarrow B = \frac{C}{\log_2(1+SNR)}$$

$SNR = 35\,dB \Rightarrow SNR = 3162.27$

$$B = \frac{35.389 \times 10^6}{\log_2(1+3162.27)} = 3.04375 \text{ MHz}$$

3-6:

$T_{int} = 20$ ms , $B = 10{,}000$ byte, $SNR = 35dB$

First we need to workout maximum transmission data rate R_T

$$R_T = \frac{1}{T_{int}} \times B = \frac{1}{20 \times 10^{-3}} \times (10000 \times 8)$$

$= 4.0$ Mbps

$C = 4.0$ Mbps, $SNR = 35\,dB = 3162.27$

[2020, S2]

Using $B = \frac{C}{\log_2(1+SNR)} = 344{,}000 \text{ Hz}$

$= 344 \text{ KHz}$

3-7:

$\lambda_1 = 1300 \text{ nm}, \quad \lambda_2 = 1304 \text{ nm}$

(a) Transmission Bandwidth $B = f_1 - f_2 = \frac{c}{\lambda_1} - \frac{c}{\lambda_2}$

c is the speed of Light in free space

$c = 3\times108 \text{ m/sec}$

$$B = \frac{c}{\lambda_1} - \frac{c}{\lambda_2} = \frac{3\times10^8}{1300\times10^{-9}} - \frac{3\times10^8}{1304\times10^{-9}}$$

$$= 2.307\times10^{14} - 2.3\times10^{14}$$

$$= 7.6\times10^{11} \text{ Hz}$$

(b) In this case, $m = 8$ bits/Hz

Link transmission rate, $R = 2Bm = 2\times7\times10^{11}\times8$

$\Rightarrow R = 1.12\times10^{13}$ bps

$= 11.2$ tbps (Terrabits per sec)

3-8:

Total data rate required for the street

$R_{total} = 10\times100\times10^6 = 1$ Gbits/sec

Using the shannon's channel capacity theorram

$R_{total} = C = B\log_2(1+SNR)$

$\Rightarrow SNR = 2^{C/B} - 1$

$= 2^{\frac{1\times10^9}{100\times100}} - 1 = 2^{10} - 1 = 1023$

$SNR(dB) = 10\log_{10}(1023) = 30.09 \text{ dB}$

[2020, S2]

3-9: $R = 2.048 \times 10^6$ bps

Frame rate $F = 8000$ frames/sec

TDM frame duration $T_f = \frac{1}{F} = \frac{1}{8000} = 125 \times 10^{-6}$ sec

(a) No. of bits/frame $n_{bf} = T_f \times R = 2.048 \times 10^6 \times 125 \times 10^{-6}$

$= 256$ bits

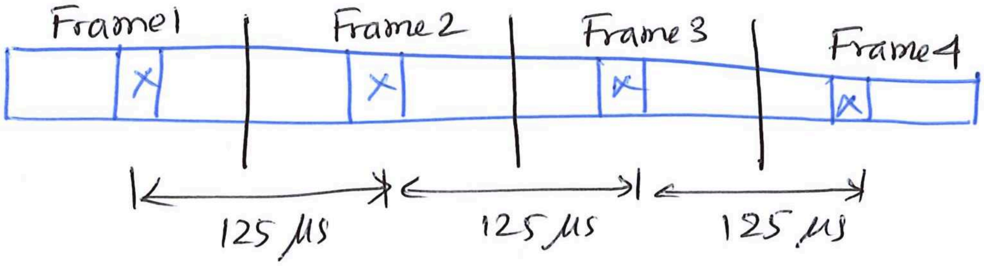
(b) No. of bits/slot; $n_{bs} = \frac{n_{bf}}{8} = \frac{256}{8} = 32$ bits

(c) Link data rate, $R_L = n_{bs} \times 8000 = 32 \times 8000$

$= 256{,}000$ bps

$= 256$ kbps

3-10: Using a TDM link a terminal can transmit using time slots. A terminal can transmit number of bits equal to the slot size at a time. As worked out in problem 3-9, the slot size is 32 bits, hence, the terminal can send 32 bits in each TDM frame using a slot transmission sequence as shown below.



Total transfer delay, $D_{trans} = N * t_f$

where N is the number of frame required to transmit the file

$$N = \frac{\text{File size}}{\text{slot size}} = \frac{9600 \times 8}{32} = 2400 \text{ frames}$$

$D_{trans} = 2400 \times 125 \times 10^{-6} = 0.3$ sec.

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[2020, S2]