Solutions to Mid-Term Exam

Question 1

The throughput is the average number of *data* bits correctly received (and thus delivered to the data sink) per unit time. In this question each character takes the same amount of time to transmit so we can compute the throughput by dividing the number of data bits per character by the time taken to transmit each character.

For 8 data bits, no parity and a bit rate of 9600 bps 8 data bits are transmitted in $\frac{1+8+1}{9600} \approx 1.042$ ms so the throughput is $\frac{8}{1.024} = 7680$ bps.

For 7 data bits, 1 parity bit and a bit rate of 4800 bps 7 data bits are transmitted in $\frac{1+7+1+1}{4800} \approx 2.083$ ms so the throughput is $\frac{7}{2.083} = 3360$ bps.

Question 2

(a) If the range of frequencies is between 12.1 GHz and 12.125 GHz the bandwidth is 25 MHz which is much less than the frequency so this is a **band-pass** channel.

If the range of frequencies is between DC and 20 kHz this is a **low-pass** channel.

(b) The gain of an amplifier in dB is the difference between the input and output levels in dBm. The input power in dBm can be computed as $10\log(P)$ where P is in mW. The power (in mW) consumed by a load of resistance R for an applied (rms) voltage V is $\frac{V^2}{R\times 1000}$

For an input level of 7 μV the power level is $10\log(\frac{7\times 10^{-6\times 2}}{50\times 10^3}) \approx -90$ dBm so the gain is $0-(-90) = 90$ dB.

For an input level of 7 mV the power level is $10\log(\frac{7\times 10^{-3\times 2}}{50\times 10^3}) \approx -30$ dBm so the gain is $0-(-30) = 30$ dB.

(c) A linear channel does not change the frequencies present in the input signal although it can alter their amplitudes and phases. The output of a non-linear channel often contains harmonics of the input signal.

In this case the output contains the input plus the third harmonic so it must be a non-linear channel.

(d) An RS-232 output must have a level between -3 and $+3$ V. A pin with a voltage outside this range is either an input or unused.

If the RTS pin reads 0 V it is likely an input and if DSR reads 5 V it is likely an output. These pins are inputs and outputs respectively on a DCE so this interface is wired as a DCE.

If the CTS pin reads 0 V it is likely an input and if DTR reads 5 V it is likely an output. These pins are inputs and outputs respectively on a DTE so this interface is wired as a DTE.

Question 3

The relative dielectric constant (ε_r) of air is approximately 1. The formula for the characteristic impedance of co-ax cable is:

$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln(\frac{D}{d})$$

from which we can derive the required tubing (shield) diameter (D) as a function of the other parameters:

$$D = d\exp(\frac{Z_0}{60})$$

For $d = 2$ mm and $Z_0 = 50\ \Omega$, $D \approx 4.6$ mm.
For $d = 2$ mm and $Z_0 = 75\ \Omega$, $D \approx 7.0$ mm.

Question 4

(a) The Shannon capacity theorem says that error-free transmission is not possible at rates above the capacity C given by:

$$C = B\log_2(1+\frac{S}{N})$$

If we set the capacity equal to the bit rate we need to transmit without errors we can solve for the minimum required signal power as a function of the other parameters:

$$S = N\left(2^{\left(\frac{C}{B}\right)} - 1\right)$$

The noise power is 0 dBm which is 1 mW.

For a bit rate of $C = 12$ kbps and a bandwidth $B = 3$ kHz the required signal power is $S = 15$ mW.

For a bit rate of $C = 16$ kbps and a bandwidth $B = 4$ kHz the required signal power is also $S = 15$ mW.

(b) The Nyquist no-ISI theorem says that we can transmit symbols at twice the -6 dB bandwidth if the filter meets specific symmetry conditions (which are met by a brick-wall filter).

For a bandwidth[1] of 3 kHz the no-ISI symbol rate would be 6 kHz.

For a bandwidth of 4 kHz the no-ISI symbol rate would be 8 kHz.

[1] A brick-wall filter has only one bandwidth.