1. Based on the Shannon capacity equation.

a) Write the Shannon capacity equation. If we have infinite bandwidth, can we obtain infinite capacity? If we have infinite SNR, can we obtain infinite capacity? Why?

[40%]

b) A picture includes 4×10^6 elements; each element has 256 colors. The probability distribution of each color is equal and independent. Calculate the amount of information of a picture.

[30%]

c) If $SNR = 1023$, calculate the required bandwidth B if we want to transmit this picture within 80 seconds.

2. A cosine wave $X(t) = A_0 \cos(\omega_0 t + \Phi)$ is a random process, whose amplitude and frequency are definitely given as A_0 and ω_0, respectively, and the initial phase Φ is a random variable with a uniform distribution over the range of $[-\pi, \pi]$.

a) Calculate the mean of $X(t)$.

[10%]

b) Calculate the autocorrelation function $R(\tau)$ of $X(t)$.

[20%]

c) Calculate the average power of $X(t)$.

[20%]

d) Calculate the direct-current power of $X(t)$.

[20%]

e) Calculate the alternating-current power of $X(t)$.

[20%]

f) Calculate the power spectrum density of $P_x(f)$ of $X(t)$.

[10%]

3. For an AM (amplitude modulation) signal of $f(t) = 2\cos(4000\pi t) + 8\cos(200\pi t) \cdot \cos(4000\pi t)$

a) Calculate the expression of baseband signal $m(t)$.

[10%]

b) Calculate the bandwidths of both the AM signal and the baseband signal.

[30%]

c) Calculate the signal power of the AM signal.

[15%]

d) Calculate the modulation efficiency of the AM signal.

[15%]

e) Compare the difference between linear modulations AM, DSB (double sideband), SSB (single sideband).

[15%]

f) For AM, SSB, DSB sort the efficiency from high to low.

[15%]

4. In the PCM(Pulse-Code Modulation) system, the sampling value of the input signal is $I_s = +768mv$, the input voltage level is $[-4096mv, 4096mv]$, A-law is adopted to encode 13 broken lines. After that, we do TDM-PCM (time division multiple-Pulse-Code Modulation), there are 6 roads, the baseband signals are transmitted with the cosine rolling-off filter, with $\alpha = 0.5$, the cut-off frequency is $480kHz$.

   a) Calculate the 8-bit PCM code $C_1C_2C_3C_4C_5C_6C_7C_8$.

   [40%]

   b) Calculate quantization level and quantization error.

   [30%]

   c) Calculate maximum transmission bit rate.

   [15%]

   d) Calculate the highest frequency of analog signals allows in each road.

   [15%]

5. When $M = 4$, the channel transmission function $H(f)$ is given by

$$H(f) = \begin{cases} 1 - \dfrac{|f|}{2\times10^5} & |f| \leqslant 2\times10^5 Hz \\ 0 & others \end{cases}$$

   a) Calculate the maximum transmission symbol rate and bit rate.

   [20%]

   b) Calculate the related spectrum efficiency and bit spectrum efficiency.

   [30%]

c) When $R_b = 4 \times 5\ bps$, analyze whether the system can transmit without inter symbol interference.

[20%]

d) What is the maximum spectrum efficiency of the ideal low-pass system?

[15%]

e) Compare the advantages and disadvantages of a LPF and a rolling-off filter.

[15%]

6. The binary bit stream to be transmitted is: 10001101, with transmission rate $R_B = 400Baud$.

a) For FSK signal, symbol '1' and '0': $s_1(t) = Acos(800\pi t), s_0(t) = Acos(1600\pi t)$, respectively. What is the kind of demodulation method we could use?

[10%]

b) Draw the demodulation block diagram, draw the waveforms of each block.

[55%]

c) What is the bandwidth of FSK?

[10%]

d) Compare the system performances of ASK (Amplitude Shift Keying), FSK (Frequency shift keying), PSK (Phase shift keying), DPSK (Differential phase shift keying), in terms of BER, the spectrum efficiency, and the channel sensitivity.

[25%]