10.1 The spectrum of baseband signal is

$$S_v(f) = \frac{1}{T} \cdot \frac{c(f)}{|X_{re}(f)|^2} = \frac{1}{T} \cdot |X_{re}(f)|^2$$

when $T = \frac{1}{2\text{Hz}}$ and

$$X_{re}(f) = \begin{cases} \frac{T}{2} & 0 \leq |f| \leq \frac{1}{4T} \\ \frac{T}{2} \cdot \cos (2\pi T \cdot |f| - \frac{1}{4T}) & \frac{1}{4T} \leq |f| \leq \frac{3}{4T} \\ 0 & \text{otherwise.} \end{cases}$$

If the carrier signal has the form $c(t) = A \cdot \cos 2\pi fc t$

then spectrum of DSB-SC modulated signal,

$$S_v(f) = A^2 \left[ S_v(f+fc) + S_v(f-fc) \right]$$

2) Assuming bandwidth coherent demodulation using a matched filter, the received signal $r(t)$ is first passed through a linear filter with impulse response

$$g_{kr}(t) = A X_{re}(T-t) \cos (2\pi fc (T-t))$$
The output of the matched filter is sampled at $t=T$ and the samples were passed to the detector. The detector is a simple threshold device that decides if a binary 1 or 0 was transmitted depending on the sign of the input samples. The following figure shows block diagram of the optimal bandpass coherent demodulator.

10.5. The bandwidth of channel is

$$W = 2000 - 600 = 2400 \text{ Hz}.$$ 

Symbol rate $R = \frac{2400}{2} = 1200 \text{ symbol/sec } (\text{QPSK})$.

We use raised cosine ($\alpha=1$) for spectral shaping.

$$X_{\text{RC}}(f) = \frac{T}{2} \left( 1 + \cos \left( \frac{\pi f T}{2} \right) \right) = \frac{1}{2400} \cos \left( \frac{\pi f T}{2400} \right)$$

If the desired spectral characteristic is split evenly between the transmit filter $G_T(t)$ and receive filter $G_R(t)$

$$G_T(t) = G_R(t) = \sqrt{\frac{1}{1200}} \cos \left( \frac{\pi f T}{2400} \right), \quad \text{if } f < \frac{T}{T} = 1200$$
The block diagram of the transmitter

\[ \begin{array}{c}
\text{an} \\
g_{\text{PSK}} \\
to \text{channel}
\end{array} \]

a) If the bit rate is 4800 bps

\[ R = 2400 \text{ sym/sec} \]

In order to satisfy Nyquist criterion, the signal pulse used for spectral shaping should have the spectrum

\[ X(f) = \frac{T}{2} \pi \left( \frac{f}{W} \right) \]

Thus, freq. response of transmit filter \( g_t(t) = \frac{T}{2} \pi \left( \frac{f}{W} \right) \)

\[ W = 3200 - 300 = 3000 \text{ Hz} \]

In order to transmit 9600 bps, with \( R = 2400 \text{ sym/sec} \)

The amount of information per bit

\[ k = \frac{9600}{2400} = 4 \]

Hence, a \( 4^4 = 16 \text{QAM} \) signal constellation is needed.

The carrier frequency \( f_c = 1800 \text{ Hz} \), which is mid-frequency.
If the frequency band of a band-pass channel, if the pulse is raised cosine with roll off factor \( \alpha \),

\[
P_a = 1200(1 + \alpha)
\]

\[
\Rightarrow \quad \alpha = 0.25
\]

The spectrum sketch is shown below of transmitted pulse

---

10.9  
**First constellation**

\[
P_a = \frac{1}{8} \left( 4 \times (2A)^2 + 4 \times (2\sqrt{2}A)^2 \right) = 6A^2
\]

**Second constellation**

\[
P_b = \frac{1}{8} \left( 4 \times (\sqrt{3}A)^2 + 2 \times (\sqrt{2}A)^2 + 2A^2 \right) = \frac{9}{2}A^2
\]

\[P_b < P_a, \text{ second constellation is more power efficient.}\]
The number of bits / symbol

\[ k = \frac{4800}{R} \geq \frac{4800}{2400} = 2. \]

Thus, 4 QAM is used. The error rate for M-ary QAM

\[ P_m = 1 - \left(1 - 2 \left(1 - \frac{1}{\sqrt{M}} \right) \right) A \left( \frac{3kE_b}{(M-1)N_0} \right)^2 \rightarrow (1) \]

with \( P_m = 10^{-5} \), \( k = 2 \), we obtain

\[ A \left( \frac{2E_b}{N_0} \right) = 5 \times 10^{-6} \Rightarrow \frac{E_b}{N_0} = 9.7682 \]

2) If bit rate = 9600 bps.

\[ k = 4 \quad \text{and} \quad \text{we have}\ 16\text{-QAM constellation.} \]

Use formula (1) for \( k = 4 \) and \( P_m = 10^{-5} \), we get

\[ \frac{E_b}{N_0} = 25.36 \]

3) If bit rate = 19200 bps

\[ k = 8 \]
\[
\frac{E_b}{N_0} = 659.89
\]

<table>
<thead>
<tr>
<th>(k)</th>
<th>2</th>
<th>4</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNR(dB)</td>
<td>9.89</td>
<td>14.04</td>
<td>28.19</td>
</tr>
</tbody>
</table>

It is observed, there is an increase in transmitted power of approx. 3dB per additional bit per symbol.