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2. A noiseless 8-kHz channel is sampled every 1 ms. What is the maximum data rate?

解答： 根据 Nyquist 定理，有最大数据速率

$C = 2H\log_2 V$,

由于不知道单个码元携带的信息量 $\log_2 V$.

(或者说码元种类数 V)

故无法计算最大数据速率.

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3. If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?

解答： 信噪比 $\frac{S}{N} = 20\ \text{dB} = 10^2 = 100$.

根据 Shannon 定理，有最大数据速率

$C_S = H\log_2(1+\frac{S}{N})$，其中带宽 $H = 3\times10^3\ \text{Hz}$.

计算得 $C_S = 3\times10^3 \times \log_2 101\ \text{bps}$

$\approx 19.97\ \text{kbps}$.

又 Nyquist 定理有 $C_N = 2H\log_2 V$，因二进制信号取 $V=2$.

得 $C_N = 6\ \text{kbps}$.

综上所述，最大数据速率为两者较小值，即 6 kbps.

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4. What signal-to-noise ratio is needed to put a T1 carrier with data rate 1.544Mbps on a 100-kHz line?

解答： 根据 Shannon 定理，有

$C = H \log_2(1+\frac{S}{N})$. 代入 $C = 1.544\,Mbps$, $H = 100\,kHz$.

可解得 $\frac{S}{N} = 2^{\frac{C}{H}} - 1 = 2^{15.44} - 1 \approx 46\,dB$.

即可知信噪比应为约 46 dB 或更高.

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7. It is desired to send a sequence of computer screen images over an optical fiber. The screen is 1920 × 1200 pixels, each pixel being 24 bits. There are 50 screen images per second. How much bandwidth is needed?

解答： 所需带宽 $C = \frac{n\ bit}{t\ sec}$. 其中

n 为有秒发送的 bit 数，即

$n = 50t \times 1920 \times 1200 \times 24 = 2488320000t$ ~~$= 2488320000t$~~

$= 2764800000t$.

代入得

$C = 2.7648\,Gbps \approx 2.765\,Gbps$.

即所需带宽为约 2.765 Gbps.

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8. Is the Nyquist theorem true for high-quality single-mode optical fiber or only for copper wire?

解答： Nyquist 定理是数学定理，与采用的具体技术无关。
因此，Nyquist 定理适用于任何模拟信道，
在本题中，Nyquist 定理既在高质量单模光纤上成立，
也在铜线上成立。

21. A modem constellation diagram similar to Fig. 2-23 has data points at (0, 1) and (0, 2). Does the modem use phase modulation or amplitude modulation?

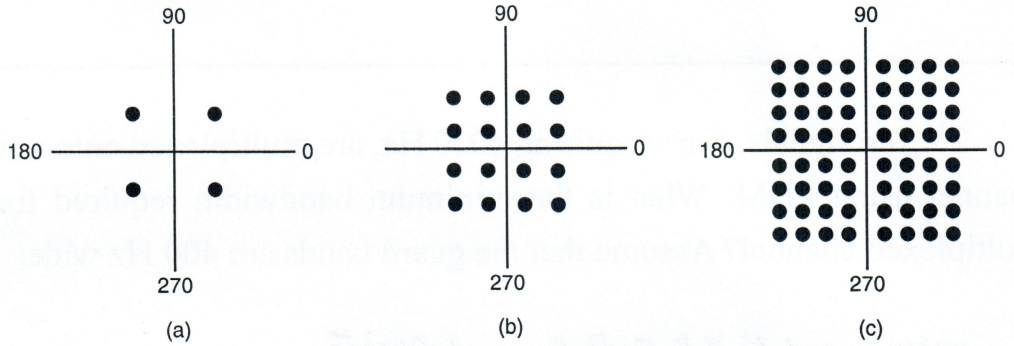


Figure 2-23. (a) QPSK. (b) QAM-16. (c) QAM-64.

解答： 数据点 (0,1), (0,2) 的相位均为 0，而振幅分别为 1，2。
这说明使用的是振幅调制。

24. An ADSL system using DMT allocates 3/4 of the available data channels to the down-stream link. It uses QAM-64 modulation on each channel. What is the capacity of the downstream link?

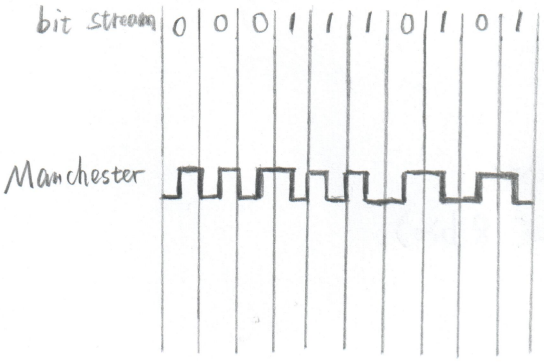
解答： ADSL中可用的 user data channels 数量为 248.
采样率为 4000 Baud. 故
下行链路总容量为
$248 \times \frac{3}{4} \times 4000 \times \log_2 64 = 4.464$ Mbps.

25. Ten signals, each requiring 4000 Hz, are multiplexed onto a single channel using FDM. What is the minimum bandwidth required for the multiplexed channel? Assume that the guard bands are 400 Hz wide.

解答： n个信道复用需要 n-1 个保护带,
故可知带宽应为 $(n \times 4000 + (n-1) \times 400)$ Hz.
代入 $n=10$, 得
总带宽至少为 43.6 kHz.

14. Sketch the Manchester encoding on a classic Ethernet for the bit stream 0001110101.

解答： 绘制如下.



26. Why has the PCM sampling time been set at 125 μs?

解答： 这是因为话音信道所带宽为4kHz.
由 Nyquist 定理，采样频率应为 8kHz，
即每 1/8 μs 采样一次.

28. Compare the maximum data rate of a noiseless 4-kHz channel using

(a) Analog encoding (e.g., QPSK) with 2 bits per sample.

(b) The E1 PCM system.

解答：

(a) $C_a = 2H\log_2 V = 16$ kbps.

(b) $C_b = 8 \times 2 \times 4000$ bps $= 64$ kbps

(E1 PCM 每个时隙传送 8 bit).

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36. Compare the delay in sending an x-bit message over a k-hop path in a circuit-switched network and in a (lightly loaded) packet-switched network. The circuit setup time is s sec, the propagation delay is d sec per hop, the packet size is p bits, and the data rate is b bps. Under what conditions does the packet network have a lower delay? Also, explain the conditions under which a packet-switched network is preferable to a circuit switched network.

解答： 在 circuit-switched 网络中，

在 $t = S$ 时刻电路建立，在 $t = S + \frac{x}{b} + kd$ 时刻信息到达.

在 packet-switched 网络中，

在 $t = \frac{x}{b}$ 时刻信息的最后一个 bit 发送

最后一个 packet 被转发 $k-1$ 次，总延时为 $\frac{x}{b} + (k-1)\frac{p}{b} + kd$.

因此，若 $S > \frac{(k-1)p}{b}$，则 packet-switched 网络更快.

此外，当需要在交换机存在故障时进行容错传输时，

分组交换更加适用。

37. Suppose that x bits of user data are to be transmitted over a k-hop path in a packet switched network as a series of packets, each containing p data bits and h header bits, with $x \gg p + h$. The bit rate of the lines is b bps and the propagation delay is negligible. What value of p minimizes the total delay?

解答： packet 个数 $n = \frac{x}{p}$.

从而总数据量为 $n(p+h) = \frac{x(p+h)}{p}$ bit.

传送延迟 $t_1 = \frac{x(p+h)}{pb}$ s.

转发延迟 $t_2 = \frac{(k-1)(p+h)}{b}$ s.

故总延迟为 x, k, p, h, b 的函数.

即 $t(x,k,p,h,b) = \frac{1}{b}\left(\frac{x(p+h)}{p} + (k-1)(p+h)\right)$

由 Fermat 引理，令 $\frac{\partial t}{\partial p} = 0$，得

$\frac{1}{b}\left((k-1) + \left(-\frac{xh}{p^2}\right)\right) = 0$

从而解得 $p_0 = \sqrt{\frac{xh}{k-1}}$.

经检验 $\frac{\partial^2 t}{\partial p^2}(p_0) = \frac{2xh}{bp_0^3} > 0$，即 t 在 $p = p_0$ 处取极小值.

故总延迟在 $p = \sqrt{\frac{xh}{k-1}}$ 处最小.