PROBLEMS

1. Compute the Fourier coefficients for the function f(t) = t (0 ≤ t ≤ 1).

同理

c=1

1. A noiseless 4-kHz channel is sampled every 1 msec. What is the maximum data rate? How does the maximum data rate change if the channel is noisy, with a signal-to-noise ratio of 30 dB?

P88

无噪声的情况下，无论采样的速率如何，信道都可以运载任意数量的信息，因为每个采样值都可以发送大量数据。由尼奎斯特定理，知道无噪声的带宽为4kHz信道不可能以超过8000bps的速率传输二进制，即传输的samples的速率不超过8000 samples/sec，假设每个sample的占n位，那么最大速率就是8000n bps。在30 dB的情况下，对应的信噪比是1000，所以最大比特率=4 kHz \* log2(1+1000) = 39.87 kbps

1. Television channels are 6 MHz wide. How many bits/sec can be sent if four-level digital signals are used? Assume a noiseless channel.

2\*B\*log2(V)=2\*6\*log2(4)=24 Mbps

1. 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?

尼奎斯特定理的速率是2\*3\*log2(2)=6 kbps，香农最大速率=3\*log2(1+100)=19.975 kbps。最大速率为6 kbps.

1. What signal-to-noise ratio is needed to put a T1 carrier on a 50-kHz line?

T1载波：P135

T1载波的带宽是1.544Mbps，所以由香浓最大速率知 50\*log2(1+S/N)=1544，解得S/N=2^31-1，所以是10\*log10(2^31-1)=9.296 dB

1. What are the advantages of fiber optics over copper as a transmission medium? Is there any downside of using fiber optics over copper?

P96光纤和铜线的比较

光纤比铜线能处理更高的带宽，这使得它非常适用于高端网络。光纤具有相对较低的衰减，所以在较长的线路上，大约每50km才需要一个中继器，铜线则是5km。节约了成本。光纤不受电源涌浪、电磁干扰、电源故障的影响。不受腐蚀性化学物质侵蚀的影响，能被应用于恶劣的工业环境。光纤比铜轻，而且细小。安装费用低得多。光纤不会漏光，而且不易被接入，这些特性使得光纤很难被搭线窃听，有很高的安全性。

缺点，光纤是一项相对陌生的技术，要求较高的操作技能，而且这种技能并不是每一个工程师都具备；光纤过度弯曲时容易折断。由于光传输技术本质是单向的，所以要求双向通信使用两根光纤，或者在一根光纤上划分频段。光纤接口的成本远远高于电子接口的成本。

1. How much bandwidth is there in 0.1 microns of spectrum at a wavelength of 1 micron?

频率=c/波长=300/1e-6 MHz=3e8 MHz=3e5 GHz

带宽=频率\*使用波长比率=3e5\*0.1/1=3e4 GHz

1. It is desired to send a sequence of computer screen images over an optical fiber. The screen is 2560 × 1600 pixels, each pixel being 24 bits. There are 60 screen images per second. How much bandwidth is needed, and how many microns of wavelength are needed for this band at 1.30 microns?

像素占总bit=2560\*1600\*24，每秒60幅，那么每秒共传2560\*1600\*24\*60bit，所以总共的速度是5.898Gbps，假定每次传输n位，那么带宽就是5.898/n GHz， 那么在1.3微米波段的话，设对应的波长为x，那么x满足方程：带宽=频率\*波长比率=c/1.3 um \* x/1.3 um ，5.898/n GHz = 3e8 m/s / 1.3 um \* x/1.3 um -> x=3.323e-11 m 得 3.323e-5 um

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

适用，因为尼奎斯特定理只是说带宽为B的信道，经过2B次采样就可以重构出被过滤的信号。再多的采样，也不能让被过滤信号更精确（2B次采样就已经还原了）。这个定理是承接傅里叶变换说的，与任何材质无关。

1. Radio antennas often work best when the diameter of the antenna is equal to the wavelength of the radio wave. Reasonable antennas range from 1 cm to 5 meters in diameter. What frequency range does this cover?

1~5米，用c=波长\*频率，得到6e7 Hz~3e8 Hz

1. A laser beam 1 mm wide is aimed at a detector 1 mm wide 100 m away on the roof of a building. How much of an angular diversion (in degrees) does the laser have to have before it misses the detector?

三角函数：对边长度为物体的直径1mm=1e-3 m，长边长度为100 m，所以夹角应该最大是

arctan(1e-3/100)=1e-5弧度，对应的角度是0.00057°

1. The 66 low-orbit satellites in the Iridium project are divided into six necklaces around the earth. At the altitude they are using, the period is 90 minutes. What is the average interval for handoffs for a stationary transmitter?

66颗卫星分成6个链，假设每一条链卫星数相同，则每一条链11颗卫星。每一圈90分钟，假设均匀间隔，则相隔90\*60/11=490.9秒，所以每490.9秒切换一下。

1. Calculate the end-to-end transit time for a packet for both GEO (altitude: 35,800 km), MEO (altitude: 18,000 km) and LEO (altitude: 750 km) satellites.

用2\*高度/光速来算时间，分别为0.2387秒，0.012秒，0.005秒

1. What is the latency of a call originating at the North Pole to reach the South Pole if the call is routed via Iridium satellites? Assume that the switching time at the satellites is 10 microseconds and earth’s radius is 6371 km.

P110

铱星卫星距地面750km，每隔32维度有一颗卫星，从南极到北极共经过6颗卫星，所以总的距离是750\*2(地面到卫星和卫星到地面)+PI\*(6371+750) (半圆周长)=23860 km,花费在传输距离的时间是23860km/3e8m/s=0.0795333s,经过6颗卫星，延时6\*10e-6s=0.00006s，总共79.593 ms

1. What is the minimum bandwidth needed to achieve a data rate of B bits/sec if the signal is transmitted using NRZ, MLT-3, and Manchester encoding? Explain your answer.

NRZ:P113 时钟图中文版有误

NRZ编码：至多两位：01就能引发一次正负电压的循环，意味着至少要B/2Hz的带宽才能获得B bps的比特率。

MLT-3:

MLT-3是双极性码，有”-1”、“0”、“1”三种电平，编码后直流成份大大减少，可以进行电路传输，100Base-TX采用此码型。

MLT-3编码规则：

1).如果下一输入为“0”，则电平保持不变；

2).如果下一输入为“1”，则产生跳变，此时又分两种情况。

(a).如果前一输出是“＋1”或“－1”，则下一输出为“0”；

(b).如果前一输出非“0”，其信号极性和最近一个非“0”相反。

至多4位：1111，引发一次电压循环，意味着只是要B/4Hz的带宽才能获得B bos的比特率。

Manchester:

每一位都会引发一次电压循环，所以需要B Hz的带宽才能获得B bps的比特率。

1. Prove that in 4B/5B encoding, a signal transition will occur at least every four bit times.

4B/5B使用了NRZI，所以每一次1传递时，电压会变化一下。而4B/5B满足了5位比特模式的选择结果永远不会出现连续的3个0，所以每4bit，总会有一个1被传递，故每4bit一次电压转换会发生一次。

1. How many end office codes were there pre-1984, when each end office was named by its three-digit area code and the first three digits of the local number? Area codes started with a digit in the range 2–9, had a 0 or 1 as the second digit, and ended with any digit. The first two digits of a local number were always in the range 2–9. The third digit could be any digit.

区域号共(9-2+1)\*2\*10=160，本地号共(9-2+1)\*(9-2+1)\*10=640，所以共160\*640=102400

1. A simple telephone system consists of two end offices and a single toll office to which each end office is connected by a 1-MHz full-duplex trunk. The average telephone is used to make four calls per 8-hour workday. The mean call duration is 6 min. Ten percent of the calls are long distance (i.e., pass through the toll office). What is the maximum number of telephones an end office can support? (Assume 4 kHz per circuit.) Explain why a telephone company may decide to support a lesser number of telephones than this maximum number at the end office.

??

1. A regional telephone company has 10 million subscribers. Each of their telephones is connected to a central office by a copper twisted pair. The average length of these twisted pairs is 10 km. How much is the copper in the local loops worth? Assume that the cross section of each strand is a circle 1 mm in diameter, the density of copper is 9.0 grams/cm3, and that copper sells for $6 per kilogram.

每根线算股（双绞线）

10000000\*10\*1000\*2\*PI\*0.0005\*0.0005\*9000\*6=8.4823$

1. Is an oil pipeline a simplex system, a half-duplex system, a full-duplex system, or none of the above? What about a river or a walkie-talkie-style communication?

石油管道可以正向 也可以反向，但是不能同时又正又逆，所以是半双工系统。河流是单工系统，因为只能一个方向流动。对讲机因为同一时间只能接受或者发送，所以也是半双工系统。

1. The cost of a fast microprocessor has dropped to the point where it is now possible to put one in each modem. How does that affect the handling of telephone line errors? Does it negate the need for error checking/correction in layer 2?
2. A modem constellation diagram similar to Fig. 2-23 has data points at the following coordinates: (1, 1), (1, −1), (−1, 1), and (−1, −1). How many bps can a modem with these parameters achieve at 1200 symbols/second?

有四种状态，对应的bit位数就是log2(4)=2，所以每秒能有 2400 bps。

1. What is the maximum bit rate achievable in a V.32 standard modem if the baud rate is 1200 and no error correction is used?

V.32调制解调器：P129

32种信号，所以共log2(32)=5位，然后总的最大速率就是1200\*5=6000 bps

1. How many frequencies does a full-duplex QAM-64 modem use?

QAM-64有64个不同状态，可以一个符号传输log2(64)=6 bits，但是使用了多少频率不知道。与是否使用了FDM技术有关。

1. 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.

总带宽=10个信号+9个保护带=40000+9\*400=43600Hz

1. Why has the PCM sampling time been set at 125 μsec?

PCM 脉冲编码解调：P134

125微秒对应的采样频率是1/0.0000125=8000次/秒，所以由尼奎斯特定律，这个采样速度能捕捉一切4kHz的带宽信息。而电话一般占的是3100Hz的语言信道。

1. What is the percent overhead on a T1 carrier? That is, what percent of the 1.544 Mbps are not delivered to the end user? How does it relate to the percent overhead in OC-1 or OC-768 lines?

T1:P135

有24\*7=168bit用作数据，一共193个bit，所以有25bit没有用于数据，所以开销为25/193=12.95%。

OC:P138

OC-1 (51.84-49.536)/51.84=4.444%

OC-768 (39813.12-38043.648)/39813.12=4.444%

1. 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 T1 PCM system.

共8000次采样/秒，所以a)的速度是16000 bps. b)的速度是56000 bps

1. If a T1 carrier system slips and loses track of where it is, it tries to resynchronize using the first bit in each frame. How many frames will have to be inspected on average to resynchronize with a probability of 0.001 of being wrong?

??

1. What is the difference, if any, between the demodulator part of a modem and the coder part of a codec? (After all, both convert analog signals to digital ones.)

解调器接受被调制的正弦信号然后输出被调制前的数字信号。

而编码部分是将声音信号变成数字信号。

二者的接受对象不一样。而且解调器相当于一个解码的过程，而编码相当于是创建码的过程（把非数字信号转成一种数字信号。而调制器是相当于还原了数字信号）。

1. SONET clocks have a drift rate of about 1 part in 10^9. How long does it take for the drift to equal the width of 1 bit? Do you see any practical implications of this calculation? If so, what?

SONET同步光网络P137

OC-1的传输速率大概是50Mbps，所以大约传输每bit消耗的时间是20纳秒，偏差在1e9意味着每隔20e9纳秒会偏差20纳秒，即偏差1bit。所以差不多20秒左右就会偏差一位。

所以时钟得每隔10秒左右就都同步一次，以免偏差累积到20秒使得偏差。

1. How long will it take to transmit a 1-GB file from one VSAT to another using a hub as shown in Figure 2-17? Assume that the uplink is 1 Mbps, the downlink is 7 Mbps, and circuit switching is used with 1.2 sec circuit setup time.

建立电路1.2秒。上行传输是最慢的，所以限制了下载的传输速度，所以下载和上传的速度都按照1Mbps算，同时只需算一次就可以了（边传边下的话），1GB/1Mbps=2^10MB/1Mbps=2^13Mb/1Mbps=2^13s。与带集线器的卫星通讯系统延迟是540ms(书上写的)。所以总用时是1.2+2^13+0.54=8193.64s

1. Calculate the transmit time in the previous problem if packet switching is used instead. Assume that the packet size is 64 KB, the switching delay in the satellite and hub is 10 microseconds, and the packet header size is 32 bytes.

包一共有1GB/64KB=2^30B/2^16B=2^14，每个包额外占32B，即2^14\*2^8=2^22bits，与卫星的连接时540ms，一共的时间是(2^22+2^33)/2^20+0.54=8196.54 s

1. In Fig. 2-40, the user data rate for OC-3 is stated to be 148.608 Mbps. Show how this number can be derived from the SONET OC-3 parameters. What will be the gross, SPE, and user data rates of an OC-3072 line?

它相当于是三路的OC-1，所以是OC-1的三倍。

OC/VT：P138

OC-1是这样得来的：每帧中有86\*9的字节是带数据的字节，每秒有8000帧，所以速度是86\*9\*8000\*8=49.536 Mbps。OC-3相当于三路的OC-1，是三倍的关系，速度是3\*49.536=148.608 Mbps

OC-3072是OC-1的3072倍，总速率=51.84\*3072=159252.48Mbps=159.17Gbps，SPE=153944.064 Mbps=153.94 Gbps，速率=49.536\*3072=152174.592Mbps=152.17Gbps

1. To accommodate lower data rates than STS-1, SONET has a system of virtual tributaries (VTs). A VT is a partial payload that can be inserted into an STS-1 frame and combined with other partial payloads to fill the data frame. VT1.5 uses 3 columns, VT2 uses 4 columns, VT3 uses 6 columns, and VT6 uses 12 columns of an STS-1 frame. Which VT can accommodate (a) A DS-1 service (1.544 Mbps)? (b) European CEPT-1 service (2.048 Mbps)? (c) A DS-2 service (6.312 Mbps)?

VT1.5的传输速率是(3\*9)\*(8)\*(8000)=1.728 Mbps，第一个括号是每一帧的带信息字节数，第二个括号是每字节占8位，第三个括号是每秒8000帧。

VT2的传输速率是4\*9\*8\*8000=2.304 Mbps

VT3的传输速率是6\*9\*8\*8000=3.456Mbps

VT6的传输速率是12\*9\*8\*8000=6.912Mbps

1.728Mbps >1.544Mbps，所以VT1.5能满足a)的需求。

2.304Mbps>2.048Mbps，所以VT2能满足b)的需求。

6.912Mbps>6.312Mbps，所以VT6能满足c)的需求。

如果说大的速度能兼容小的速度，为什么不直接用OC-1？

1. What is the available user bandwidth in an OC-12c connection?

OC-1c:P139

OC-12c 有12\*87=1044列数据，软后有一列作为路径开销，所以共1043列数据，9行不变，所以每帧有1043\*9\*8bit，每秒8000帧不变，速率=1043\*9\*8\*8000=600.768Mbps

1. Three packet-switching networks each contain n nodes. The first network has a star topology with a central switch, the second is a (bidirectional) ring, and the third is fully interconnected, with a wire from every node to every other node. What are the best-, average-, and worst-case transmission paths in hops?

P124拓扑结构

第一个总是跳转2次（中心处），第二个可能跳转1~n/2次，期望的次数是n/4。最后一个总是跳转1次。

奇怪的中文翻译。

第一个中心点结构：最好2次，最坏2次，平均2次。

第二个双向环结构：最好1次，最坏n/2次，平均n/4次。

第三个全连接：最好1次，最坏1次，平均1次。

但是如果从效率（用到的连接线\*平均次数）来看：第一个2\*n\*2=O(n)，第二个2\*n\*(n/4)=O(n^2)，第三个O(n^2)，效率最好的是第一个。

1. 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 circuitswitched network.

电路交换的时间：s+d\*k+x/b。（即建立连接的时间+每个hop的延迟时间+传输的总时间）

包交换的时间：x/b+k\*d+(k-1)\*p/b。（传输的总时间x/p\*p/b+每个hop的延迟时间+包在找路径过程中最短跳转时的传输时间）

所以(k-1)\*p/b<s时，有包交换用时少。

1. Suppose that x bits of user data are to be transmitted over a k-hop path in a packetswitched network as a series of packets, each containing p data bits and h header bits, with x > > 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?

包数x/p，总的传输数据是(p+h)\*x/p，传输的时间是(p+h)\*x/p/b，包在找路径中最短跳转时的传输时间为(p+h)\*(k-1)/b，time=(p+h)\*x/p/b + (p+h)\*(k-1)/b ， 对p求极小值点得到p=sqrt(hx\*(k-1))

1. In a typical mobile phone system with hexagonal cells, it is forbidden to reuse a frequency band in an adjacent cell. If 840 frequencies are available, how many can be used in a given cell?

840/3=280

1. The actual layout of cells is seldom as regular that as shown in Fig. 2-45. Even the shapes of individual cells are typically irregular. Give a possible reason why this might be. How do these irregular shapes affect frequency assignment to each cell?

不规则原因：每个蜂窝的地形不是平坦的，一栋大楼可能会影响蜂窝的边界。每个地形的用户密度不一样，城市里和农村的密度不同，所以城市应该有更密集的蜂窝设备（城市的蜂窝更小）。每个天线所在的地点也是不能保证就能恰好满足要求。

导致的结果：相邻的蜂窝可能不是恰好是六边形的了，可能会成为其他情况。此时仍要保证能让两个蜂窝的频率不同。

1. Make a rough estimate of the number of PCS microcells 100 m in diameter it would take to cover San Francisco (120 square km).

S\_1=100\*100\*PI/4=2500PI m^2，120 km^2/2500PI m^2=15279

1. Sometimes when a mobile user crosses the boundary from one cell to another, the current call is abruptly terminated, even though all transmitters and receivers are functioning perfectly. Why?

相邻蜂窝使用的频率是不同的，所以当一个用户从一个区域移动到另一个，他将会使用一个新的频率。转换频率时就会中断一下。

1. Suppose that A, B, and C are simultaneously transmitting 0 bits, using a CDMA system with the chip sequences of Fig. 2-28(a). What is the resulting chip sequence?

A\_+B\_+C\_=(3,1,1,-1,-3,-1,-1,1)

1. Consider a different way of looking at the orthogonality property of CDMA chip sequences. Each bit in a pair of sequences can match or not match. Express the orthogonality property in terms of matches and mismatches.
2. A CDMA receiver gets the following chips: (−1 +1−3 +1−1 −3 +1 +1). Assuming the chip sequences defined in Fig. 2-28(a), which stations transmitted, and which bits did each one send?

让这个序列依次乘ABCD得到：

1,-1,0,1，即AD送1，B送-1,C无。

1. In Figure 2-28, there are four stations that can transmit. Suppose four more stations are added. Provide the chip sequences of these stations.

(+1,+1,+1,+1,+1,+1,+1,+1)

(+1,+1,+1,+1,-1,-1,-1,-1)

(+1,+1,-1,-1,+1,+1,-1,-1)

(+1,-1,+1,-1,+1,-1,+1,-1)

1. At the low end, the telephone system is star shaped, with all the local loops in a neighborhood converging on an end office. In contrast, cable television consists of a single long cable snaking its way past all the houses in the same neighborhood. Suppose that a future TV cable were 10-Gbps fiber instead of copper. Could it be used to simulate the telephone model of everybody having their own private line to the end office? If so, how many one-telephone houses could be hooked up to a single fiber?

64 kbps是数字PCM电话所需要的传输速度，将一根10Gbps的光纤分成小份，每份大小为64 kbps，可以分得10Gbps/64kbps=156250个。

1. A cable company decides to provide Internet access over cable in a neighborhood consisting of 5000 houses. The company uses a coaxial cable and spectrum allocation allowing 100 Mbps downstream bandwidth per cable. To attract customers, the company decides to guarantee at least 2 Mbps downstream bandwidth to each house at any time. Describe what the cable company needs to do to provide this guarantee.

同轴电缆：P156

100/2=50户用一根同轴电缆, 5000/50=100，即分出100个同轴电缆。

1. Using the spectral allocation shown in Fig. 2-52 and the information given in the text, how many Mbps does a cable system allocate to upstream and how many to downstream?
2. How fast can a cable user receive data if the network is otherwise idle? Assume that the user interface is (a) 10-Mbps Ethernet (b) 100-Mbps Ethernet (c) 54-Mbps Wireless.

52. Multiplexing STS-1 multiple data streams, called tributaries, plays an important role in SONET. A 3:1 multiplexer multiplexes three input STS-1 tributaries onto one output STS-3 stream. This multiplexing is done byte for byte. That is, the first three output bytes are the first bytes of tributaries 1, 2, and 3, respectively. the next three output bytes are the second bytes of tributaries 1, 2, and 3, respectively, and so on. Write a program that simulates this 3:1 multiplexer. Your program should consist of five processes. The main process creates four processes, one each for the three STS-1 tributaries and one for the multiplexer. Each tributary process reads in an STS-1 frame from an input file as a sequence of 810 bytes. They send their frames (byte by byte) to the multiplexer process. The multiplexer process receives these bytes and outputs an STS-3 frame (byte by byte) by writing it to standard output. Use pipes for communication among processes.

53. Write a program to implement CDMA. Assume that the length of a chip sequence is eight and the number of stations transmitting is four. Your program consists of three sets of processes: four transmitter processes (t0, t1, t2, and t3), one joiner process, and four receiver processes (r0, r1, r2, and r3). The main program, which also acts as the joiner process first reads four chip sequences (bipolar notation) from the standard input and a sequence of 4 bits (1 bit per transmitter process to be transmitted), and forks off four pairs of transmitter and receiver processes. Each pair of transmitter/receiver processes (t0,r0; t1,r1; t2,r2; t3,r3) is assigned one chip sequence and each transmitter process is assigned 1 bit (first bit to t0, second bit to t1, and so on). Next, each transmitter process computes the signal to be transmitted (a sequence of 8 bits) and sends it to the joiner process. After receiving signals from all four transmitter processes, the joiner process combines the signals and sends the combined signal to the four receiver processes. Each receiver process then computes the bit it has received and prints it to standard output. Use pipes for communication between processes.