Solutions to Assignment 1

Question 1

兔 is the (Simplified) Chinese character for "rabbit."

On unicode.org you can look up the Unicode code point as: U+5154 which is binary 0101 0001 0101 0100. This is encoded to UTF-8 using the third row of Table 3-6 of the Unicode standard with zzzz=0101, yyyy yy= 0001 01 and xxxxxx=01 0100. The UTF-8 encoding is 1110 0101 10 0001 01 and 10 01 0100 which is 0xE5, 0x85, 0x94 and takes three bytes.

Question 2

The value 1234 (decimal) is 4D2 hex ($4 \times 256 + 13 \times 16 + 2$). If stored as a 16-bit value at memory location 0x1000 in little-endian order the least-significant byte, 0xd2, will be stored at the specified memory location (0x1000) and the MS byte, 0x04 will be stored in the next memory location at 0x1001:

address	data
0FFF	
1000	D2
1001	04
1002	

Question 3

(a) There are eight different possible symbols (two possible durations times four levels for each duration).

(b) If there are 2^n symbols we can transmit n bits per symbol. In this case $n = 3$ so we can transmit 3 bits per symbol.

(c) The average symbol duration is 1.5 μs and each symbol transmits 3 bits so the average data rate is $\frac{3}{1.5 \times 10^6} = 2$ Mb/s. Note that averaging the two rates (3/2=1.5 Mb/s and 3/1=3 Mb/s) would give you an answer of 2.25 Mb/s which is incorrect.

(d) The baud rate is defined as the inverse of the minimum time between signal level transitions which in this case is 1 μs. So the baud rate is 1 MHz.

Question 4

(a) If each packet contains 20 ms of speech the payload is $20 \times 10^{-3} \times 8 \times 10^3 = 160$ bytes which is $160 \times 8 = 1280$ bits.

(b) If each VoIP packets contains 20 bytes of header overhead, the fraction of each packet that is payload is $\frac{160}{160+20} \approx 89\%$.

(c) Each channel requires a rate of $\frac{1280+20\times 8}{20\times 10^{-3}} = 72$ kb/s. So a system with a data rate of 100 Mb/s with no other overhad (e.g. gaps between packets) could carry $\frac{100\times 10^6}{72\times 10^3} = 1388$ channels (the result needs to be rounded down as we can't transmit a fraction of a speech channel).

(d) Assuming no lost packets the throughput per channel is the number of payload bits per second or $\frac{1280}{20\times 10^{-3}} = 64$ kb/s.

Question 5

If the level on the UART output pin is L (low) when no data is being transmitted, then L must correspond to the mark level since mark is the level transmitted over an RS-232 interface when no data is being transmitted.

Question 6

If the UART pin above is labelled TxD and is an output, then this interface is meant to be a DTE since on a DTE side of an interface TxD is an output (TxD is an input on the DCE side).

Question 7

Resistance is inversely proportional to cross-sectional area. The diameter doubles for each decrease of 6 in AWG gauge so 12-gauge wire has $2^{(24-12)/6} = 4$ times the diameter of 24-gauge wire. Since the cross-sectional area is proportional to the radius (or diameter), the 12-gauge wire has $4^2 = 16$ times the cross-sectional area so 16 parallel strands of 24-gauge wire have the same cross-sectional area and thus the same resistance as one 12-gauge wire.

Question 8

From the equation for the capacitance of a cylindrical capacitor we can solve for the dielectric constant:

$$\varepsilon_r = \frac{C \ln(D/d)}{2\pi\varepsilon_0 L}$$

and using $C = 20 \times 10^{-9}$, $D = 4.6$ mm, $d = 1$ mm, $\varepsilon_0 = 8.85$ pF/m and $L = 300$ m, we find $\varepsilon_r \approx 1.8$. Knowing ε_r we can calculate

$$Z_0 \approx \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right) \approx 68\,\Omega$$

Question 9

A typical example of distribution single-mode 12-fiber cable would be Corning 012ED8-31331-20. Vendors include Anixter and Accu-Tech (via Amazon). Pricing is about 50 cents (US) per foot so a 1000-foot roll would cost about \$500.

Question 10

(a) The area of a sphere of radius d is $4\pi d^2$. A power of P_T equally distributed over that area would result in a power density of $\frac{P_T}{4\pi d^2}$. The power incident on an area A_e would thus be $A_e \frac{P_T}{4\pi d^2}$. Setting this equal to the received power predicted from the Friis equation with $G_T = 1$:

$$A_e \frac{P_T}{4\pi d^2} = P_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

and we can solve for G_R:

$$G_R = \frac{A_e 4\pi}{\lambda^2}$$

(b) At a frequency of 30×10^9 Hz the wavelength $\lambda = c/f = 3 \times 10^8 / 3 \times 10^{10} = 0.01$ m. An antenna with an (effective) area of 1 m^2 would thus have a gain of:

$$G_R = \frac{1 \cdot 4\pi}{(0.01)^2} \approx 126 \times 10^3 \approx 51 \text{ dB}$$

Question 11

(a) According to Wikipedia (and other sources) OFNR stands for Optical Fiber Non-conductive Riser. The cable materials are self-extinguishing and this cable would be used where it is important to limit the spread of fire such as spaces between floors in a building ("risers").

OFNP stands for Optical Fiber Non-conductive Plenum. In addition to limiting the spread of fire, the cable materials are designed to limit the generation of toxic gases when burned and this cable would be used where it is important to limit generation of such gases such as in air distribution spaces ("plenums").

(b) The spaces in the ceilings of most classrooms in SW1 are used for air distribution and would require the installation of OFNP-rated optical fiber cable.

Question 12

The (complex) value of the transfer function can be computed at each frequency by substituting the appropriate value of f. We can re-write the equation as:

$$H(f) = \left(1 + j\left(\frac{f}{3000}\right)^4\right)^{-\frac{1}{2}}$$

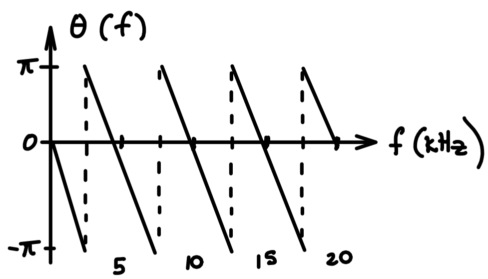
For $f = 300$ we can ignore the imaginary component since it is much smaller than the real component and $H(f) \approx 1$. Similarly, for $f = 30$ kHz the imaginary component is much larger and $H(f) \approx (j10^4)^{-\frac{1}{2}} = \left(10^4 e^{j\frac{\pi}{2}}\right)^{-\frac{1}{2}} = 10^{-2}\angle -45°$. For $f = 3$ kHz, the real and imaginary components are both 1 so $H(f) \approx \left(\sqrt{2}e^{j\frac{\pi}{4}}\right)^{-\frac{1}{2}} \approx 0.84\angle -22.5°$.

We can confirm this using Matlab:

```
> f=[3,3000,30E3];
> h=sqrt(1./(1+j*(f/3000).^4));
> abs(h)
ans =

   1.0000000    0.8408964    0.0100000

> 180/pi*angle(h)
ans =

  -2.8648e-11   -2.2500e+01   -4.4997e+01
```

Question 13

(a) The phase response of a channel with a delay τ is $\theta(f) = -2\pi f\tau$. For $\tau = 0.2 \times 10^{-3}$, $\theta(f) = -0.4\pi f \times 10^{-3}$. This is a straight line with an origin at $\theta(0) = 0$ and a slope of -0.4π/kHz. The phase will reach $-\pi$ at $f = \frac{1}{0.4} = 2.5$ kHz and will wrap around to $+\pi$. The graph would look like:



(b) Yes, this a linear-phase channel (the phase response is a straight line).

Question 14

(a) If the group delay varies between 10.75 μs and 11.25μs, the maximum variation is $11.75 - 11.25 = 0.5\mu$s.

To limit the dispersion due to group delay variation to 10% of the symbol period, the symbol period must be more than $\frac{0.5}{10\%} = 5\mu$s. The symbol rate must thus be less than $\frac{1}{5\times10^{-6}} = 200$ kHz.

(b) This cannot be a linear-phase channel because the delay varies with frequency.

Question 15

The THD is (the square root of) the ratio of the sum of the harmonic powers to the power in the test signal (call it P). The 200 kHz harmonic is 20 dB down relative to the test signal so it has a power of $P \times 10^{-20/10} = 0.01P$. Similarly the 300 kHz harmonic has a power of $P \times 10^{-23/10} = 0.005P$. Thus the THD is $\sqrt{\frac{0.015P}{P}} \approx 12\%$.

Note that the definition of THD as the square root of the power ratio is more commonly used than the definition given in the lecture notes (the power ratio).

Question 16

(a) To calculate the probability that the path loss will be less than 18 dB we first find the normalized threshold using the given mean $\mu = 30$ dB and standard deviation $\sigma = 8$ dB as $t = \frac{18-30}{8} = -1.5$. The probability that the path loss is less than 18 dB is thus $P(-1.5)$. Using a calculator gives a probability of about 0.067 and the graph in Lecture 4 also gives about 7%.

(b) To find the probability that it exceeds 38 dB we first find the probability that it is less than 38 dB. The normalized threshold in this case is $t = \frac{38-30}{8} = 1$ and $P(1) = 0.841$ (from graph or calculator). The probability that it exceeds this value is 1 minus the probability that it is less or $1 - 0.841 \approx 16\%$.

Question 17

NEXT is caused by near-end transmissions interfering with near-end reception. FEXT is caused by far-end transmissions interfering with near-end reception.

If the interface was receiving data but not transmitting it then there would be no near-end transmitter and thus no NEXT. If there were a remote transmitter (this is not stated in the question) it might cause FEXT to the near-end receiver.

If the interface was both transmitting and receiving then there could be NEXT if the local transmitter affected the near-end receiver. If there were a remote transmitter (this is not stated in the question) it might cause FEXT to the near-end receiver.