SOLUTIONS MANUAL

DATA AND COMPUTER COMMUNICATIONS
TENTH EDITION

CHAPTERS 1–13

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NOTICE

This manual contains solutions to the review questions and homework problems in *Cryptography and Network Security, Sixth Edition*. If you spot an error in a solution or in the wording of a problem, I would greatly appreciate it if you would forward the information via email to wllmst@me.net. An errata sheet for this manual, if needed, is available at http://www.box.net/shared/nz7n14ura7 . File name is S-Crypto6e-mmyy.

W.S.

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Chapter 2 Protocol Architecture

Answers to Questions

2.1 The network access layer is concerned with the exchange of data between a computer and the network to which it is attached.

2.2 The transport layer is concerned with data reliability and correct sequencing.

2.3 A protocol is the set of rules or conventions governing the way in which two entities cooperate to exchange data.

2.4 A PDU is the combination of data from the next higher communications layer and control information.

2.5 The software structure that implements the communications function. Typically, the protocol architecture consists of a layered set of protocols, with one or more protocols at each layer.

2.6 Transmission Control Protocol/Internet Protocol (TCP/IP) are two protocols originally designed to provide low level support for internetworking. The term is also used generically to refer to a more comprehensive collection of protocols developed by the U.S. Department of Defense and the Internet community.

2.7 Layering decomposes the overall communications problem into a number of more manageable subproblems.

2.8 A router is a device that operates at the Network layer of the OSI model to connect dissimilar networks.

2.9 IPv4.

2.10 No, other transport layer protocols, such as UDP, are also used. Some traffic uses no transport protocol, such as ICMP.

2.11 IPv4 - 32 bits; IPv6 - 128 bits

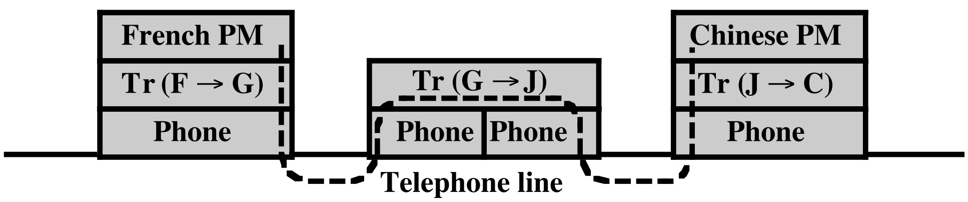
ANSWERS TO PROBLEMS

2.1 The guest effectively places the order with the cook. The host communicates this order to the clerk, who places the order with the cook. The phone system provides the physical means for the order to be transported from host to clerk. The cook gives the pizza to the clerk with the order form (acting as a "header" to the pizza). The clerk boxes the pizza with the delivery address, and the delivery van encloses all of the orders to be delivered. The road provides the physical path for delivery.

2.2 a.

The PMs speak as if they are speaking directly to each other. For example, when the French PM speaks, he addresses his remarks directly to the Chinese PM. However, the message is actually passed through two translators via the phone system. The French PM's translator translates his remarks into English and telephones these to the Chinese PM's translator, who translates these remarks into Chinese.

b.



An intermediate node serves to translate the message before passing it on. Note that the intermediate node handles the message only up to the second level; a minister's level is not needed.

2.3 Perhaps the major disadvantage is the processing and data overhead. There is processing overhead because as many as seven modules (OSI model) are invoked to move data from the application through the communications software. There is data overhead because of the appending of multiple headers to the data. Another possible disadvantage is that there must be at least one protocol standard per layer. With so many layers, it takes a long time to develop and promulgate the standards.

2.4 No. There is no way to be assured that the last message gets through, except by acknowledging it. Thus, either the acknowledgment process continues forever, or one army has to send the last message and then act with uncertainty.

2.5 A case could be made either way. **First**, look at the functions performed at the network layer to deal with the communications network (hiding the details from the upper layers). The network layer is responsible for routing data through the network, but with a broadcast network, routing is not needed. Other functions, such as sequencing, flow control, error control between end systems, can be accomplished at layer 2, because the link layer will be a protocol directly between the two end systems, with no intervening switches. So it would seem that a network layer is not needed. **Second**, consider the network layer from the point of view of the upper layer using it. The upper layer sees itself attached to an access point into a network supporting communication with multiple devices. The layer for assuring that data sent across a network is delivered to one of a number of other end systems is the network layer. This argues for inclusion of a network layer.

In fact, the OSI layer 2 is split into two sublayers. The lower sublayer is concerned with medium access control (MAC), assuring that only one end system at a time transmits; the MAC sublayer is also responsible for addressing other end systems across the LAN. The upper sublayer is called Logical Link Control (LLC). LLC performs traditional link control functions. With the MAC/LLC combination, no network layer is needed (but an internet layer may be needed).

2.6 **a.** No. This would violate the principle of separation of layers. To layer (N – 1), the N-level PDU is simply data. The (N – 1) entity does not know about the internal format of the N-level PDU. It breaks that PDU into fragments and reassembles them in the proper order.

b. Each N-level PDU must retain its own header, for the same reason given in (a).

2.7 Data plus transport header plus internet header equals 1820 bits. This data is delivered in a sequence of packets, each of which contains 24 bits of network header and up to 776 bits of higher-layer headers and/or data. Three network packets are needed. Total bits delivered = $1820 + 3 \times 24 = 1892$ bits.

2.8 UDP provides the source and destination port addresses and a checksum that covers the data field. These functions would not normally be performed by protocols above the transport layer. Applications can't provide port addresses (they aren't really addresses). Port-ids have to be unambiguous between the application and the layer (or OS). If they were provided by the application then the same port-id could be assigned by different applications and layer (or OS) couldn't distinguish them. UDP therefore is a necessity. Thus UDP provides a useful, though limited, service.

2.9 In the case of IP and UDP, these are unreliable protocols that do not guarantee delivery, so they do not notify the source. TCP does guarantee delivery. However, the technique that is used is a timeout. If the source does not receive an acknowledgment to data within a given period of time, the source retransmits.

2.10 UDP has a fixed-sized header. The header in TCP is of variable length.

2.11 Suppose that A sends a data packet k to B and the ACK from B is delayed but not lost. A resends packet k, which B acknowledges. Eventually A receives 2 ACKs to packet k, each of which triggers transmission of packet (k + 1). B will ACK both copies of packet (k + 1), causing A to send two copies of packet (k + 2). From now on, 2 copies of every data packet and ACK will be sent.

2.12 TFTP can transfer a maximum of 512 bytes per round trip (data sent, ACK received). The maximum throughput is therefore 512 bytes divided by the round-trip time.

2.13 The "netascii" transfer mode implies the file data are transmitted as lines of ASCII text terminated by the character sequence {CR, LF}, and that both systems must convert between this format and the one they use to store the text files locally. This means that when the "netascii" transfer mode is employed, the file sizes of the local and the remote file may differ, without any implication of errors in the data transfer. For example, UNIX systems terminate lines by means of a single LF character, while other systems, such as Microsoft Windows, terminate lines by means of the character sequence {CR, LF}. This means that a given text file will usually occupy more space in a Windows host than in a UNIX system.

2.14 If the same TIDs are used in twice in immediate succession, there's a chance that packets of the first instance of the connection that were delayed in the network arrive during the life of the second instance of the connection, and, as they would have the correct TIDs, they could be (mistakenly) considered as valid.

2.15 TFTP needs to keep a copy of only the last packet it has sent, since the acknowledgement mechanism it implements guarantees that all the previous packets have been received, and thus will not need to be retransmitted.

2.16 This could trigger an "error storm". Suppose host A receives an error packet from host B, and responds it by sending an error packet back to host B. This packet could trigger another error packet from host B, which would (again) trigger an error packet at host A. Thus, error messages would bounce from one host to the other, indefinitely, congesting the network and consuming the resources of the participating systems.

2.17 The disadvantage is that using a fixed value for the retransmission timer means the timer will not reflect the characteristics of the network on which the data transfer is taking place. For example, if both hosts are on the same local area network, a 5-second timeout is more than enough. On the other hand, if the transfer is taking place over a (long delay) satellite link, then a 5-second timeout might be too short, and could trigger unnecessary retransmissions. On the other hand, using a fixed value for the retransmission timer keeps the TFTP implementation simple, which is the objective the designers of TFTP had in mind.

2.18 TFTP does not implement any error detection mechanism for the transmitted data. Thus, reliability depends on the service provided by the underlying transport protocol (UDP). While the UDP includes a checksum for detecting errors, its use is optional. Therefore, if UDP checksums are not enabled, data could be corrupted without being detected by the destination host.

2.19 **a.** The internet protocol can be defined as a separate layer. The functions performed by IP are clearly distinct from those performed at a network layer and those performed at a transport layer, so this would make good sense.

b. The session and transport layer both are involved in providing an end-to-end service to the OSI user, and could easily be combined. This has been done in TCP/IP, which provides a direct application interface to TCP.

Sockets Solutions

Solutions to Sockets programming assignments are in file Solutions-DCC10e-Sockets.zip

Chapter 3 Data Transmission

Answers to Questions

3.1 With guided media, the electromagnetic waves are guided along an enclosed physical path whereas unguided media provide a means for transmitting electromagnetic waves but do not guide them.

3.2 A continuous or analog signal is one in which the signal intensity varies in a smooth fashion over time while a discrete or digital signal is one in which the signal intensity maintains one of a finite number of constant levels for some period of time and then changes to another constant level.

3.3 Amplitude, frequency, and phase are three important characteristics of a periodic signal.

3.4 2π radians.

3.5 The relationship is $\lambda f = v$, where λ is the wavelength, f is the frequency, and v is the speed at which the signal is traveling.

3.6 The fundamental frequency is the lowest frequency component in the Fourier representation of a periodic quantity.

3.7 The spectrum of a signal is the frequencies it contains while the bandwidth of a signal is the width of the spectrum.

3.8 Attenuation is the gradual weakening of a signal over distance.

3.9 The rate at which data can be transmitted over a given communication path, or channel, under given conditions, is referred to as the channel capacity.

3.10 Bandwidth, noise, and error rate.

Answers to Problems

3.1 **a.** If two devices transmit at the same time, their signals will be on the medium at the same time, interfering with each other; i.e., their signals will overlap and become garbled.
b. See discussion in Chapter 11 on medium access control.

3.2 Period = 1/1000 = 0.001 s = 1 ms.

3.3 **a.** $\sin(2\pi ft - \pi) + \sin(2\pi ft + \pi) = 2\sin(2\pi ft + \pi)$ or $2\sin(2\pi ft - \pi)$ or $-2\sin(2\pi ft)$
b. $\sin(2\pi ft) + \sin(2\pi ft - \pi) = 0$.

3.4

N	C		D		E		F		G		A		B		C
F	264		297		330		352		396		440		495		528
D		33		33		22		44		44		55		33	
W	1.25		1.1		1		0.93		0.83		0.75		0.67		0.63

N = note; F = frequency (Hz); D = frequency difference;
W = wavelength (m)

3.5 $2\sin(4\pi t + \pi)$; $A = 2$, $f = 2$, $\phi = \pi$

3.6 $(1 + 0.1\cos 5t)\cos 100t = \cos 100t + 0.1\cos 5t \cos 100t$. From the trigonometric identity $\cos a \cos b = (1/2)(\cos(a + b) + \cos(a - b))$, this equation can be rewritten as the linear combination of three sinusoids:
$\cos 100t + 0.05\cos 105t + 0.05\cos 95t$

3.7 We have $\cos^2 x = \cos x \cos x = (1/2)(\cos(2x) + \cos(0)) = (1/2)(\cos(2x) + 1)$. Then:
$f(t) = (10\cos t)^2 = 100\cos^2 t = 50 + 50\cos(2t)$. The period of $\cos(2t)$ is π and therefore the period of $f(t)$ is π.

3.8 If $f_1(t)$ is periodic with period X, then $f_1(t) = f_1(t + X) = f_1(t + nX)$ where n is an integer and X is the smallest value such that $f_1(t) = f_1(t + X)$. Similarly, $f_2(t) = f_2(t + Y) = f_2(t + mY)$. We have $f(t) = f_1(t) + f_2(t)$. If $f(t)$ is periodic with period Z, then $f(t) = f(t + Z)$. Therefore $f_1(t) + f_2(t) = f_1(t + Z) + f_2(t + Z)$. This last equation is satisfied if $f_1(t) = f_1(t + Z)$ and $f_2(t) = f_2(t + Z)$. This leads to the condition $Z = nX = mY$ for some integers n and m. We can rewrite this last as $(n/m) = (Y/X)$. We can therefore conclude that if the ratio (Y/X) is a rational number, then $f(t)$ is periodic.

3.9 The signal would be a low-amplitude, rapidly changing waveform.

3.10 No transmission medium is capable of transmitting the entire spectrum of frequencies. A real signal therefore is band limited, with frequencies above a certain point absent. However, most of the information is in the lower frequencies. This is not a problem if it is remembered that the object of the transmission is to send signals that represent binary 1s and 0s. Even though there will be some distortion because of the loss of higher frequencies, the shape of the original pulse is known (by the specifications for the transmission system). Thus, the receiver will usually be able to distinguish a binary 0 from a binary 1.

3.11 A 6-bit code allows only 64 unique characters to be defined. Several *shift lock codes* were defined in various versions of TTS (shift, supershift, unshift). These codes change the meaning of all codes that follow until a new shift lock code appears. Thus, with two shift locks, $3 \times (64 - 3) = 183$ different codes can be defined. The actual number is less, since some codes, such as space, are "don't-cares" with respect to shift locks.

3.12 **a.** $25 \times 512 \times 512 \times 8 = 52.4$ Mb
b. $30 \times 512 \times 512 \times 8 = 62.9$ Mbps
c. $25 \times 30 \times 512 \times 512 = 196.6$ MB for each study

3.13 **a.** (30 pictures/s) (480 $\times$ 500 pixels/picture) = 7.2×10^6 pixels/s
Each pixel can take on one of 32 values and can therefore be represented by 5 bits:

$$R = 7.2 \times 10^6 \text{ pixels/s} \times 5 \text{ bits/pixel} = 36 \text{ Mbps}$$

b. We use the formula: $C = B \log_2 (1 + SNR)$

$B = 4.5 \times 10^6$ MHz = bandwidth, and
$SNR_{dB} = 35 = 10 \log_{10} (SNR)$, hence
$SNR = 10^{35/10} = 10^{3.5}$, and therefore
$C = 4.5 \times 10^6 \log_2 (1 + 10^{3.5}) = 4.5 \times 10^6 \times \log_2 (3163)$
$C = (4.5 \times 10^6 \times 11.63) = 52.335 \times 10^6$ bps

c. Allow each pixel to have one of ten intensity levels and let each pixel be one of three colors (red, blue, green) for a total of $10 \times 3 = 30$ levels for each pixel element.

3.14 $N = 10 \log k + 10 \log T + 10 \log B$
$= -228.6 \text{ dBW} + 10 \log 10^4 + 10 \log 10^7$
$= -228.6 + 40 + 70 = -118.6$ dBW

3.15 Using Shannon's equation: $C = B \log_2 (1 + SNR)$
We have $W = 300$ Hz $(SNR)_{dB} = 3$
Therefore, $SNR = 10^{0.3}$
$C = 300 \log_2 (1 + 10^{0.3}) = 300 \log_2 (2.995) = 474$ bps

3.16 Using Nyquist's equation: $C = 2B \log_2 M$

We have $C = 9600$ bps

a. $\log_2 M = 4$, because a signal element encodes a 4-bit word

Therefore, $C = 9600 = 2B \times 4$, and $B = 1200$ Hz

b. $9600 = 2B \times 8$, and $B = 600$ Hz

3.17 $N = 1.38 \times 10^{-23} \times (50 + 273) \times 10{,}000 = 4.5 \times 10^{-17}$ watts

3.18 **a.** Using Shannon's formula: $C = 3000 \log_2 (1+400000) = 56$ Kbps

b. Due to the fact there is a distortion level (as well as other potentially detrimental impacts to the rated capacity, the actual maximum will be somewhat degraded from the theoretical maximum. A discussion of these relevant impacts should be included and a qualitative value discussed.

3.19 Nyquist analyzed the theoretical capacity of a noiseless channel; therefore, in that case, the signaling rate is limited solely by channel bandwidth. Shannon addressed the question of what signaling rate can be achieved over a channel with a given bandwidth, a given signal power, and in the presence of noise.

3.20 **a.** Using Shannon's formula $C = 10^6 \log_2(1 + 63) = 6$ MHz.

b. Data rate = 4 MHz. Using Nyquist's formula $4 \times 10^6 = 2 \times 10^6 \log_2 M$

$M = 2^2 = 4$

3.21 $C = B \log_2 (1 + SNR)$

$20 \times 10^6 = 3 \times 10^6 \times \log_2(1 + SNR)$

$\log_2(1 + SNR) = 6.67$

$1 + SNR = 102$

$SNR = 101$

3.22 **a.** Output waveform:

$\sin (2\pi f_1 t) + 1/3 \sin (2\pi(3f_1)t) + 1/5 \sin (2\pi(5f_1)t) + 1/7 \sin (2\pi (7f_1)t)$

where $f_1 = 1/T = 1$ kHz

Output power = 1/2 (1 + 1/9 + 1/25 + 1/49) = 0.586 watt

b. Output noise power = 8 kHz × 0.1 μWatt/Hz = 0.8 mWatt

SNR = 0.586/0.0008 = 732.5 $(SNR)_{db} = 28.65$

3.23 $(E_b/N_0) = -151$ dBW – 10 log 2400 – 10 log 1500 + 228.6 dBW = 12 dBW

3.24 Let us rewrite equation (3.1) as

$$B \times \frac{1}{C} = \frac{1}{\log_2(1 + SNR)}$$

$$\text{Bandwidth} \times (\text{Transmission time}) = (\text{Measure of distortion})$$

3.25

Decibels	1	2	3	4	5	6	7	8	9	10
Losses	0.8	0.63	0.5	0.4	0.32	0.25	0.2	0.16	0.125	0.1
Gains	1.25	1.6	2	2.5	3.2	4.0	5.0	6.3	8.0	10

3.26 For a voltage ratio, we have

$N_{dB} = 30 = 20 \log(V_2/V_1)$
$V_2/V_1 = 10^{30/20} = 10^{1.5} = 31.6$

3.27 Power (dBW) = 10 log (Power/1W) = 10 log20 = 13 dBW

Chapter 4 Transmission Media

Answers to Questions

4.1 The twisting of the individual pairs reduces electromagnetic interference. For example, it reduces crosstalk between wire pairs bundled into a cable.

4.2 Twisted pair wire is subject to interference, limited in distance, bandwidth, and data rate.

4.3 Unshielded twisted pair (UTP) is ordinary telephone wire, with no form of electromagnetic shielding around the wire. Shielded twisted pair (STP) surrounds the wire with a metallic braid or sheathing that reduces interference.

4.4 Optical fiber consists of a column of glass or plastic surrounded by an opaque outer jacket. The glass or plastic itself consists of two concentric columns. The inner column called the core has a higher index of refraction than the outer column called the cladding.

4.5 Point-to-point microwave transmission has a high data rate and less attenuation than twisted pair or coaxial cable. It is affected by rainfall, however, especially above 10 GHz. It is also requires line of sight and is subject to interference from other microwave transmission, which can be intense in some places.

4.6 Direct broadcast transmission is a technique in which satellite video signals are transmitted directly to the home for continuous operation.

4.7 A satellite must use different uplink and downlink frequencies for continuous operation in order to avoid interference.

4.8 Broadcast is omnidirectional, does not require dish shaped antennas, and the antennas do not have to be rigidly mounted in precise alignment.

4.9 The two functions of an antenna are: **(1)** For transmission of a signal, radio-frequency electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into the surrounding environment (atmosphere, space, water); **(2)** for reception of a signal, electromagnetic energy impinging on the antenna is converted into radio-frequency electrical energy and fed into the receiver.

4.10 An **isotropic antenna** is a point in space that radiates power in all directions equally.

4.11 A parabolic antenna creates, in theory, a parallel beam without dispersion. In practice, there will be some beam spread. Nevertheless, it produces a highly focused, directional beam.

4.12 Effective area and wavelength.

4.13 Free space loss.

4.14 Refraction is the bending of a radio beam caused by changes in the speed of propagation at a point of change in the medium.

4.15 **Diffraction** occurs at the edge of an impenetrable body that is large compared to the wavelength of the radio wave. The edge in effect become a source and waves radiate in different directions from the edge, allowing a beam to bend around an obstacle. If the size of an obstacle is on the order of the wavelength of the signal or less, **scattering** occurs. An incoming signal is scattered into several weaker outgoing signals in unpredictable directions.

ANSWERS TO PROBLEMS

4.1 Elapsed time = 2 hours, 15 minutes = 8100 seconds

Number of DVDs = (10^7 g)/(15 g/DVD) = 666667 diskettes

Data transfer rate = $\frac{\left(8.54\times10^{9}\text{ bits/DVD}\right)\times\left(666667\text{ DVDs}\right)}{8100\text{ seconds}}\approx 703\text{ Gbps}$

4.2 10 log (P_o/P_i) = −20dB; Therefore, P_o/P_i = 0.01
For P_i = 0.5 Watt, P_o = 0.005 Watt

SNR = 0.005/(4.5×10^{-6}) = 1.11×10^3
SNR_{dB} = 10 log (1.11×10^3) = 30 dB

4.3 The allowable power loss is $10 \times \log 100 = 20$ dB

a. From Figure 4.3, the attenuation is about 13 dB per km.
Length = (20 dB)/(13 dB per km) = 1.5 km

b. Length = (20 dB)/(20 dB per km) = 1 km

c. Length = (20 dB)/(2.5 dB per km) = 8 km

d. Length = (20 dB)/(10 dB per km) = 2 km

e. Length = (20 dB)/(0.2 dB per km) = 100 km

4.4 An electromagnetic wave cannot penetrate an enclosing conductor. If the outer conductor of a coaxial cable is everywhere held at ground potential, no external disturbance can reach the inner, signal-carrying, conductor.

4.5 From Equation 4,2, the ratio of transmitted power to received power is
$P_t/P_r = (4\pi d/\lambda)^2$
If we double the frequency, we halve λ, or if we double the distance, we double d, so the new ratio for either of these events is:
$P_t/P_{r2} = (8\pi d/\lambda)^2$
Therefore:
$10 \log (P_r/P_{r2}) = 10 \log (2^2) = 6$ dB

4.6 We have $\lambda f = c$; in this case $\lambda \times 30 = 3 \times 10^8$ m/sec, which yields a wavelength of 10,000 km. Half of that is 5,000 km which is comparable to the east-to-west dimension of the continental U.S. While an antenna this size is impractical, the U.S. Defense Department has considered using large parts of Wisconsin and Michigan to make an antenna many kilometers in diameter.

4.7 **a.** Using $\lambda f = c$, we have $\lambda = (3 \times 10^8$ m/sec)/(300 Hz) = 1,000 km, so that
$\lambda/2 = 500$ km.

b. The carrier frequency corresponding to $\lambda/2 = 1$ m is given by:

$$f = c/\lambda = (3 \times 10^8 \text{ m/sec})/(2 \text{ m}) = 150 \text{ MHz}.$$

4.8 $\lambda = 2 \times 2.5 \times 10^{-3}$ m $= 5 \times 10^{-3}$ m
$f = c/\lambda = (3 \times 10^8$ m/sec)/(5×10^{-3} m) $= 6 \times 10^{10}$ Hz = 60 GHz

4.9 The received signal is, essentially, the same. The received power will increase by a factor of 4

4.10 Signal loss is proportional to the square of the frequency. Thus, the higher the frequency, the higher power is needed to obtain a given SNR. Power is much more readily available at earth stations than at satellites. Therefore, it makes more sense to put the higher power requirements on the earth stations than on the satellites.

4.11

Distance (km)	Radio (dB)	Wire (dB)
1	−6	−3
2	−12	−6
4	−18	−12
8	−24	−24
16	−30	−28

4.12 **a.** First, take the derivative of both sides of the equation $y^2 = 2px$:

$$\frac{dy}{dx}y^2 = \frac{dy}{dx}(2px);\ 2y\frac{dy}{dx} = 2p;\ \frac{dy}{dx} = \frac{p}{y}$$

Therefore tan β = (p/y_1).

b. The slope of PF is $(y_1 - 0)/(x_1 - (p/2))$. Therefore:

$$\tan\alpha = \frac{\dfrac{y_1}{x_1 - \dfrac{p}{2}} - \dfrac{p}{y_1}}{1 + \dfrac{y_1}{x_1 - \dfrac{p}{2}}\dfrac{p}{y_1}} = \frac{y_1^2 - px_1 + \dfrac{1}{2}p^2}{x_1y_1 - \dfrac{1}{2}py_1 + py_1}$$

Because $y_1^2 = 2px_1$, this simplifies to tan α = (p/y_1).

4.13 L_{dB} = 20 log(f_{MHz}) + 120 +20 log (d_{km}) + 60 – 147.56
= 20 log(f_{MHz}) +20 log (d_{km}) + 32.44

4.14 **a.** From Appendix 3A, $\text{Power}_{\text{dBW}}$ = 10 log (Power_{W}) = 10 log (50) = 17 dBW
$\text{Power}_{\text{dBm}}$ = 10 log (Power_{mW}) = 10 log (50,000) = 47 dBm

b. Using Equation (4.3),
L_{dB} = 20 log(900×10^6) +20 log (100) – 147.56 = 120 + 59.08 +40 – 147.56 = 71.52
Therefore, received power in dBm = 47 – 71.52 = –24.52 dBm

c L_{dB} = 120 + 59.08 +80 – 147.56 =111.52; $P_{r,\text{dBm}}$ = 47 – 111.52 = –64.52 dBm

d The antenna gain results in an increase of 3 dB, so that $P_{r,\text{dBm}}$ = –61.52 dBm

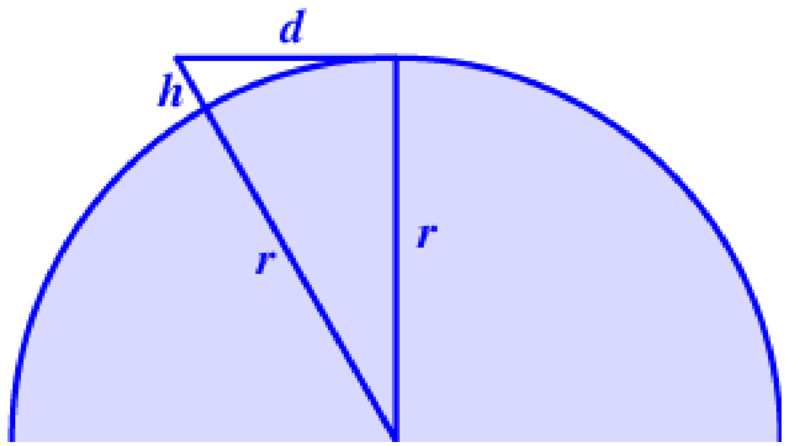
4.15 a. $G = 7A/\lambda^2 = 7Af^2/c^2 = (7 \times \pi \times (0.6)^2 \times (2\times10^9)^2]/(3 \times 10^8)^2 =$ 351.85
G_{dB} = 25.46 dB

b. 0.1 W x 351.85 = 35.185 W

c. Use $L_{dB} = 20 \log (4\pi) + 20 \log (d) + 20 \log (f) - 20 \log (c) - 10 \log(G_r) - 10 \log (G_t)$

L_{dB} = 21.98 + 87.6 + 186.02 – 169.54 – 25.46 – 25.46 = 75.14 dB
The transmitter power, in dBm is 10 log (100) = 20.
The available received signal power is 20 – 75.14 = –55.14 dBm

4.16



By the Pythagorean theorem: $d^2 + r^2 = (r + h)^2$
Or, $d^2 = 2rh + h^2$. The h^2 term is negligible with respect to $2rh$, so we use $d^2 = 2rh$.

Then, $d_{km} = \sqrt{2r_{km}h_{km}} = \sqrt{2r_{km}h_m / 1000} = \sqrt{2 \times 6.37 \times h_m} = 3.57\sqrt{h_m}$

4.17 For radio line of sight, we use $d = 3.57\sqrt{\mathrm{K}h}$, with K = 4/3, we have $80^2 = (3.57)^2 \times 1.33 \times h$. Solving for h, we get h = 378 m.

4.18 Let *RI* = refractive index, α = angle of incidence, β = angle of refraction

$(\sin \alpha)/\sin \beta) = \mathrm{RI}_{air}/\mathrm{RI}_{water} = 1.0003/(4/3) = 0.75$
$\sin \beta = 0.5/0.75 = 0.66$; $\beta = 41.8°$

CHAPTER 5 SIGNAL ENCODING TECHNIQUES

ANSWERS TO QUESTIONS

5.1 **Signal spectrum:** A lack of high-frequency components means that less bandwidth is required for transmission. In addition, lack of a direct-current (dc) component means that ac coupling via transformer is possible. The magnitude of the effects of signal distortion and interference depend on the spectral properties of the transmitted signal. **Clocking:** Encoding can be used to synchronize the transmitter and receiver. **Error detection:** It is useful to have some error detection capability built into the physical signaling encoding scheme. **Signal interference and noise immunity:** Certain codes exhibit superior performance in the presence of noise. **Cost and complexity:** The higher the signaling rate to achieve a given data rate, the greater the cost. Some codes require a signaling rate that is in fact greater than the actual data rate.

5.2 In differential encoding, the signal is decoded by comparing the polarity of adjacent signal elements rather than determining the absolute value of a signal element.

5.3 Non return-to-zero-level (NRZ-L) is a data encoding scheme in which a negative voltage is used to represent binary one and a positive voltage is used to represent binary zero. As with NRZ-L, NRZI maintains a constant voltage pulse for the duration of a bit time. The data themselves are encoded as the presence or absence of a signal transition at the beginning of the bit time. A transition (low to high or high to low) at the beginning of a bit time denotes a binary 1 for that bit time; no transition indicates a binary 0.

5.4 For **bipolar-AMI** scheme, a binary 0 is represented by no line signal, and a binary 1 is represented by a positive or negative pulse. The binary 1 pulses must alternate in polarity. For **pseudoternary**, a binary 1 a is represented by the absence of a line signal, and a binary 0 by alternating positive and negative pulses.