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Study Material with Classroom Practice Questions

Chapter 1 Communication Networks
(Solutions for Text Book Practice Questions)

Objective Practice Solutions

01. Ans: (b)
Sol: Data Link Layer is responsible for the decoding bit stream into **frames**.

02. Ans: (a)

03. Ans: (c)
Sol: Frame encapsulates packet

04. Ans: (d)
Sol: The End-to-End delivery of the entire message is the responsibility of the Transport layer.

05. Ans: (b)
Sol: As the data packets moves from the upper to lower layers, headers are added.

06. Ans: (a)
Sol: **Data link layer:** Ensures reliable transport of data over a Physical point-to-point link

Network layer: Routes data from one network node to the next

Transport layer: Allows end - to - end communication between two processes

07. Ans: (b)
Sol: Ethernet implements Connectionless service for its operation

08. Ans: (d)
Sol: TCP/IP model does not have session layer and presentation layer but OSI model have these layer.

09. Ans: (b)
Sol: ISO OSI reference model has 7 layers.

10. Ans: (a)
Sol: The physical layer concerns with Bit - by - bit delivery.

11. Ans: (a)
Sol: The data link layer takes the packets from Network layer and encapsulates them into frames for transmission.

12. Ans: (b)
Sol: The network layer protocol of internet is Internet protocol.

13. Ans: (a)
Sol: User datagram protocol is called connectionless because all UDP packets are treated independently by transport layer.

14. Ans: (a)
Sol: SMTP protocol deals with emails in application layer.

15. Ans: (a)
Sol: Ethernet frame consists of MAC address.

16. Ans: (a)
Sol: In Star topology there is a central controller or hub.

17. Ans: (b)
Sol: WAN is a Data communication system spanning states, countries, or the whole world.

Conventional Practice Solutions

01.

Sol: Difference between LAN and WAN

	LAN	**WAN**
Distance coverage	Limited coverage, about upto 2 miles(or 2500 meters)	Unlimited (usually in 1000Km) range, uses repeater and other connectivity for range extension
Speed of operation	High, typically 10, 100 and 1000 Mbps	Slow, about 1.5 Mbps (May vary based on wireless technologies used)
Technologies used for medium	Locally installed, twisted pair, fiber optic cable, wireless (e.g. WLAN, Zigbee)	Locally installed and based on common carrier e.g. twisted pair wires, fiber, coaxial cable, wireless including wireless and cellular network based
Applications	Used mainly by fixed desktop computers and portable computers (e.g. laptops). Now-a-days it is used by smart phones due to emergence of WLAN network	Can be used by any devices, but desktop devices are mainly using this network type.

02.

Sol: Given: At each layer, n bits of information is added/appended.

$= nh$

Total message = original message + overhead $= m + nh$

$$\% \text{ of overhead } = \frac{nh}{m+nh}\times 100$$

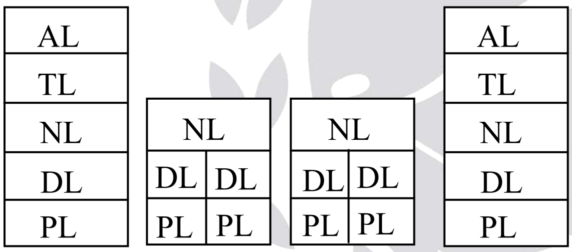
03.

Sol:

TCP	**UDP**
• Connection – Oriented • Reliability in delivery of messages • Splitting messages into datagrams • Keep track of order (or sequence) • Use checksums for detecting errors	• Connectionless • No attempt to fragment messages • No reassembly and synchronization • In case of error, message is retransmitted • No acknowledgment
• Remote procedures are not idempotent • Reliability is must • Messages exceed UDP packet size	• Remote procedures are idempotent • Server and client messages fit completely with a packet • The server handles multiple clients (UDP is stateless)

04.

Sol: Network layer 4 times, Data link layer 6 times.



NL = 4 Times

DL = 6 times

05.

Sol: Advantages and disadvantages of layered architecture in a network

The following are the advantages of a layered architecture:

Layered architecture increases flexibility, maintainability, and scalability. In a Layered architecture we separate the user interface from the business logic, and the business logic from the data access logic. Separation of concerns among these logical layers and components is easily achieved with the help of layered architecture.

Multiple applications can reuse the components. For example if we want a windows user interface rather than a web browser interface, this can be done in an easy and fast way by just replacing the UI component. All the other components like business logic, data access and the database remains the same. Layered architecture allows to swap and reuse components.

Layered architecture enables teams to work on different parts of the application parallely with minimal dependencies on other teams.

Layered architecture enables develop loosely coupled systems.

Different components of the application can be independently deployed, maintained, and updated, on different time schedules.

Layered architecture also makes it possible to configure different levels of security to different components deployed on different boxes. So Layered architecture, enables you to secure portions of the application behind the firewall and make other components accessible from the Internet.

Layered architecture also helps you to test the components independently of each other.

The following are the disadvantages of a layered architecture:

There might be a negative impact on the performance as we have the extra overhead of passing through layers instead of calling a component directly.

Development of user-intensive applications can sometime take longer if the layering prevents the use of user interface components that directly interact with the database.

The use of layers helps to control and encapsulate the complexity of large applications, but adds complexity to simple applications.

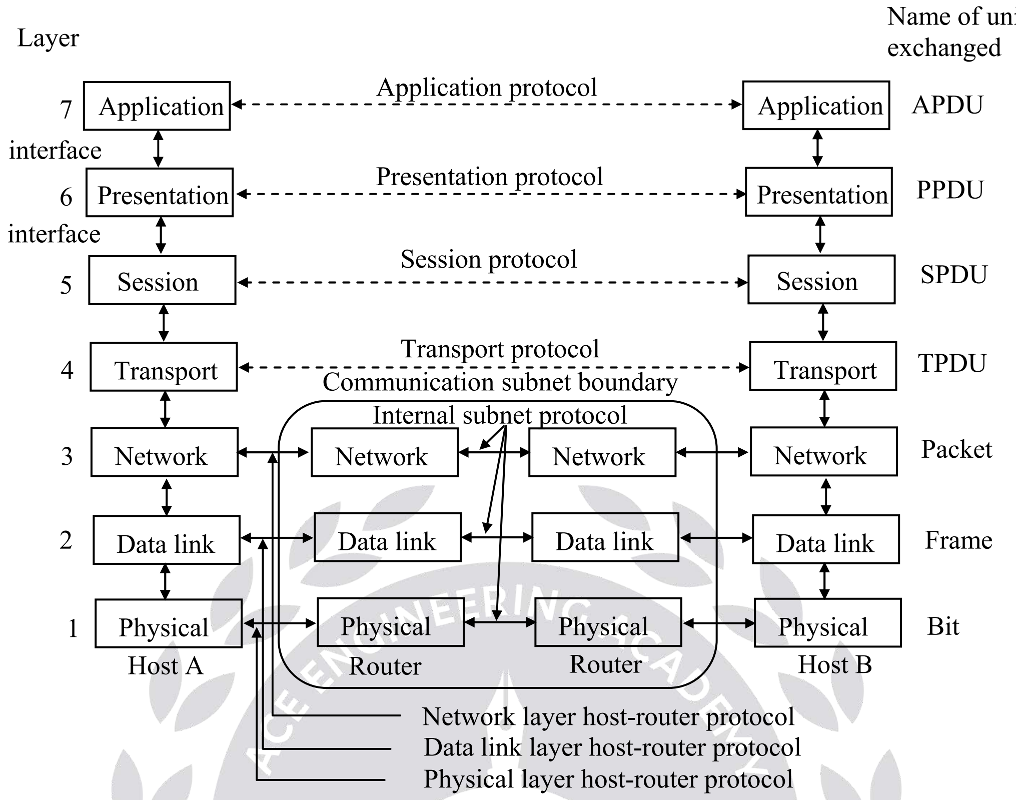
Changes to lower level interfaces tend to percolate to higher levels, especially if the relaxed layered approach is used.

06.

Sol: ***The OSI model has 7 layers:***

The principles that were applied to arrive at the seven layers are as follows:

01. A layer should be created where a different level of abstraction is needed.
02. Each layer should perform a well defined function.
03. The function of each layer should be chosen with an eye towards defining internationally standardized protocols.
04. The layer boundaries should be chosen to minimize the information flow across the interfaces.
05. The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity, and small enough that the architecture does not become unwieldy.



The ISO OSI model is depicted as above figure

The functionality of each layer is as follows.

The Physical Layer

- The main task of the physical layer is to transmit raw bits over a communication channel.
- The design issues deal with mechanical, electrical, and procedural interfaces, and the physical transmission medium, which lies below the physical layer.
- The physical layer may be sure that the given stream of bits was encoded and transmitted.
- The other issues related to raw bits are solved in higher layer.

The Data Link Layer

The main task of the data link layer is to take a raw transmission facility and transform it into a line that appears free of undetected transmission error to the network layer. To accomplish this, the sender breaks the input data into data frames (typically a few hundred or a few thousand bytes), transmits the frames sequentially, and processes the acknowledgment frames sent back by the receiver.

The issues that the layer has to solve:

- To create and to recognize frame boundaries - typically by attaching special bit patterns to the beginning and end of the frame,
- To solve the problems caused by damaged, lost or duplicate frames,
- To keep a fast transmitter from drowning a slow receiver in data.

The data link layer may be sure that his data were delivered without errors to the neighbor node.

The Network Layer

The main task of the network layer is to determine how data can be delivered from source to destination. The network layer is concerned with controlling the operation of the subnet.

The issues that the layer has to solve:

- To implement the routing mechanism,
- To control congestions,
- To do accounting,
- To allow interconnection of heterogeneous networks.

The network layer may be sure that his packet was delivered to the given destination. However, the delivery of the packets need not to be in the order in which they were transmitted.

The Transport Layer

The basic function of the transport layer is to accept data from the session layer, split it up into smaller units if needed, pass them to the network layer, and ensure that the pieces all arrive correctly at the other end.

The issues that the transport layer has to solve:

- To realize a transport connection by several network connections if the session layer requires a high throughput or multiplex several transport connections onto the same network connection if network connections are expensive,
- To provide different type of services for the session layer,
- To implement a kind of flow control.

The transport layer is a true end-to-end layer, from source to destination.

The transport layer may be sure that his message will be delivered to the destination regardless of the state of the network. He need not worry about the technical feature of the network.

The Session Layer

The session layer allows users on different machines to establish sessions between them. A session allows ordinary data transport.

Some of these services are:

- Dialog control
- Token management
- Synchronization

The Presentation Layer

A typical example of a presentation service is encoding data in a standard agreed upon way. Different computers may use different ways of internal coding of characters or numbers. In order to make it possible for computers with different representations to communicate, the data structures to be exchanged can be defined in an abstract way. The presentation layer manages these abstract data structures and converts from the representation used inside the computer to the network standard representation and back.

The Application Layer

The application layer contains a variety of protocols that are commonly needed.
Such as application layer function is filter transfer. It must handle different incompatibilities between file systems on different computers. Further facilities of the application layer are electronic mail, remote job entry, directory lookup and others.

Switch vs Router: The differences are depicted in the following table.

Switching	Routing
Layer 2 Switches perform switching	Layer 3 devices like router perform routing
Switching will be faster as switch uses ASIC technology	Routing will be slower as it is software based
Switching is done at layer 2 of OSI model	Routing is done at layer 3 of OSI Model
If the destination is not known to switch it will broadcast the frame	If the destination is not known to router it will drop the packet.
Switching is done in same broadcast domain	Routing is done in different networks.
Switching is done by using MAC address	Routing is done by using IP address
Protocol data unit at layer 2 is frame	Protocol data unit at layer 3 is packet

Chapter 2

Switching

(Packets, Multiplexed Streams)

Objective Practice Solutions

01. Ans: (c)

Sol: Frame relay technique uses connection oriented packet switching.

02. Ans: (a)

Sol: Given data

Circuit setup time = 's' sec

Bandwidth = bit rate = 'b' bps

Path = 'k'-hop

Propagation delay = 'd' sec per hop

Connection release = not given

Packet size = 'p' bits

Message size = 'x' bits

k = 3

k – hop path (hop means jump)

$T_P = \frac{d}{v} = \frac{m}{m/s} = \text{sec}$

Total delay = I + II + III

I. Circuit setup time = s

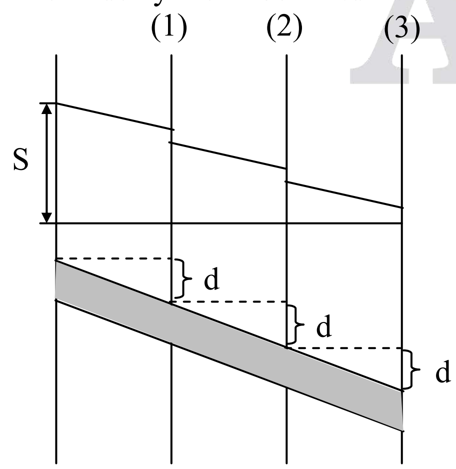
II. $T_X = \frac{L}{B} = \frac{\text{message size}}{\text{bit rate}} = \frac{x}{b}$

III. T_P=one hop → propagation time='d' sec

For k hop → propagation time ?

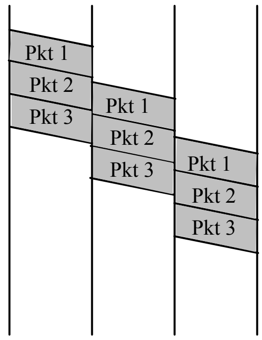
= k × d

∴ Total delay = s + x/b + k.d



03. Ans: (d)

Sol:



- The last packet is getting retransmitted at k – 1 hops so the delay is $(k-1)\frac{p}{b}$.
- There is no set of time (NO S)
- Transmission delay is x/b

  $= \frac{p_1 + p_2 + .. + p_n}{b}$
- Message

  For k hop → propagation time?

  = k × d
- Total time = x/b + k.d + $(k-1)\frac{p}{b}$

04. Ans: (a)

Sol: A packet can be forwarded before the next packet arrives in virtual circuit connections, so in between the packets the delay jitter is zero.

05. Ans: (c)

Sol: Packet switching is the method by which the internet works, it features delivery of packets of data between devices over a shared network. For example the school web server sending a webpage over the internet or sending an email to a friend. To get from one device to another the data packets will have to travel through network adapters, switches, routers and other network nodes. The route taken by each packet might vary and at times there might be a lot of data travelling through these nodes meaning packets will be queued. This results in varying times it takes to send data from one device to another depending on the traffic load in the network.

Packet switching is a method of grouping data transmitted over a digital network into packets which are composed of a header and a payload. Data in the header is used by networking hardware to direct the packet to its destination where the payload is extracted and used by application software. Packet switching is the primary basis for data communications in computer networks worldwide.

Conventional Practice Solutions

01.

Sol: Difference between E_1 carrier and T_1 carrier

E_1 and T_1 are digital telecommunication carrier standards; in other words, multi-channel telecommunication systems, which are time multiplexed into a single carrier to transmit and receive. Both standards use two pairs of wires for transmit and receive paths to achieve full duplex communication. Initially, both methods are developed in order to send voice channels over copper wires simultaneously, which leads to less transmission cost.

- Data rate of E_1 is 2048kbps as per the recommendations of ITU-T, while the data rate of T_1 is 1.544Mbps as per the ANSI recommendations.
- E_1 comprises of 32 simultaneous channels, while T_1 consists of 24 simultaneous channels, which has 64kbps data rate in each channel.
- Since both systems initially designed to transmit PCM voice, frame rate of both carriers are designed as 8000 frames per second to support 8kHz sampling rate of PCM.
- Even though both E_1 and T_1 have same 125μS frame interval, E_1 transmit 256 bits, while T_1 transmit 193 bits within the same period.
- Both E_1 and T_1 carrier methods are initially developed to transmit and receive pulse code modulated voice signals over time multiplexed copper wires.

02.

Sol: Circuit Switched Vs Packet Switched

Item	**Circuit Switched**	**Packet Switched**
Dedicated "copper" path	Yes	No
Bandwidth available	Fixed	Dynamic
Potentially wasted bandwidth	Yes	No
Store-and-Forward transmission	No	Yes
Each packet follows the same route	Yes	No
Call setup	Required	Not needed
When can congestion occur	At setup time	On every packet
Charging	Per minute	Per packet

Chapter 3 Protocols (TCP/IP)

Objective Practice Solutions

01. Ans: (b)

Sol: TCP Services: SMTP, HTTP, FTP

02. Ans: (b)

Sol: Host-to-Host layer in the TCP/IP stack is equivalent to the Transport layer of the OSI model.

03. Ans: (d)

04. Ans: (b)

Sol: SMTP protocol deals with emails

05. Ans: (a)

Sol: TCP protocol ensures reliable delivery.

06. Ans: (d)

Sol: TCP/IP model does not have session layer & presentation layer but OSI model have these layers.

07. Ans: (c)

Sol: An IPv4 address consists of 32-bits

08. Ans: (a)

09. Ans: (d)

10. Ans: (b)

11. Ans: (d)

12. Ans: (b)

Sol:

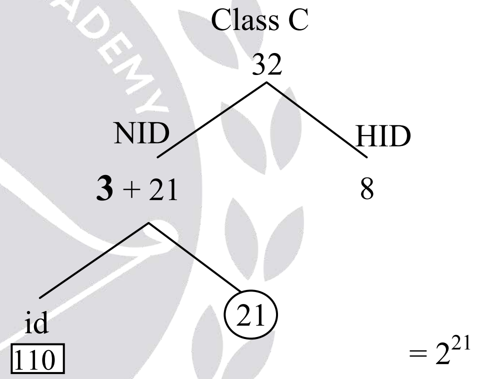
0001	0111.	0010	1010.	1000	0100.	1100	1000
1	7	2	A	8	4	C	8

1 7	2 A	8 4	C 8
1×16^1	2×16^1	8×16^1	12×16^1
$+ 7\times16^0$	$+10\times16^0$	$+4\times16^0$	$+8\times16^0$
= 23	= 42	= 132	= 200

$\therefore$ 23.42.132.200

13. Ans: (c)

Sol:

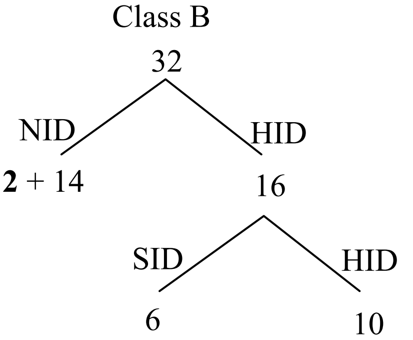


$= 2^{21}$

From NID, 3 bits are reserved for prefix of class C address therefore number of networks all allowed under class C address are $2^{24-3} = 2^{21}$.

14. Ans: (d)

Sol:



64 departments = 2^6

1111 1111. 1111 1111. 1111 1100. 0000 0000

255. 255. 252. 0

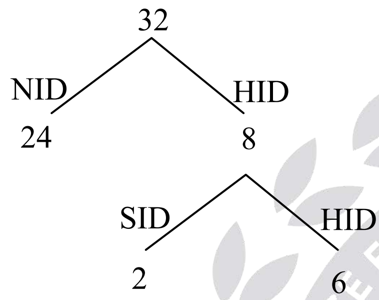
15. (i) Ans: (a) (i) Ans: (b)

(iii) Ans: (b)

Sol: SM = 255.255.255.192

192 = 1100 0000

Class C



Class C network has 24-bits NID and 8 bit HID

(i) 2 bits are borrowed from HID

(ii) no. of subnets = $2^2 = 4$

(iii) no. of system per subnet = $2^6 - 2$

$= 64 - 2 = 62$

16. Ans: (d)

Sol: → TCP enable two hosts to establish a connection and exchange streams of data.

→ TCP guarantees delivery of data in the same order in which they are sent.

→ TCP segmentation offload is used to reduce the CPU overhead of TCP/IP on fast networks.

17. Ans: (a)

Sol: NAT is short for Network Address Translation. NAT is an Internet standard that enables a local area network (LAN) to use one set of IP addresses for internal traffic and a second set of addresses for external traffic. A NAT box located where the LAN meets the Internet makes all necessary IP address translations.

The Purpose of NAT

NAT serves for three main purposes:

- Provides a type of firewall by hiding internal IP addresses.
- Enables a company to use more internal IP addresses. Since they're used internally only, there's no possibility of conflict with IP addresses used by other companies and organizations.
- Allows a company to combine multiple ISDN connections into a single Internet connection.

18. Ans: (a)

Sol: Connection-Oriented and Connectionless Protocols in TCP/IP. Looking again at TCP/IP, it has two main protocols that operate at the transport layer of the OSI Reference Model. One is the Transmission Control Protocol (TCP), which is connection-oriented; the other, the User Datagram Protocol (UDP), is connectionless.

Connection-oriented protocol service is sometimes called a "reliable" network service, because it guarantees that data will arrive in the proper sequence. Transmission

Control Protocol (TCP) is a connection-oriented protocol. TCP is used for applications that require the establishment of connections (as well as TCP's other service features), such as FTP; it works using a set of rules, as described earlier, by which a logical connection is negotiated prior to sending data.

UDP is used by other applications that don't need connections or other features, but do need the faster performance that UDP can offer by not needing to make such connections before sending data.

Conventional Practice Solutions

01.

Sol:

1100 0010. 0010 1111. 0001 0101. 1000 0010

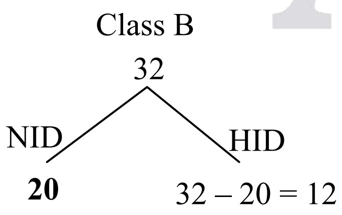
C 2 2 F 1 5 8 2

C 2	2 F	1 5	8 2
12×16^1	2×16^1	1×16^1	8×16^1
$+2\times16^0$	$+15\times16^0$	$+5\times16^0$	$+2\times16^0$
= 194	= 47	= 21	= 130

∴ 194.47.21.130

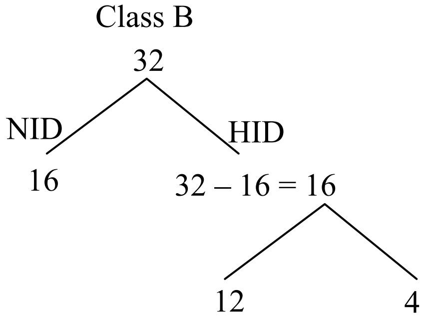
02.

Sol: In given problem network part is of 20 bits.



Among 20 NID bits we are not going to use 2 bits which are fixed for class B prefix so number of networks possible are $2^{20-2} = 2^{18}$ and number of hosts possible are $2^{12} - 2$.

03.



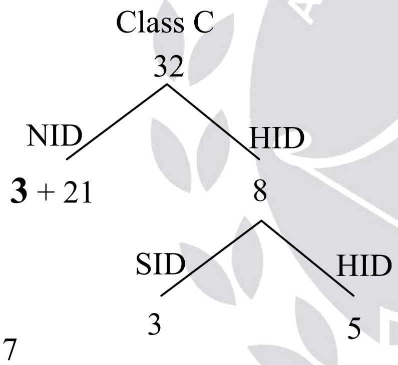
255. 255. 255. 240

1111 1111. 1111 1111. 1111 1111. 1111 0000

Hosts per subnet = $2^4 - 2$

04.

Sol:



$2^x = 7$

$\therefore\ x = 3$

$2^3 = 8$ subnets can be formed

$2^5 - 2 = 30$ hosts per subnet

1111 1111. 1111 1111. 1111 1111. 1110 0000

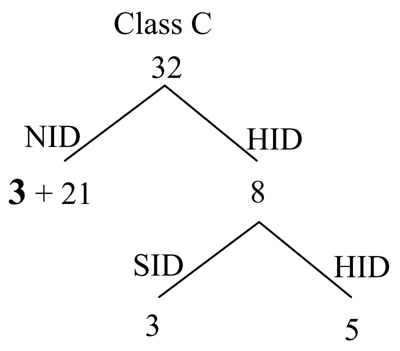
255. 255. 255. 224

(or)

Given 25 hosts per subnet

$2^x = 25$

x = 5 hosts per subnet



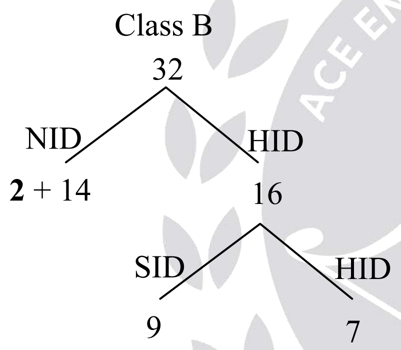
Subnet mask → /27

05.

Sol: 100 LAN's

$2^x = 100$ hosts

$\therefore x = 7$



/25 ⇒ 255.255.255.128

06.

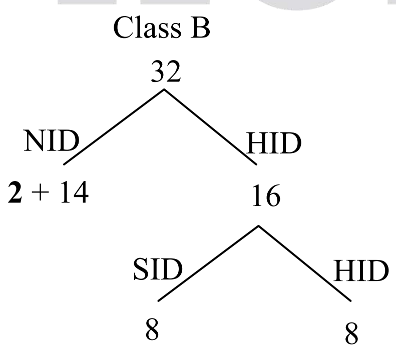
Sol: Subnet mask → / 24

⇒ 255.255.255.128

Given LANs = 150

$2^x = 150$

$x = 8$

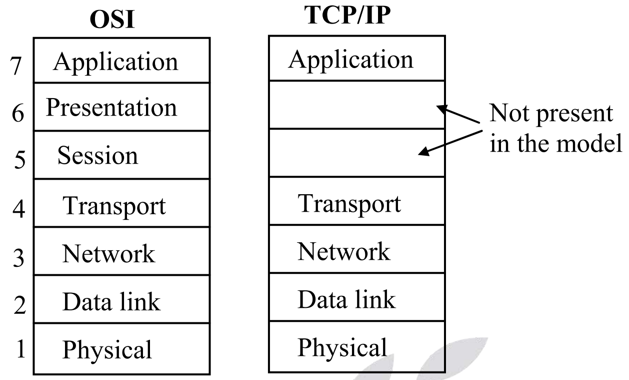


16+8 = 24

07.

Sol: TCP/IP reference model originates from the grandparent of all computer networks, the ARPANET and now is used in its successor, the worldwide Internet.

The following figure depicts the correlation of layers in ISO/OSI vs TCP/IP architectures



The Host-to-Network Layer

The Host-to-network layer is the lowest layer of the TCP/IP reference model. It combines the link layer and the physical layer of the ISO/OSI model. At this layer, data is transferred between adjacent network nodes in a WAN or between nodes on the same LAN. The host-to-network layer provides the methods to transfer data between network entities. It also provides error detection and correction procedures, since the errors might come from the physical transfer. The host-to-network layer is responsible for physically transmitting the bit stream and reconstructing the "framed" data from a received bit stream for the higher layers.

The Internet layer

The Internet layer is the backbone of the whole architecture. It is a connectionless internetwork layer forming a base for a packet-switching network. Its job is to permit hosts to inject packets into any network and have them travel independently to the destination. It works in analogy with the mail system. A person can drop a sequence of international letters into a mail box in one country. With a little luck, most of them will be delivered to the correct address in the destination country.

The Internet layer defines an official packet format and protocol called IP (Internet Protocol). The job of the Internet layer is to deliver IP packets where they are supposed to go. TCP/IP Internet layer is very similar in functionality to the OSI network layer.

The Transport Layer

The layer above the internet layer in the TCP/IP model is now usually called transport layer. It is designed to allow peer entities on the source and destination hosts to carry on a conversation, the same as in the OSI transport layer. Two end-to-end protocols have been defined here:

- TCP (Transmission Control Protocol): is a reliable connection oriented protocol that allows a byte stream originating on the machine to be delivered without error on any other machine in the internet. It fragments the incoming byte stream into discrete messages and passes each one onto the internet layer. At the destination, the receiving TCP process reassembles the received messages into the output stream. TCP also handles flow control.

- UDP (User Datagram Protocol): is an unreliable, connectionless protocol for applications that do not want TCP's sequencing or flow control and wish to provide their own. It is also widely used for one/shot, client/server type request/reply queries and applications in which prompt delivery is more important than accurate delivery.

The Application Layer

The application layer is on the top of the transport layer. It contains all the higher level protocols.

- Virtual terminal (TELNET) - allows a user on one machine to log into a distant machine and work there.
- File transfer protocol (FTP) - provides a way to move data efficiently from one machine to another.
- Electronic mail (SMTP) - specialized protocol for electronic mail.
- Domain name service(DNS) - for mapping host names onto their network addresses.

Types of address at each layer

Application layer: addresses are associated with DNS domain names
Transport layer: addresses are TCP/UDP port numbers
Internet layer: IP addresses (IPv4 or IPv6), known as logical addresses
Host to network layer: On LAN, the addresses are MAC-IDs, known as physical addresses

08.
Sol:

(i) # Customers = 64 = 2^6
hosts = 256 = 2^8
Addresses used by Group A
= # customers * # hosts
= $2^6 * 2^8 = 2^{14}$

(ii) # customers = 128 = 2^7
hosts = 128 = 2^7
Addresses used by group B = $2^7 * 2^7 = 2^{14}$

(iii) # customers = 128 = 2^7
hosts = 64 = 2^6

Addresses used by Group C = $2^7 * 2^6 = 2^{13}$
Total addresses left = $2^{16} - (2^{14} + 2^{14} + 2^{13})$
$= 2^{16} - 2^{13} (2 + 2 + 1)$
$= 2^{13} [2^3 - 5]$
Total addresses left = $3 * 2^{13}$

Chapter 4 Cellular Network

Objective Practice Solutions

01. Ans: (d)

Sol: The main part(s) of basic cellular system is
(i) A mobile Unit
(ii) A cell Site
(iii) A mobile Telephone Switching Office

02. Ans: (a)

Sol: The basic GSM is based on connection oriented traffic channels.

Conventional Practice Solutions

01.

Sol:

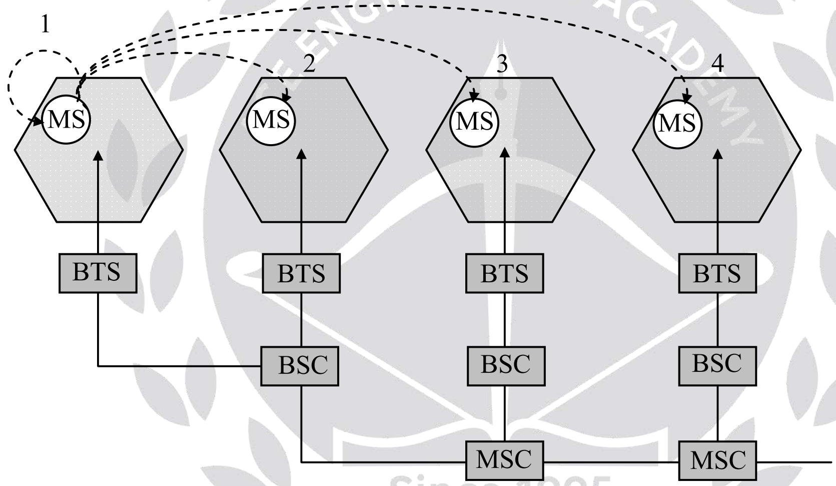


Fig: Types of handover in GSM

Figure Shows four possible handover scenarios in GSM:

- **Intra-cell handover:** Within a cell, narrow-band interference could make transmission at a certain frequency impossible. The BSC could then decide to change the carrier frequency (scenario 1)
- **Inter-cell, intra-BSC handover:** This is a typical handover scenario. The mobile station moves from one cell to another, but stays within the control of the same BSC. The BSC then performs a handover, assigns a new radio channel in the new cell and releases the old one (scenario 2)
- **Inter-BSC, intra-MSC handover:** As a BSC only controls a limited number of cells, GSM also has to perform handovers between cells controlled by different BSCs. This handover then has to be controlled by the MSC (scenario 3). This situation is also shown in figure.
- **Inter MSC handover:** A handover could be required between two cells belonging to different MSCs. Now both MSCs perform the handover together (scenario 4).

02.
Sol:
GSM Security

1) **Authentication of the registered subscribers only:** the validation of only those users is subscribed who are authorized ones. And this legitimation is done by means of registration wherein the user's need to select a service provider who they think satisfy their communication needs and the usage of services is in budget. A verification task would be performed. Further a positive result of this task connects the subscriber with service provider where he can make use of all services provided.

2) **Subscriber identity protection:** when a service provider has an authorized subscriber by means of some valid documentation few preventive measures are taken to keep his identity a private matter, this is again done by taking into account the security aspect.

3) **Mobile phones are inoperable without a SIM:** a Subscriber Identity Module (SIM) defines the company of service provider which is card shape of 25mm*15mm. These are active only after inserting in reserved in-built structure of handset. There are certain handset also available in market which are reserved for only one specific kind of SIM and do not respond if any other SIM is inserted in them. Until and unless these SIM is inserted inside the phone the communication won't proceed further as there will be null connection between Mobile station (MS) and Base Transceiver Station (BTS).

3) **Duplicate SIMs are not allowed on the network:** when an subscriber gets authenticated, an unique SIM number is allocated to him as a result there would be no two subscribers having same SIM number. If under any circumstances such case exists then, on safety measures the services on both the SIMs are blocked.

5) **Securely stored Ki:** it is the subscriber authentication key which is generated at the beginning of process which usually is a 128 bit key used for authentication of subscriber by the operator. This key is stored in Subscriber's SIM. Further during processing it gets acquainted into Operator's Home Locator Register (HLR)

Authentication

The GSM network authenticates the identity of the subscriber through the use of a challenge response mechanism. A 128-bit random number (RAND) is sent to the MS. The MS computes the 32-bit signed response (SRES) based on the encryption of the random number (RAND) with the authentication algorithm (A3) using the individual subscriber authentication key (Ki). Upon receiving the signed response (SRES) from the subscriber, the GSM network repeats the calculation to verify the identity of the subscriber. Note that the individual subscriber authentication key (Ki) is never transmitted over the radio channel. It is present in the subscriber's SIM, as well as the AuC, HLR and VLR databases. If the received SRES agrees with the calculated value, the MS has been successfully authenticated and may continue. If the values do not match, the connection is terminated and an authentication failure is indicated to the MS. In order to achieve this, there are certain Authentication goals as:

1) Subscriber (SIM holder) authentication this is done to keep a track of secure user's on, an account to test their loyalty towards the service provider. Every SIM can be protected by a Personal Identification Number (PIN). For the security purpose, a four digit code is established which usually

gives three attempts before the phone is blocked. Also for bypassing the PIN, the prerequisite is a Pin Unblocking Key (PUK)[6] which is an eight digit code and is set by manufacturer. To unlock this PUK maximum ten attempts are given for the next one the SIM gets permanently blocked.

2) Protection of the network against unauthorized use wherein a strict provision is made for not allowing any services to an unauthenticated subscriber. The last measure of authentication is to create a session key. The architecture of GSM itself has an Authentication center (AuC) whose function is to provide parameters for authentication and encryption functions (RAND, SRES, Kc)

Encryption and Decryption

Further the prime phenomenon involved in security is Encryption. The entire security handling revolves around this term. In technical terms encryption means the process wherein encoding of message, data, information is done. Further a precaution is taken that these encoded bits are received and read only by authorized receiver. Also being advantageous, the encrypted data bits do not intercept. In this encryption the message bits are termed to be plaintext, which is processed by means of encryption algorithm giving rise to cipher text. On majority, the usage of pseudo random encryption key generation algorithm is observed. The cipher text can only be read after decryption. Dealing with encryption has been classified in two prime terms as- Private Key encryption and Public key encryption.

(a) **Private Key encryption:** It is also called as Systematic key encryption. In this type the keys allocated for encryption and decryption are same. This provision makes the communication process very easy, the only precaution necessary would be two different entities involved in secret communication must beforehand make sure of having same keys to make the process simplified and error free.

(b) **Public key encryption**: This was first evolved in 1973 until then all encryption schemes used were private type. As the name suggests, in this type the encryption keys were made public to all who wish to encrypt message but, only the receiving entity had the decryption key and was eligible to read the encrypted message bits.

Decryption:

After encryption we are left out with the cipher text. The process of converting cipher text back to plaintext is nothing but decryption. A measure must be taken that to decrypt a particular piece of cipher text; the key that was used to encrypt the data must only be used. The goal of every encryption algorithm is to make it as difficult as possible to decrypt the generated cipher text without using the key. When selecting an encryption algorithm, it is a good idea to choose one that has been in use for several years and has successfully resisted all attacks. Dealing with the algorithm prospect, A5 is a stream cipher consisting of three clock-controlled linear feedback shift register (LFSRs) [7] of degree 19, 22 and 23. The clock control is a threshold function of the middle bits of each of the three shift registers. The sum of the degrees of the three shift registers is 64. The 64-bit session key is used to initialize the contents of the shift registers. The 22-bit TDMA frame number is fed into the shift registers. Two 114-bit key streams are produced for each TDMA frame, which are XOR-ed with the uplink and downlink traffic channels.

(c) Key Generation: This section focuses on key length as a figure of merit of an encryption algorithm. A machine capable of testing one million keys per second is possible by today's standards. In considering the strength of an encryption algorithm, the value of the information being protected should be taken into account. It is generally accepted that data encryption standard (DES) with its 56-bit key will have reached the end of its useful lifetime by the turn of the century for protecting data such as banking transactions. Assuming that the A5 algorithm has an effective key length of 40 bits (instead of 64), it currently provides adequate protection for information with a short lifetime. A common observation is that the "tactical lifetime" of cellular telephone conversations is on the order of weeks. Ciphering When it comes to GSM security Ciphering is one of the most prominent security procedures which are designed with a motive of protecting the subscriber's identity and data bits. When ciphering is active, all information exchanged between the mobile and the network on the dedicated radio channels is encrypted as by means of key wherein this same key is common for both encryption and decryption procedure

Authentication Algorithm A3

It is operator-dependent and is an operator option. The A3 algorithm is a one-way function. That means it is easy to compute the output parameter SRES by using the A3 algorithm but very complex to retrieve the input parameters (RAND and KI) from the output parameters. Remember the key to GSM's security is keeping KI unknown. To summarize its operation one can say, it does generation of SRES response to MSC's random challenge RAND

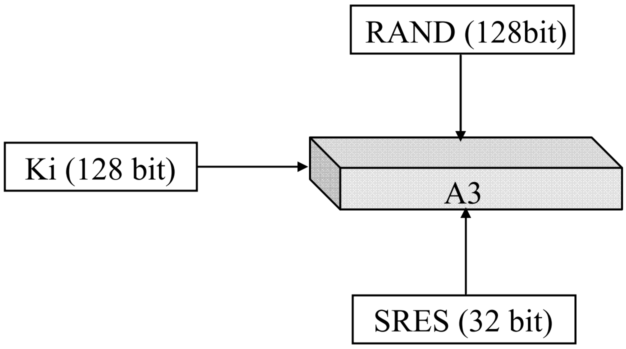


Fig: A3 Algorithm

Ciphering Key Generating Algorithm A8

Unlike A3, it is also operator-dependent. In most providers the A3 and A8 algorithms are combined into a single hash function known as COMP128. The COMP128 creates KC and SRES, in a single instance. It does generation of session key Ks. A8 is never a public approach.

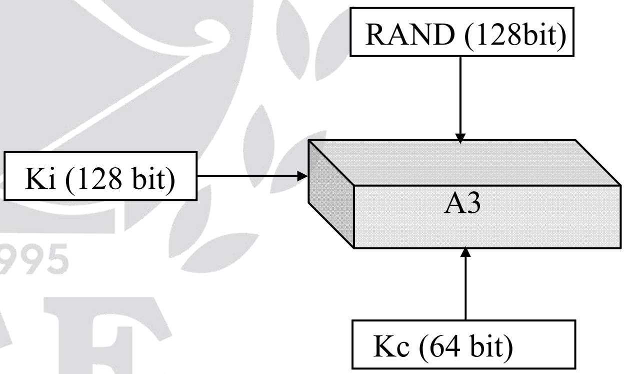


Fig: A8 Algorithm

Both A8 and A3 are implemented on SIM. It is the operator who decides which algorithm to use. Hence algorithm implementation is independent of hardware manufacturers and network operators. The logical implementation of A8 and A3 can be represented as:

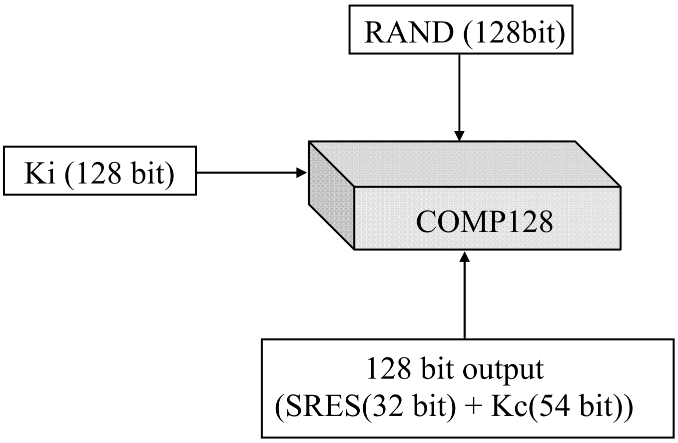


Fig: Logical Implementation

Chapter 5 Network Security

Objective Practice Solutions

01. Ans: (d)

Sol: RSA Algorithm:

Step: (I) $p = 3, q = 11$

Step: (II) $n = p \times q = 3 \times 11 = 33$

$z = (p - 1)(q - 1)$
$= (3 - 1)(11 - 1)$
$= (2 \times 10)$
$= 20$
$z = 20$

Step: (III) Given e = 3: Public key

Step: (IV) $(d \times e) \bmod z = 1$

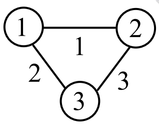
$(d \times 3) \bmod 20 = 1$
$21 \bmod 20 = 1$
$(d \times 3) = 21$
$d = \frac{21}{3} = 7$

private key = 7

02. Ans: (c)

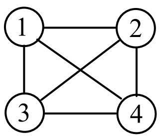
Sol: 2-nodes

3-nodes



3 keys $\Rightarrow 1 + 2$

4-nodes



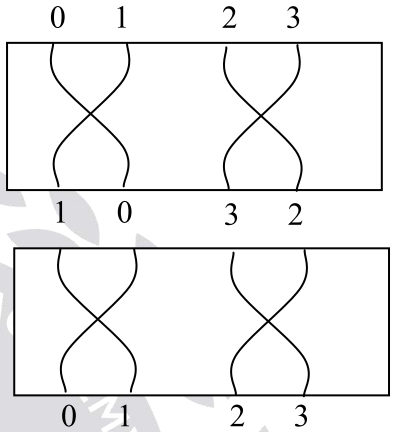
$1 + 2 + 3 = 6$ keys

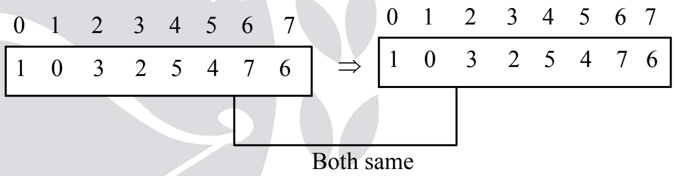
N-nodes $\Rightarrow 1 + 2 \ldots + (N-1) = \frac{N(N-1)}{2}$ keys

Conventional Practice Solutions

01.

Sol: Symmetric in nature





Both are in symmetric nature. Hence $IP = IP^{-1}$

02. Ans: 11

Sol: $p = 13, q = 17$

$K_u = \{e, u\} = \{35\}$

$K_r = d = ?$

RSA steps

1. $p = 13 \quad q = 17$
2. $n = 13 \times 17$

$\phi(n) = (p - 1)(q - 1) = 12 \times 16 = 192$

$d = ?$

$e = 35$

So $(e \times d) \bmod \phi(n) = 1$

$(35 \times d) \bmod 192 = 1$

$d = 11$

Chapter 6 Microwave Communication

Objective Practice Solutions

01. Ans: (a)

Sol:

- For television broadcasting we are using VHF and UHF frequency bands since we need to transmit both audio and video signals.
- For these frequency bands, we are using space wave (line-of-sight) propagation because at such frequencies sky wave and ground wave propagations both fail.
- At this frequency range, sky wave are fail to reflect from ionosphere (rather they penetrate through it) and ground waves are completely attenuated after few hundred meter propagation because of wave tilt and attenuation by earth surface.
- This mode of propagation is also used in radar and frequency modulations.

02. Ans: (b)

Sol:

- The sky waves (Ionospheric waves) are used at medium and high frequencies for very long distance radio communications.
- Since, in this mode of propagation EM waves reach the receiving point after reflection from the ionosphere which is situated above earth surface as shown in figure.

(a)

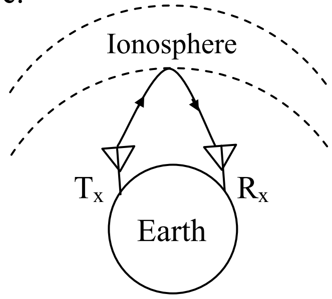


Fig. single reflection of radio waves from ionosphere

(b)

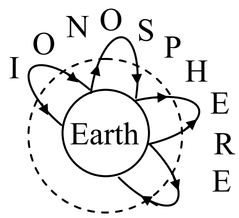


Fig. Multiple reflections of radio wave from ionosphere

- In a single reflection from the ionosphere the radio waves cover a distance not more than 4000km as shown in figure (a).
- Extremely long distance i.e., round the globe communications also possible with the multiple reflections of sky waves as shown in figure (b).

03. Ans: (b)

Sol:

- The relative permittivity of the ionosphere at radio frequency is less than one.

04. Ans: (b)

Sol: The disappearance of few layers in the night is due to recombination of ions into molecules as shown in figure (a) and (b) which shows electron density during night and day.

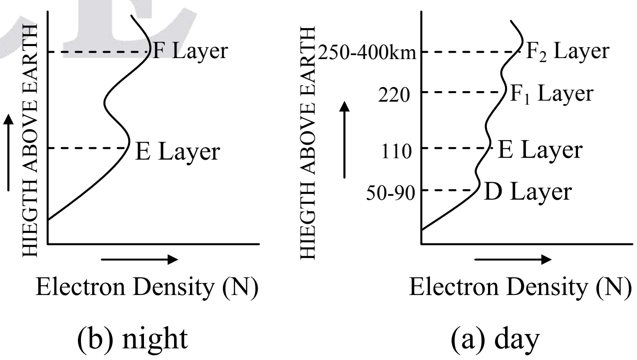
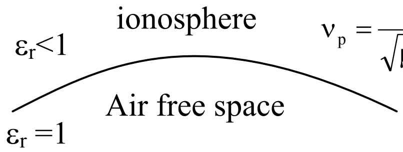


Fig. Electrons density variation during (a)day, (b) night

05. Ans: (b)
Sol:



$$\nu_p = \frac{1}{\sqrt{\mu_0\varepsilon_0}\sqrt{\varepsilon_r}}$$

$$\nu_p = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$(\nu_p)_{air} = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \text{ \_\_\_\_\_\_(1)}$$

$$(\nu_p)_{ionosphere} = \frac{1}{\sqrt{\mu_0\varepsilon_0}\sqrt{\varepsilon_r}} \text{ \_\_\_\_\_\_(2)}$$

From equation (1) and (2),

$(\nu_p)_{ionosphere} > (\nu_p)_{air}$ [$\because \varepsilon_r < 1$]

i.e., when a wave travels from air into ionosphere, the velocity of the wave increases.

06. Ans: (c)
Sol:

- Ground wave is propagating around the curvature of the earth and hence it is unaffected whether it is day (or) night.
- Whereas for tropospheric waves and sky waves are effected in different ways in day and night. Since these waves are travelling in earth atmosphere.
- During daytime few extra layers are created and these are having no effect on night since they are disappeared (due to recombination of ionosphere into molecules).

07. Ans: (a)
Sol:

- D-layer is the lowest layer of the ionosphere as shown in figure.
  D-layer range is 50-90 km and it exists at an average height of 70km.

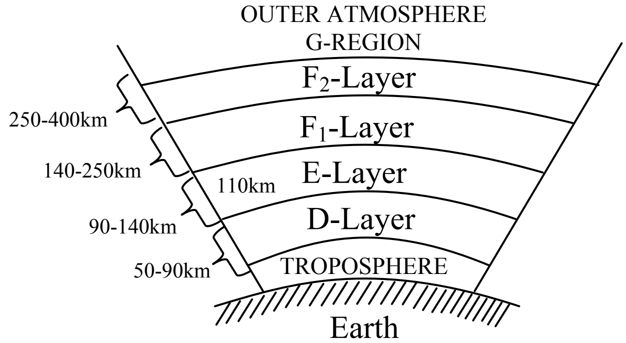


Fig. Typical heights of ionospheric layers above earth

08. Ans: (b)
Sol:

- The phenomenon of propagating microwave signals around the curvature of the earth over a distances upto 1000km is known as "Duct propagation" as shown in figure.
- Duct propagation phenomenon occurs mostly at UHF and micro wave frequencies.

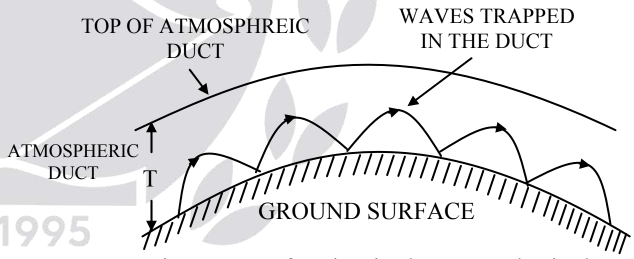


Fig. super-refraction in the atmospheric duct

- The temperature inversions cause ducts, of cool air to be sandwiched between surface of the earth and a layer of warm air.
- Duct is formed in troposphere.

09. Ans: (d)
Sol:

- During daytime F-layer will not present since it splits into two layers F_1 and F_2 as shown in figure.

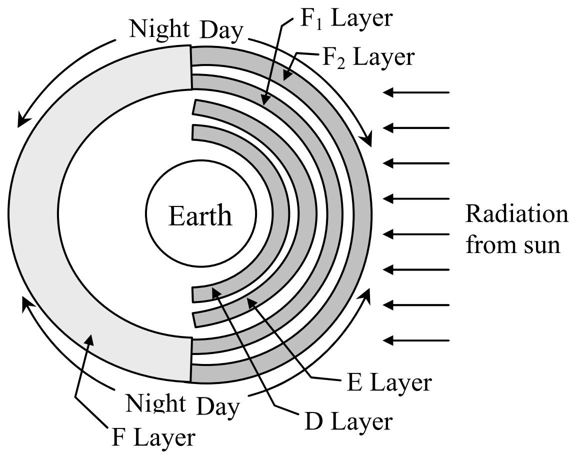


Fig: Different layers of Ionosphere during day and night

10. Ans: (c)

Sol:

- The refractive index of the ionized layer is,

$$n = \sqrt{1 - \frac{81N}{f^2}}$$

Where, N → electron density
F → plasma frequency

11. Ans: (b)

Sol:

- MUF (Maximum usable Frequency) is the maximum frequency that can be reflected back to the earth by the ionosphere other than vertical incidence.

  i.e., $F_{MUF} = f_c \sec\phi$

  where, ϕ is a angle of incidence f_c is a critical frequency.

  $F_{MUF(max)} = 3.6\ f_c$

12. Ans: (c)

Sol: Critical frequency is the highest frequency that can be reflected back by the particular layer of ionosphere for vertical incidence.

For a vertical incidence, the angle of incidence becomes zero and the electron density becomes maximum.

$$\Rightarrow n = \sqrt{1 - \frac{81N_{max}}{f_c^2}} = 0$$

$$\therefore f_c = 9\sqrt{N_{max}}$$

13. Ans: (c)

Sol:

- Ionosphere is divided into different layers and each of the layer exhibits different characteristics as shown in figure below.
- The density of the layers increases until noon and then decrease slowly throughout the afternoon since ionization depends on the radiation from the sun.
- During day time ionosphere consists of D, E, F_1 and F_2 layers as shown in figure.

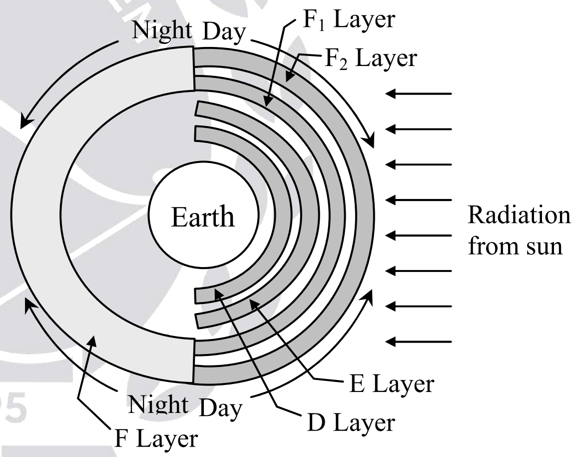


Fig: Different layers of Ionosphere during day and night

14. Ans: (a)

Sol:

- The absorption of electromagnetic waves by the atmosphere depends on the frequency of the waves.
- The absorption of some of it's energy of electromagnetic wave is more for high frequency waves than low frequency waves.

15. Ans: (a)

Sol:

- Skip distance is the minimum distance from the transmitter at which a sky wave of given frequency is returned to the earth by ionosphere.
- Skip distance depends on the wave's frequency and angle of incidence, and the degree of ionization.
- The wave of lower frequency is bent round more quickly than the wave of higher frequency. Therefore higher the frequency, the higher the skip distance.

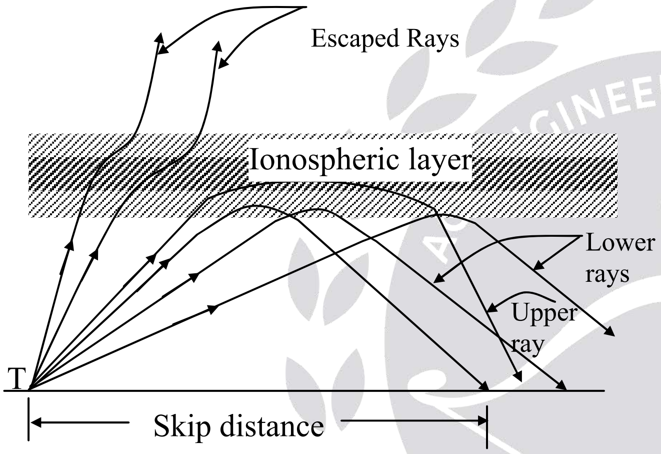


Fig: Effects of ionosphere on rays of varying incidence.

16. Ans: (c)

Sol:

- VLF band is in the range of 3kHz to 30kHz and wavelengths from 10 to 100 kilometers.
- VLF waves required low power to transmit because of this they are used for a few radio navigation services, government time radio stations and for secure military communications.

17. Ans: (d)

Sol:

- Refraction is the change in direction of propagation of a wave due to a change in its transmission medium.
- Due to change in medium, the phase velocity of the wave is changed but its frequency remains constant.
- This is most commonly observed when a wave passes from one medium to another at any angle other than from the normal.
- We are observing same as mentioned in above points in ionospheric propagation.

18. Ans: (d)

Sol:

- Troposcatter propagation is of practical importance at VHF, UHF and microwaves.

19. Ans: (c)

Sol:

- Scatter propagation is possible in the VHF and UHF bands and it propagated much beyond the line-of-sight propagation through the forward scattering in the tropospheric irregularities, as shown in figure

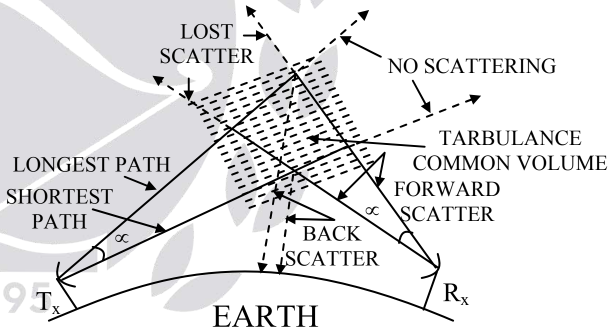


Fig. Tropospheric scatter propagation

20. Ans: (c)

Sol:

- In night, few layers of ionosphere (D, E, F_1 & F_2) are disappeared due to recombination of ions into molecules.
- Because of this reason, the effect of these layers on HF band frequencies is not present.
- So, we are getting better HF reception at night.

21. Ans: (a)
Sol:
- Given, Critical frequency (f_c) = 30MHz
  Angle of incidence (ϕ) = 60°
  We know, $f_{(MUF)} = f_c \sec\phi$
  $= (30M)(\sec 60°)$
  $= 60MHz$

22. Ans: (d)
Sol:
- Upto MHz frequency range is more reliable in terrestrial communications beyond-the-horizon without repeaters. Hence, option (d) is the correct answer

23. Ans: (b)
Sol:
- Ground waves can travel maximum few hundred km, after that they are attenuated.
- Space wave propagation is limited to the line-of-sight distance and also limited by the curvature of the earth.
- Troposcatter wave propagation is much beyond the line-of-sight distance through forward scattering in the tropospheric irregularities for UHF and microwave signals.
- Ionospheric waves are used at high frequencies for very long distance communications.

  Actually the correct order is 3, 1, 2, 4 but out of these options option (b) is more suitable.

24. Ans: (d)
Sol:
- At high frequencies, ground wave propagating affected due to wave tilting since the orientation of the vertically polarized ground wave is changing close to horizontal polarization.
- So, at high frequency the ground wave attenuation by ground is much more than at low frequency over the same ground as shown in figure
- LF communication signals are used at low power.

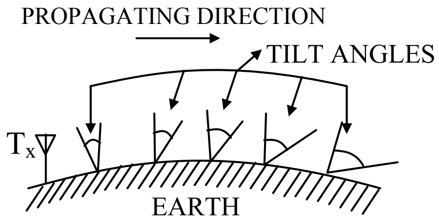


Fig. Tilting wave fronts in ground wave propagation

25. Ans: (c)
Sol:
- Given, Transmitting antenna height (h_t) = 196 meters
  Radio horizon (km) = $4.12\sqrt{h_t(\text{meters})}$
  $= 4.12\sqrt{196}$
  $= 4.12 \times 14$
  $\therefore$ Radio horizon (km) = 57.68km

26. Ans: (b)
Sol:
- In microwave terrestrial LOS link, the space wave propagation is limited to the line of sight distance and is also limited by the curvature of the earth.
- So, the location of the next repeater in this propagation is also limited by curvature of the earth.

27. Ans: (a)
Sol:
- Given, Height of transmitting and receiving antenna (h_t & h_r) = 25m
  Maximum hop length (dkm) $\cong 4\left(\sqrt{h_t} + \sqrt{h_r}\right)$
  $\Rightarrow d_{km} \cong 4[\sqrt{25} + \sqrt{25}]$
  $\cong 4(10)$
  $\therefore d_{km} \cong 40km$

28. Ans: (c)
Sol:
- The ionosphere acts like a reflecting surface and is able to reflect back EM waves of frequencies between 2 to 30MHz. EM waves of frequency more than 30 MHz are not reflected back from the ionosphere rather they penetrate through it.

- Here, the EM wave frequency is 60MHz, then a communication link spanning a distance of 600km cannot be established at 60MHz via the ionosphere because the 60MHz wave is not reflected by any of the layers of ionosphere.

29. Ans: (a)
Sol:

- In day time the ionospheric layers (D, E, F_1 & F_2) are present and the signal absorption in the lowers (D & E) is more.
  Where as in night these layers are disappeared, then the signal quality is poor in day compared to night.

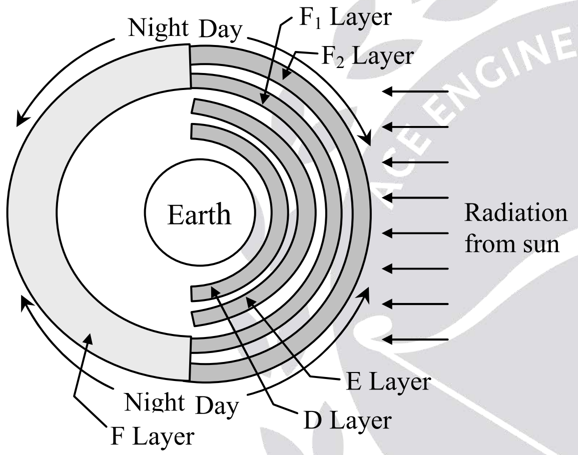


Fig: Different layers of Ionosphere during day and night

30. Ans: (d)
Sol:

- Ground wave propagation is suitable for low and medium frequency i.e., upto 2MHz only.
- Sky wave propagation is suitable for medium and high frequencies i.e,, between 2 to 30MHz only.
- Space wave propagation is suitable for very high frequencies (VHF), UHF and microwaves i.e., between 30M to 30MHz only.
- Troposcatter wave propagation is suitable for VHF, UHF and microwave signals beyond the line of sight distance and the range is above 300MHz.
  Hence, option (d) is correct.

Conventional Practice Solutions

01.

Sol: Fade Margin = 30 log D + 10 log (6ABf) – 10 log (1 – R) – 70

D = Distance (km) = 60

A = Roughness factor = 4 [smooth terrain]

B = 0.125 [dry area]

f = Frequency [GHz] = 6

R = Reliability = 0.9999

FM = 30 log 60 + 10 log (6ABf) – 10 log (1 – R) – 70

= 30 log 60 + 10 log 6 × 4 × 0.125 × 6 –10 log (1 – 0.9999) – 70

= 35.89 dB

02.

Sol: System gain = G_S

Transmitted power = P_t

C_{min} = Receiver minimum input power

$G_S = P_t - C_{min}$

G_S = 120 dB

Noise power = N = –115 dBm

= –145 dB

$$\frac{C}{N} = (C)dB - (N)dB = 30dB$$

(C)dB = (N)dB + 30 dB

(C)dB = –145 + 30

= –115dB

System gain = $P_t - C$

$P_t = G_S + C$

= 120dB – 115dB

= 5dB

03.

Sol: D = 30

f = 4

R = 0.999 Reliability

A = 4 Water or Smooth area

B = 1

FM = 30 log D + 10 log 6 ABf – 10 log (1 – R) – 70

= 30 log 30 + 10 log 6 × 4 × 1 × 4 –10 log (1 – 0.9999) – 70

= 34.136 dB

04.

Sol: f = 1.8 (GHz)

Diameter = 2.4 m

Distance = D = 40 (km)

R = 0.9999

A = 4

B = 0.5

			Branching Loss, L_b (dB)			
	Feeder Loss, L_f		Diversity		Antenna Gain, A_t or A_r	
Frequency (GHz)	Type	Loss (dB/100m)	Frequency	Space	Size (m)	Gain (dB)
1.8	Air-filled coaxial cable	5.4	5	2	1.2	25.2
					2.4	31.2
					3.0	33.2
					3.7	34.7
7.4	EWP 64 eliptical waveguide	4.7	3	2	1.5	38.8
					2.4	43.1
					3.0	44.8
					3.7	46.5
8.0	EWP 6 eliptical waveguide	6.5	3	2	2.4	43.8
					3.0	45.6
					3.7	47.3
					4.8	49.8

Fade margin = 30 log D + 10 log (6ABf) – 10 log (1 – R) – 70

FM = 30 log 40 + 10 log (6 × 4 × 0.5 × 1.8) – 10 log (1 – 0.9999) – 70

FM = 31.4 dB

Path loss = L_p = 92.4 + 20 log f + 20 log D

= 92.4 + 5.11 + 32.04

= 129.55 dB

Using table L_b = (2 + 2)dB = Branching losses

L_f = 10.8 dB

A_t = A_r = 31.2 dB

System gain = FM + L_p + L_b + L_f – A_t – A_r

= 31.4 + 129.55 + 10.8 + 4 – 31.2 – 31.2

= 113.35 dB

05.

Sol: f = 7.4 [GHz] A = 1 (average terrain)

diameter = 2.4 m B = 0.125 (dry climate)

R = 0.9999 $\frac{C}{N} = 28\text{dB}$

D = 40 km

Feeder length = 120m & 80m

			Branching Loss, L_b (dB)			
	Feeder Loss, L_f		Diversity		Antenna Gain, A_t or A_r	
Frequency (GHz)	Type	Loss (dB/100m)	Frequency	Space	Size (m)	Gain (dB)
1.8	Air-filled coaxial cable	5.4	5	2	1.2	25.2
					2.4	31.2
					3.0	33.2
					3.7	34.7
7.4	EWP 64 eliptical waveguide	4.7	3	2	1.5	38.8
					2.4	43.1
					3.0	44.8
					3.7	46.5
8.0	EWP 6 eliptical waveguide	6.5	3	2	2.4	43.8
					3.0	45.6
					3.7	47.3
					4.8	49.8

Fade Margin = $30 \log_{10} D + 10 \log (6\,ABf) - 10 \log (1 - R) - 70$

$= [30 \log_{10} 40 + 10 \log (6 \times 1 \times 0.125 \times 7.4) - 10 \log (1 - 0.9999) - 70]$ dB

FM = 25.504 dB

Using the above table $A_t = A_r = 43.1$ dB

Path loss = $L_p = 92.4 + 20 \log f + 20 \log D$

$= 92.4 + 20 \log 7.4 + 20 \log 40$

$L_p = 141.825$ dB

L_b = Total Branching loss = 3 + 3 = 6 dB (using table)

L_f = Total Feeder losses = 4.7 × 2 = 9.4 dB

System gain = $FM + L_p + L_f - A_t - A_r$

= 90.529 dB

06.

Sol: Transmitter station

Transmitted power = P_t = 40 dBm = 10 dB

Branching loss = L_b = 2dB

Feeder loss = L_f = 8 dB

Antenna gain = A_f = 36 dB

Atmosphere

Path loss = L_p = 140 dB

Fade Margin = FM = 30 dB

Receiver Station

Branching loss = L_p = 2 dB

Feeder loss = L_f = 4 dB

Antenna gain = A_r = 36 dB

System gain = $G_S = FM + L_p + L_f + L_b - A_t - A_r$

$G_S = [30 + 140 + (8 + 4) + (2 + 2) - 36 - 36]$ dB

$= 186 - 72$

$= 114$ dB

Chapter 7 Satellite Communication

Objective Practice Solutions

01. Ans: (d)

Sol: The height of a geostationary satellite above the Earth's surface is h = 35,855km (Approximately $h \cong 40,000$km).

02. Ans: (d)

Sol: Given,

The height of geostationary satellite (h) = 36,000km

The down link frequency (f_{down}) = 10GHz

The up-link free space loss ($L_{up\text{-}link}$) = 1.583 dB + $L_{down\text{-}link}$

path loss in down-link,

$$(L_{up\text{-}link}) = \left(\frac{4\pi R}{\lambda}\right)^2$$

$$= 20\log\left(\frac{4\pi R}{\lambda}\right)$$

$$= 203.56 \text{ dB}$$

$\Rightarrow L_{up\text{-}link} = 1.583 + 203.56$

$\therefore L_{up\text{-}link} = 205.15$ dB

03. Ans: (c)

Sol:

- An active satellite amplifies the received signal and retransmits back to earth.
- A passive satellite reflects ratio signals back to the earth.

Hence, both statements are correct.

04. Ans: (b)

Sol: Given,

Distance between two stations (R) = 100km

The transmitted power (P_t) = 1kW

The operating frequency (f) = 100MHz

Directivity of two antennas (D) = 1.64

The maximum receiver power (P_r) = ?

$\Rightarrow$ Maximum directive gain of antennas (G) = directivity (D) = 1.64

We known,

Maximum receiver power,

$$(P_r) = \frac{P_t.G_{t,max}.G_{r,max}}{\left(\frac{4\pi R}{\lambda}\right)^2} = \frac{P_t D_t D_r}{\left(\frac{4\pi R}{\lambda}\right)^2}$$

$$\Rightarrow P_r = \frac{1\times10^3\times1.64\times1.64}{\left(\frac{4\pi\times100kt10^3}{3}\right)^2}$$

$$\left[\because \lambda = \frac{c}{f} = \frac{3\times10^8}{10^8} = 3\text{m}\right]$$

$\therefore P_r = 1.53 \times 10^{-8}$ W

05. Ans: (a)

Sol: Given,

P_t = 40dB W, L_{bo} = 3dB and L_{bf} = 3dB, G_t = 4dB

The effective isotropic radiated power

(EIRP) = $P_t - L_{bo} - L_{bf} + A_f$

= 40 – 3 – 3 + 4

$\therefore$ EIRP = 38 dBW

06. Ans: (b)

Sol:

- Geo-stationary satellite always appears stationary w.r.t to a point on the earth surface. So continuous communication is possible.

- In satellite communication, up-link and downlink frequencies are choosen different because to decrease the interference between up-link wave and down-link wave.

Hence, both statements are correct but statement-II is not correct explanation of statement-I.

07. Ans: (a)

Sol:

- A communication satellite is an active satellite which amplifies the received signal and retransmits them back to earth hence, it is also called repeater.
  Hence, both statements are correct and statement-II is the correct explanation of statement-I.

08. Ans: (b)

Sol:

- Geo-stationary satellite always appears stationary w.r.t to a point on the Earth surface. So continuous communication is possible.
- Because of this reason, geo-stationary orbit is most widely used for communication purpose.
- Because of it's altitude, it gives rise to long propagation delay.
  Hence, both statements are correct but statement-II is not correct explanation of statement-I.

09. Ans: (b)

Sol:

- Radio and television receivers are generally superhetrodyne. Since superhetrodyne receiver will decreases the effect of image frequency and decreases the distortion in wireless communication.
- Superhetrodyne receivers are better in selectivity.
  Hence, both statements are correct and statement-II is not correct explanation for statement-I.

10. Ans: (a)

Sol:

- If satellites in low, elliptical orbits used for global communication, may be distance between satellite and earth decreases but we required another communication system to track this satellite.
- Whereas in geo-stationary satellite is always synchronous with earth. So another tracking device is not required.
  Hence, both statements are correct and statement-II is correct explanation for statement-I.

11. Ans: (c)

Sol:

- The most probable bandwidth of a transponder in a satellite communication system is 36MHz.

Conventional Practice Solutions

01.

Sol: Radius = (322 + 6371)km = 6693 km

(a) Angular velocity $\eta = \frac{1}{a}\sqrt{\frac{\mu}{a}}$

a = 6693 km

$$\eta = \frac{1}{6693\times10^3}\sqrt{\frac{3.986\times10^5}{6693\times10^3}} = 3.646\times10^{-8} \text{ rad/sec.}$$

(b) Orbital period = $T = \frac{2\pi a^{3/2}}{\mu^{1/2}}$

$$T = \frac{2\pi\times(6693\times10^3)^{3/2}}{(3.986\times10^5)^{1/2}} = 172.322\times10^6 \text{ sec} = 2.87\times10^6 \text{ minutes}$$

(c) $V = \sqrt{\frac{\mu}{r}} = \sqrt{\frac{\mu}{a}}$

$$V = \sqrt{\frac{3.986\times10^5}{6693\times10^3}} = 0.244 \text{ m/s}$$

02.

Sol: f = 100kHz = 0.1MHz

D = 50km

Freespace path loss

$L_p = 32.4 + 20\log f_{(MHz)} + 20\log D_{(km)}$

$= 32.4 + 20\log 0.1 + 20\log 50$

$= 32.4 – 20 + 33.979$

$L_p = 46.379$ dB

03.

Sol: Give data

Satellite station:

Frequency (f) = 11.7GHz

Distance (R) = 38000km

Output power (P_t) = 200mW

Antenna Gain (G_t) =18.9dB

Earth station:
Antenna diameter (D) = 12ft = 3.6576m
Aperture efficiency (η) = 50% = 0.5

(a) $EIRP = P_tG_t$
$= P_t + G_t(\text{in dB})$
$EIRP = 200\times10^{-3}\times10^{1.89} = 15.52W$
EIRP = 11.91 dBW
EIRP = 41.91 dBm

(b) We know that earth receiving antenna is parabolic reflector antenna so

$$\text{Gain} = G_r = \eta\pi^2\left(\frac{D}{\lambda}\right)^2$$

$$= 0.5\times\pi^2\left(\frac{3.6576}{3/117}\right)^2 \quad \left(\lambda = \frac{3\times10^8}{11.7\times10^9} = \frac{3}{117}\right)$$

= 100413.33

= 50 dB

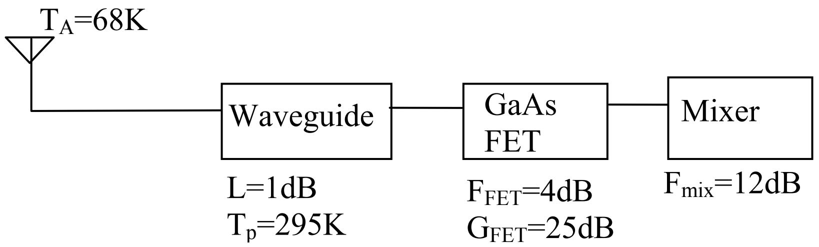
(c) Path loss $(P_\ell) = 32.4 + 20\log R_{(km)} + 20\log f_{(MHz)}$
$= 32.4 + 20\log(38000) + 20\log(11.7\times10^3)$
$P_\ell = 205.36dB$

(d) Received signal power $P_r = \frac{p_tG_tG_r}{P_\ell}$

$$P_r = \frac{200\times10^{-3}\times10^{1.89}\times100{,}413.33}{10^{20.536}}$$

$\therefore P_r = 4.53\times10^{-15}$ W
$\therefore P_r = 4.53\times10^{-12}$ mW
$\therefore P_r = -113.43$ dBm

04.
Sol:



(a) The GaAs FET amplifier noise temperature
$T_{FET} = (F_{FET} - 1)\, T_0$
$= (10^{0.4} - 1)\, 290 = 438.44K = 26.42$ dBK

(b) The mixer noise temperature

$$T_{mix} = (F_{mix} - 1)\, T_0$$
$$= (10^{1.2} - 1)\, 290$$
$$= 4306.2K$$
$$= 36.34 \text{ dBK}$$

(c) The waveguide effective input noise temperature

$$T_{we} = T_w + \frac{T_{FET}}{L} + \frac{T_{mix}}{LG_{FET}}$$

$$T_w = (F - 1)T_p \qquad (F = 10^{0.1})$$
$$= (10^{0.1} - 1)\, 295 = 76.38K$$
$$L = 10^{-0.1} = 0.794$$

$$T_{we} = 76.38 + \frac{438.44}{0.794} + \frac{4306.2}{0.794 \times 10^{2.5}}$$

$$\therefore\ T_{we} = 645.72K = 28.1dBK$$

(d) The overall noise temperature of the receiver, referred to the antenna output

$$T_{Ae} = T_A + T_{we} = 68 + 645.72 = 713.72K$$
$$= 28.53dBK$$

(e) The overall noise temperature of the receiver, referred to the GaAs FET input port

$$T_{FETe} = T_{FET} + \frac{T_{mix}}{G_{FET}}$$
$$= 438.44 + \frac{4306.2}{10^{2.5}}$$
$$\therefore\ T_{FETe} = 452.05K$$

(f) $$\left(\frac{C}{N}\right) = \frac{P_r}{kT_{Ae}B}$$

$$= P_r - K - T_{Ae} - B \text{ (in dB)}$$

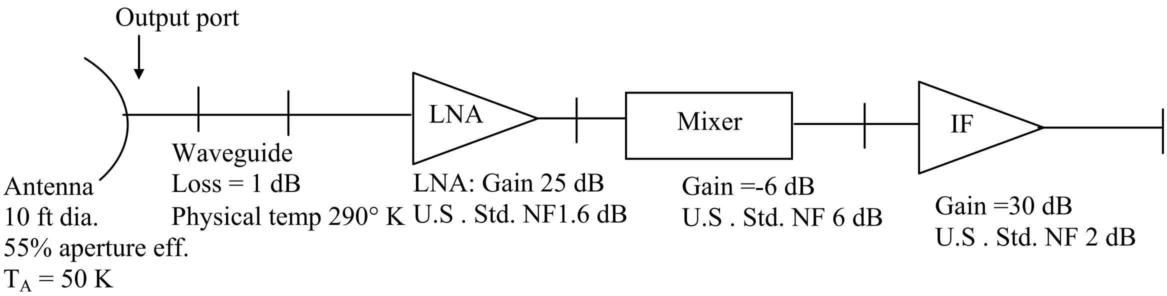
$$B = 10 \log (200) = 23.01 \text{ dBHz}$$

$$P_r = -119 \text{ dBm} = -149 \text{ dBW}$$

$$\left(\frac{C}{N}\right) = -149 - (-228.6) - 28.53 - 23.01$$

$$\therefore \left(\frac{C}{N}\right) = 28.06dB$$

05.
Sol:



$$G = \eta\pi^2\left(\frac{D}{\lambda}\right)^2 \qquad \left(\lambda = \frac{C}{f} = \frac{3\times10^8}{28\times10^8} = \frac{3}{28}\right)$$

$$= 0.55\pi^2\left(\frac{3.048\times28}{3}\right)^2 \qquad (10\text{ft} = 3.048\text{ m})$$

G = 4393.04 = 36.42 dB

Equivalent noise temperature

$$T = T_A + T_W + \frac{T_{LNA}}{L_W} + \frac{T_{MIX}}{L_W G_{LNA}} + \frac{T_{IF}}{L_W G_{LNA}\ G_{MIX}}$$

$$T_W = \left(\frac{1}{L_W} - 1\right)T_0 = \left(\frac{1}{10^{-0.1}} - 1\right)290 = 75.08\text{K}$$

$$T_{LNA} = (F_{LNA} - 1)T_0 = (10^{0.16} - 1)290 = 10.88\text{K}$$

$$T_{MIX} = (F_{MIX} - 1)T_0 = (10^{0.6} - 1)290 = 864.51\text{K}$$

$$T_{IF} = (F_{IF} - 1)T_0 = (10^{0.2} - 1)290 = 169.61\text{K}$$

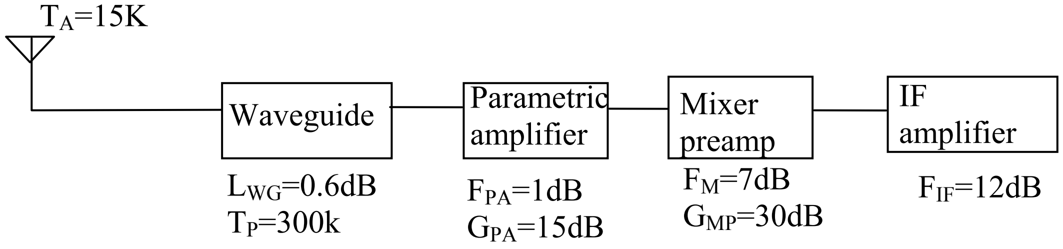
$$T = 50 + 75.08 + \frac{10.88}{10^{-0.1}} + \frac{864.51}{10^{-0.1}\times10^{2.5}} + \frac{1659.61}{10^{-0.1}\times10^{2.5}\times10^{-.6}}$$

T = 144.9 K = 21.61 dBK

$$\frac{G}{T} = 36.42 - 21.61$$

$$\therefore \frac{G}{T} = 14.8\,\text{dBK}^{-1}$$

06.
Sol:



Equivalent noise temperature

$$T = T_A + T_{WG} + \frac{T_{PA}}{L_{WG}} + \frac{T_{MP}}{L_{WG}G_{PA}} + \frac{T_{IF}}{L_{WG}G_{PA}G_{MP}}$$

$T_{WG} = (F_{WG} - 1)T_P$
$= (10^{0.06} - 1)\ 300$
$= 44.44\ K$

$T_{PA} = (F_{PA} - 1)T_0 = (10^{0.1} - 1)\ 290 = 75.08\ K$

$L_{WG} = 10^{-0.06} = 0.87$

$T_{MP} = (F_{MP} - 1)T_0 = (10^{0.7} - 1)290 = 1163.4\ K$

$G_{PA} = 15dB = 31.62$

$T_{IF} = (F_{IF} - 1)T_0 = (10^{1.2} - 1)\ 290 = 4306.19\ K$

$G_{MP} = 30dB = 1000$

$$T = 15 + 44.44 + \frac{75.08}{0.87} + \frac{1163.4}{0.87 \times 31.62} + \frac{4306.19}{0.87 \times 31.62 \times 1000}$$

$T = 188.18K = 22.74\ dBK$

Given $\frac{G}{T} = 40.7 + 20\log(f/4)dBK^{-1}$ $\quad (f = 4GHz)$

$$\frac{G}{T} = 40.7 + 20\log\left(\frac{4}{4}\right) = 40.7dBK^{-1}$$

$G = T + 40.7$

$G = 22.74 + 40.7 = 63.44dB = 2208004$

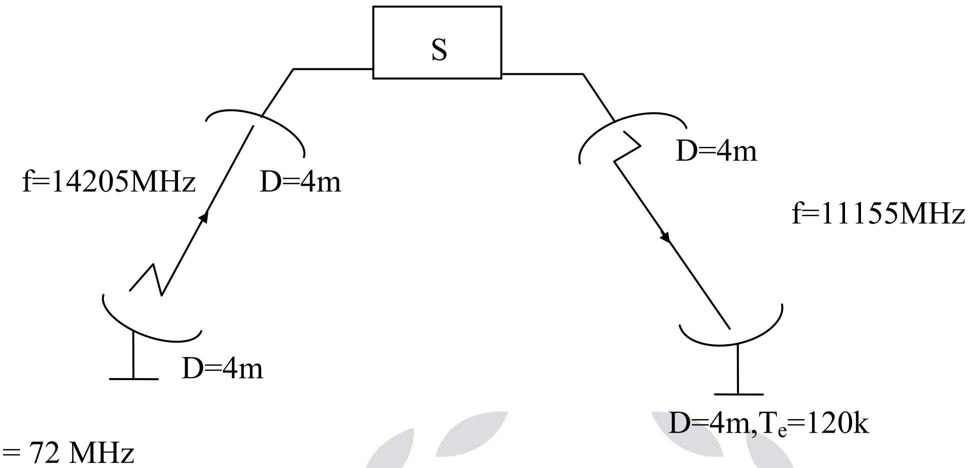
$$G = \eta\pi^2\left(\frac{D}{\lambda}\right)^2 \quad \left(\lambda = \frac{3\times10^8}{4\times10^9} = 0.075m\right)$$

$$D = \lambda\sqrt{\frac{G}{\eta\pi^2}}$$

$$= 0.075\sqrt{\frac{2208004}{0.65\times\pi^2}}$$

$\therefore\ D = 44m$

07.
Sol:



B = 72 MHz
R = 40000 km
η = 60%

$$\lambda = \frac{3\times10^8}{142.05\times10^8} = 0.0211\text{m}$$

$$G_t = 0.6\left(\frac{\pi\times D}{\lambda}\right)^2 = 0.6\left(\frac{\pi\times 4}{0.0211}\right)^2 = 53.28\,\text{dB} \ldots\ldots\ldots\ldots(1)$$

$$L_p = 20\log\left(\frac{4\pi R}{\lambda}\right) = 20\log\left(\frac{4\pi\times40\times10^6}{0.0211}\right) = 207.539\text{dB}$$

(a) Flux density of receiver(F) = –80.3 dB W/m^2

$$F = \frac{(EIRP)_U}{4\pi R^2} = (EIRP)_U - 10\log(4\pi R^2) = -80.3$$

$(EIRP)_U$ = –80.3+163.03 = 82.73

$P_t G_t = (EIRP)_U \Rightarrow P_t = 82.73 - 53.28$ (from (1))

P_t = 29.45 dBW = 881.04W

(b) $$\left(\frac{C}{N}\right)_{ts} = (EIRP)_U + \frac{G_r}{T_e} - L_p - L_b - K - B$$

$L_P = 32.4 + 20\log f_{(MHz)} + 20\log d_{(km)}$
$= 32.4 + 20\log(14205) + 20\log(40000)$
$= 207.5$dB

B = 10log(72×10^6) = 78.57 dBHz

$$\left(\frac{C}{N}\right)_{ts} = 82.73 + 3.3 - 207.5 - 4 - (-228.6) - 78.57$$

$$\therefore \left(\frac{C}{N}\right)_{ts} = 24.56\text{dB} = 285.76\text{dB}$$

(c) $\left(\frac{C}{N}\right)_{es} = (EIRP)_D + \frac{G_r}{T_e} - L_p - L_b - K - B$

$G_r = 53.28$ dB (from (1))

$T_e = 10\log120 = 20.8$dBk

$\frac{G_r}{T_e} = 53.28 - 20.8 = 32.48$dB/K

$L_p = 32.4 + 20\log f_{(MHz)} + 20\log d_{(Km)}$

$= 32.4 + 20\log(11155) + 20\log(40000)$

$L_p = 205.4$dB

$\therefore \left(\frac{C}{N}\right)_{es} = 44.4 + 32.48 - 205.4 - 4 - (-228.6) - 78.57$

$= 17.51$dB

$= 56.36$

(d) $\left(\frac{C}{N}\right)_{e} = \frac{\left(\frac{C}{N}\right)_{ts} \times \left(\frac{C}{N}\right)_{es}}{\left(\frac{C}{N}\right)_{ts} + \left(\frac{C}{N}\right)_{es}}$

$= \frac{285.76 \times 56.36}{285.76 + 56.36}$

$= 47.07$

$\therefore \left(\frac{C}{N}\right)_{e} = 16.72$dB

08.

Sol: The transponder of this satellite is operated in FDMA, so the output power is shared in proportion to each carrier bandwidth. The spectral density of each carrier is same and the C/N is same.

$P_t = 6.3W = 8dBW$

Transponder has 5dB back-off loss

So, the output power = 8 – 5 = 3dB or 2W

Station (1) & (2) → P_t = 2/3 = –1.8 dBW

Station (3) & (4) → P_t = 1/3 = –4.8dBW

Transponder gain G_t = 90dB

Station (1) & (2) → –90–1.8dB = –91.8dBW

Station (3) & (4) → –90–4.8dB = –94.8dBW

(a) Up link:

Earth station antenna gain G_t = 61.3 dB

Satellite antenna gain G_r = 22 dB

$(P_r) = (P_t) + (G_t) + (G_r) - (L_p)$ (in dB)

$(P_t) = (P_r) - (G_t) - (G_r) + (L_p)$ (in dB)

Station (1) & (2)

$P_t = -91.8 - 61.3 + 200 - 22 = 24.9$dB

Station (3) & (4)

$P_t = -94.8 - 61.3 + 200 - 22$

$= 21.9$ dBW

(b) Down link:

For a station on the 3dB contour

$P_r = P_t + G_t + G_r - L_p - 3$dB

$= -1.8 + 20 - 196 + 60 - 3 = -120.8$ dBW for (1) & (2)

$P_r = -123.8$ dBW for (3) & (4)

Noise power = KTB = –138.6dB at 10 MHz

= –141.6dB at 5 MHz

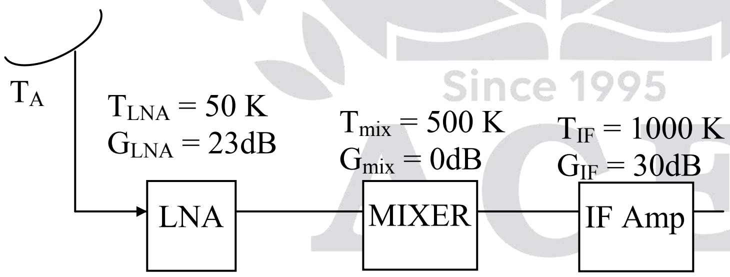
So C/N of all earth stations is

$C/N = (P_r) - (N)$

$= 17.8$ dB

09.

Sol: Consider satellite receiver as shown in the figure



Overall noise equivalent temperature

$$T_e = T_A + T_{LNA} + \frac{T_{mix}}{G_{LNA}} + \frac{T_{IF}}{G_{LNA}G_{mix}} \quad (G_{LNA} = 23\text{dB} = 10^{2.3} = 199.526)$$

$$= 50 + 50 + \frac{500}{199.526} + \frac{1000}{199.526} \quad (G_{mix} = 0\text{dB} = 1)$$

$\Rightarrow T_e = 107.51$K

10.

Sol: Uplink parameters

$$\left(\frac{C}{N}\right)_U = P_t + G_t + \frac{G}{T_e} - L_P - L_B - L_f - L_a - K - B$$

$$G_t = 6\left(\frac{D}{\lambda}\right)^2 \qquad \left(\lambda = \frac{C}{f} = \frac{3\times10^8}{14\times10^9} = 0.021\text{ m}\right)$$

$$= 6\left(\frac{10}{0.021}\right)^2 = 61.33\text{dB}$$

$$(B)_{min} = \frac{R_b}{\log_2^M} = \frac{90\times10^6}{\log_2^8} = 30\text{MHz}$$

B = 74.77dBHz

L_p = 32.4+20 log f(MHz) + 20 log d(km)

= 32.4 + 20 log (14×10^3) + 20 log(36000)

= 206.44dB

$$\left(\frac{C}{N}\right)_U = 30 + 61.33 - 4.6 - 206.44 - 3 - 3 - (-228.6) - 74.77 - 0.8$$

$$\left(\frac{C}{N}\right)_U = 27.32\text{ dB} = 539.51$$

Down link parameters

$$\left(\frac{C}{N}\right)_D = P_t + G_t + \frac{G_r}{T_e} - L_P - L_B - L_t - L_a - K - B$$

P_t = 10W = 10dBW

$$G_t = 6\left(\frac{D}{\lambda}\right)^2 \qquad \left(\lambda = \frac{C}{f} = \frac{3\times10^8}{12\times10^9} = 0.025\right)$$

$$= 6\left(\frac{0.5}{0.025}\right)^2 = 33.8\text{dB}$$

$$G_r = 6\left(\frac{D}{\lambda}\right)^2 = 6\left(\frac{10}{0.025}\right)^2 = 59.8\text{dB}$$

T_e = 200K = 23dB

$$\frac{G_r}{T_e} = 59.8 - 23 = 36.8\text{dB}$$

L_p = 32.4 + 20 logf $_{(MHz)}$ + 20 log $d_{(km)}$

= 32.4 + 20 log (12×10^3) + 20 log (36000)

= 205.1 dB

$$(B)_{min} = \frac{R_b}{\log_2^M} = \frac{90\times10^6}{\log_2^8} = 30\text{MHz}$$

B = 74.77 dBHz

$$\left(\frac{C}{N}\right)_D = 10 + 33.8 + 36.8 - 205.1 - 0.8 - 0.6 - 0 - (-228.6) - 74.77$$

$= 27.93$ dB

$= 620.87$

$$\left(\frac{C}{N}\right)_{ov} = \frac{\left(\frac{C}{N}\right)_U \left(\frac{C}{N}\right)_D}{\left(\frac{C}{N}\right)_U + \left(\frac{C}{N}\right)_D}$$

$$= \frac{539.51 \times 620.87}{539.51 + 620.87} = 288.66$$

$$\left(\frac{C}{N}\right)_{ov} = 24.6\,\text{dB}$$

11.

Sol:

$T_e = 400K$

Noise Bandwidth = 30MHz

G = 44dB

f = 12GHz

(1) $\frac{G}{T_e} = \frac{\text{Antenna Gain (Receiver)}}{\text{System Noise temparature}}$

$= G - 10\log(T_e)$

$= 44 - 10\log 400$

$= -17.97$ dB

(2) N_0 = Noise density $(W/Hz) = KT_e$

$N_0 = 10\log k + 10\log T_e$

$= 10\log(1.38 \times 10^{-23}) + 10\log(400)$

$= 10\log(1.38) - 230 + 10\log(400)$

$= -202.58$ dBW/Hz

(3) $N = N_0 B$

$N = -220.55$ Db

12.

Sol: Uplink $\left(\frac{E_b}{N_0}\right)_U = 16\text{dB} = 39.81 \approx 39.8$

Downlink $\left(\frac{E_b}{N_0}\right)_D = 13\text{dB} = 19.952 \approx 20$

Overall $\left(\frac{E_b}{N_0}\right)$ is

$$\left(\frac{E_b}{N_0}\right)_o = \frac{(E_b/N_0)_U\ (E_b/N_0)_D}{(E_b/N_0)_U + (E_b/N_0)_D}$$

$$= \frac{39.8\times 20}{39.8+20}$$

$$\left(\frac{E_b}{N_0}\right)_o = \frac{796}{59.8} = 13.31 \quad = 11.24\text{ dB}$$

$$a = \frac{2.4\times 0.85\times 10^{-6}}{2\pi\times 1.48\times (0.003)^{\frac{1}{2}}} = 4.0\mu\text{m}$$

Hence the maximum core diameter for single mode operation is now approximately 8μm.

Chapter 8 Optical Fiber Communication

Objective Practice Solutions

01. Ans: (d)

Sol: Given,

Cladding material relative permittivity (ε_r) = 2.4375

⇒ Refractive index of the cladding material (n_2) = $\sqrt{\varepsilon_r}$

= 1.561

Numerical aperture (N.A) = 0.25

We know, N.A $= \sqrt{n_1^2 - n_2^2}$

Where n_1 = Refractive index of core material.

n_2 = Refractive index of cladding material

$\Rightarrow\ 0.25 = \sqrt{n_1^2 - (1.561)^2}$

$\therefore n_1 = \sqrt{2.5}$

02. Ans: (d)

Sol: Total number of modes in step index fiber $= \frac{V^2}{2}\left(\frac{\alpha}{\alpha+2}\right)$

Where,

α = Refractive index profile

= 1 for triangular profile

= 2 for parabolic profile

V = Normal frequency $= \frac{\pi d}{\lambda}(\text{N.A})$

i.e., the total number of modes entering an optical fiber depends on core radius (r), wave length of the optical source (λ) and refractive index profile (α).

Hence, option (d) is correct.

03. Ans: (b)

Sol: Given, for a single mode optical cable

Attenuation per km = α (dB/km)

= 0.25 dB/km

We know,

$$\alpha(\text{dB/m}) = \frac{\log\left(\frac{P_i}{P_0}\right)}{L}$$

L = length of optical fiber = 100km

$$\Rightarrow 0.25 = \frac{10\log\left(\frac{0.1\text{m}}{P_0}\right)}{100}$$

$\therefore\ P_0 = -35$dBm

04. Ans: (c)

Sol:

- Numerical aperture (N.A) is used to describe the light gathering (or) light collecting ability of an optical fiber.
- The larger the magnitude of the numerical aperture, the greater the amount of external light the fiber will accept.

05. Ans: (c)

Sol:

- In a optical fiber, the refractive index of the cladding material should be always less than that of the core.
- Then only, the total internal reflection takes place in core of optical fiber.

06. Ans: (d)

Sol:

- Fibers with higher numerical aperture values generally exhibit greater losses and low bandwidth.
- In optical fiber numerical aperture band width product is constant.

07. Ans: (b)

Sol:

- To transmit a data at the rate of 1000Mbps, mostly we are going for optical fiber system.

Conventional Practice Solutions

01.

Sol: Given

Core refractive index $n_1 = 1.45$

Cladding refractive index $n_2 = 1.4$

Numerical aperture of the fiber.

$= \left(n_1^{\ 2} - n_2^{\ 2}\right)^{1/2} = 0.377$

Acceptance angle in air for fiber

$\theta_A = \sin^{-1}$ NA = 22.178^0

Critical angle at core-cladding interface φ_C

$= \sin^{-1}\dfrac{n_2}{n_1} = 74.9^0 \approx 75^0$

02.

Sol: Core diameter (2a) = 50μm = 50×10^{-6}m

$\lambda = 8\times10^{-6}$m

$n_1 = 1.55$

$\Delta = 1.5\% = 0.015$

Total number of modes

$$M = \frac{V^2}{2}$$

Where $V = \dfrac{2\pi}{\lambda} a n_1 \sqrt{2\Delta}$

$$V = \frac{2\pi\times25\times10^{-6}\times1.55\sqrt{2\times0.015}}{8\times10^{-6}}$$

V = 5.271

$$M = \frac{(5.271)^2}{2} = 13.89$$

Number of modes = 14

03.

Sol: Using with V_c = 2405

gives

$$\lambda = \frac{2\pi a n_1 (2\Delta)^{1/2}}{2.405} = \frac{24.5\times1.46(0.005)^{1/2}}{2.405}\mu m$$

= 1.214 μm

= 1214 nm

Hence the fiber single moded to a wave length of 1214 nm.

04.

Sol: Using equation, the normalized frequency for the fiber is:

$$V = \frac{2\pi}{\lambda}a(NA) = \frac{2\pi\times25\times10^{-6}\times0.2}{1\times10^{-6}} = 31.4$$

The mode volume may be obtained from equation where a parabolic profile:

$$M_g \cong \frac{V^2}{4} = \frac{986}{4} = 247$$

Hence the fiber supports approximately 247 guided modes.

$$a = \frac{2.4\times0.85\times10^{-6}}{2\pi\times1.48\times(0.003)^{\frac{1}{2}}} = 4.0\mu m$$

Hence the maximum core diameter for single mode operation is now approximately 8μm.

05.

Sol: NA = 0.173

M = 400

$$\frac{V^2}{2} = 400$$

$\Rightarrow V^2 = 800$

$V = \sqrt{800} = 28.28$

λ = 1.3 μm

$$V = \frac{2\pi a}{\lambda}NA$$

$$28.28 = \frac{2\pi a}{1.3\times10^{-6}}(0.173)$$

$a = 3.3^{82}\times10^{-5}$ = 33.82×10^{-6}m

Circular or core area

= $\pi a^2 = \pi\,(33.82\times10^{-6})^2 = 3.59\times10^{-9}m^2$

If it is a single mode fiber at $\lambda \geq 1.3$ μm then the cutoff occurs at $V \leq 2.405$

$$V = \frac{2\pi a}{1.3\times10^{-6}}(0.173)$$

$$a = 2.876\times10^{-6}\,m$$

The core area to be reduced so that it is single mode fiber is $\pi a^2 = 2.59\times10^{-11}$ m^2

07.

Sol:

(a) The overall signal attenuation in decibels through the fibre is:

$$\text{Overall attenuation} = 10\log_{10}\left(\frac{P_i}{P_0}\right)$$

$$= 10\log_{10}\left(\frac{120\times10^{-6}}{3\times10^{-6}}\right)$$

$= 10\log_{10}(40)$

$= 16\text{dB}$

(b) The signal attenuation per kilometre for the fibre may be simply obtained by dividing the overall attenuation by the fibre length which corresponds to it using

$$\alpha_{dB/km}\,L = 10\log_{10}\left(\frac{P_i}{P_0}\right)$$

$\alpha_{dB/km}\,L = 16\text{dB}$

$$\alpha_{dB/km} = \frac{16}{8} = 2$$

$\alpha_{dB/km} = 2\text{dB/km}$

(c) As $\alpha_{dB/km} = 2\text{dB/km}$, the loss incurred along 10 km of the fibre is given by

$\alpha_{dB/km}\,L = 2\times10 = 20\text{dB}$

However, the link also has nine spices (a 1km intervals) each with an attenuation of 1dB.

Therefore the loss due to the spices is 9dB.

Hence, the overall signal attenuation for the link is:

Overall attenuation = 20 + 9

= 29dB

08.

Sol: Given

Length of the optical fiber $L = 20$ km

LED output power $P_T = 30\text{mW}$

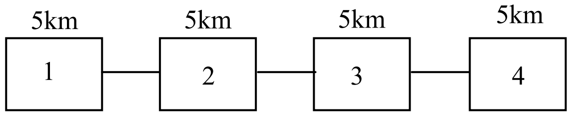
Given $\alpha = 0.5\text{dB/km}$

Number of connectors = 3

Connector loss = 2dB

Interface loss = 1.9dB

Detector loss 2.1dB



0.5dB/km

Link loss = [fiber length × fiber attenuation]
+ [splice loss × no. of splices]
+ [connector loss × no. of connectors]
+ system margin
= [5×0.5×4]+[2×3]+1.9+2.1
= 20dB

$$\text{Link loss} = 10\log\left(\frac{\text{input}}{\text{output}}\right)$$

$$= 10\log\left(\frac{\text{transmitted}}{\text{received}}\right)$$

$$20 = 10\log\left(\frac{30\times10^{-3}}{P_r}\right)$$

$P_r = 0.3\text{mW}$

$$\text{Power (indBm)} = 10\log\frac{\text{P(in mW)}}{1\text{mW}}$$

$$= 10\log\frac{0.3\text{mW}}{1\text{mW}}$$

Power = – 5.228 dBm

09.

Sol: An optical power loss model for a point -to-point link is shown in Figure. The optical power received at the photo detector depends on the amount of light coupled into the fiber & the losses occurring in the fiber and at the connectors and splices. The link loss budget is derived from the sequential loss contributions of each element in the link. Each of these loss elements is expressed in decibels (dB) as

$$\text{loss} = 10\log\frac{P_{out}}{P_{in}}$$

Where P_{in} and P_{out} are the optical powers entering and leaving the loss element, respectively. The loss value corresponding to a particular element generally is called the insertion loss for that element. In addition to the link loss contributors shown in figure a link power margin is normally provided in the analysis to allow for component aging, temperature fluctuations, and losses arising from components.

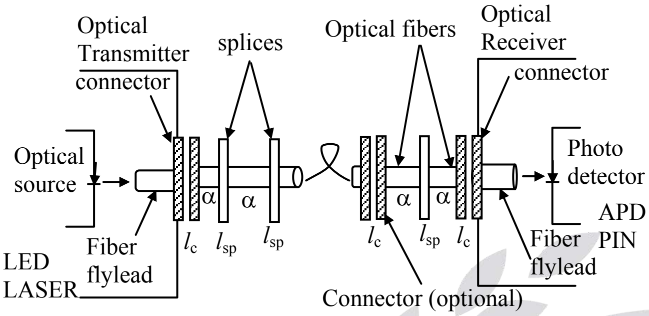


Fig. Optical power loss model for a point-to-point link. The losses occur at connectors (l_c), at splices (l_{sp}), and in the fiber (α)

The link loss budget simply considers the total optical power loss P_T that is allowed between the light source and the photodetector, and allocates this loss to cable attenuation, connector loss, splice loss, and system margin. Thus, if P_s is the optical power emerging from the end of a fiber fly lead attached to the light source of from a source-coupled connector, and if P_R is the receiver sensitivity, then

$P_T = P_S - P_R$

$= 2l_c + \alpha L$ + system margin

Given Laser diode output

⇒ Optical power emerging from the end of a fiber P_s = 3dBm.

In GaAs APD sensitivity

⇒ Receiver sensitivity = –32dBm.

Optical fibre attenuation α = 0.25dB/Km

Connector loss l_c = 1 dB

Power or system margin = 6dB

Total optical power loss

$P_T = P_S - P_R = 2l_c + \alpha L$ + system margin.

⇒ 3 – (–32) = 2(1) + 0.25L + 6

35 – 8 = 0.25L

Link distance (L) = 108 Km

10.

Sol: Given

Length of fiber = 100 km

Attenuation loss α = 0.4 dB/km

Connection loss = 1 dB

Fibers with 10 km unit lengths and connector which is used between two unit lengths, so total number of connectors = 9

Assume one connector loss at fiber receiver coupling loss

i.e, coupling loss = 1 dB

Link loss = [fiber length (km)×fiber attenuation per km] + [Splice loss×number of splices] + [connector loss×number of connectors] + [safety margin]

Link loss = (0.4×100) + (1 × 9) + 1 = 50dB

$$\text{Attenuation} = 10\log_{10}\left(\frac{P_i}{P_0}\right)$$

Input power P_i = 0dBm

$$\text{Power level (in dBm)} = 10\log\frac{P_i\,(\text{in mW})}{1\text{mW}}$$

$P_i = 10^{-3}$W

$$50 = 10\log_{10}\left(\frac{10^{-3}}{P_0}\right) \Rightarrow P_0 = 10^{-8}\text{ W}$$

Receiver sensitivity = 10 nW /Mbps

$$\text{Sensitivity} = \frac{\text{output power}}{\text{data rate}}$$

$$\text{Data rate} = \frac{\text{output power}}{\text{sensitivity}}$$

$$= \frac{10^{-8}}{10\times10^{-9}} = 10^6$$

Data rate = 1 Mbps

11.

Sol: Attenuation = 0.4 dB/km

$$\text{Attenuation} = \frac{10}{L}\log_{10}\left(\frac{P_i}{P_0}\right)\text{dB/km}$$

Optical power launched = input power = P_i

= –3dBm

Input power level (in dBm)

$$= 10\log\frac{P(\text{in mW})}{1\,\text{mW}}$$

$$-3 = 10\log\frac{P(\text{in mW})}{10^{-3}}$$

P(in mW) = $10^{-0.3}$ = 0.5 mW

The receivers uses a photo detector

Sensitivity = 10nW/Mbps

Data rate = 100 Mbps

Sensitivity of a photo detector

$$= \frac{\text{output power}}{\text{Data rate}}$$

Output power = sensitivity × data rate

$$= 10\times10^{-9}\times100 = 10^{-6}\ \text{W}$$

Signal attenuation

$$= 10\log_{10}\left(\frac{P_i}{P_0}\right) = 10\log\left(\frac{10^{-3}\times0.5}{10^{-6}}\right)$$

$= 26.98 \approx 27$ dB

Link loss = [fiber length (km) × fiber attenuation per km] + [Splice loss×number of splices] + [connector loss ×number of connectors] + [safety margin]

Given

number of splices = 3

Splices loss = 1 dB

Coupling loss = 3 dB

Link loss (or) attenuation (dB) is given

= [L (km)×0.4(dB/km)] + [1dB×3] + 3 dB

27 = 0.4 L + 3 + 3

$\therefore$ L = 52.5 km