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Rashtreeya Vidyalaya Institute of Technology and Management (RVITM), Bengaluru

BASIC ELECTRONICS & COMMUNICATION ENGINEERING (21ELN14/24)

SEMESTER-I

Module-V

Wireless Communication

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Module 5 Wireless Communication	RBT Levels
Cellular Wireless Networks - Introduction, cellular telephone system, cellular concept and frequency reuse. Wireless Network Topologies - First Generation (1G) Technology, Second Generation (2G) Technology, GSM Communications, GSM System architecture, Third Generation (3G) Technology, CDMA Technology, High-level architecture of LTE, Fourth Generation (4G) Technology, Wireless LAN, Bluetooth, Bluetooth Architecture. Text Satellite Communication – Elements of Satellite Communication, Types of satellites – GEO, LEO, MEO. Optical Fiber Communication - A fiber optic Communication system. Microwave Communication – Introduction, Frequency modulated microwave communication system.	L1, L2

5.1 Introduction

It is customary among the cellular telephone manufacturers and service providers to classify wireless communication systems into several generations. The first generation (ICJ) systems are voice-oriented analog cellular and cordless telephones. The second-generation (2G) wireless networks are voice-oriented digital cellular and PCS systems and data-oriented wireless WANs and LANs. The third-generation (3G) networks integrate cellular and PCS voice services with a variety of packet-switched data services in a unified network. In parallel to the unified 3G standardization activities, broadband local and ad hoc networks attracted tremendous attention, and they developed their own standards. One of the major current differences between these is that the 3G systems use licensed bands, and broadband and ad-hoc networks operate in unlicensed bands. The manner in which broadband local access in unlicensed bands and 3G standards in licensed bands may be integrated forms the core of the forthcoming generations of wireless networks. 4G increase in bandwidth, higher speed, and greater interoperability across communication protocols, user friendly, innovative and secure applications.

5.2 Cellular Telephone System

As shown in Fig. 5.1, a cellular system comprises the following basic components:

Mobile Station (MS): This is the mobile handset, which is used by a user to communicate with another user.

Cell: Each cellular service area is divided into small regions called cell (5 to 20 Km).

Base Station (BS): Each cell contains an antenna, which is controlled by a small office.

Mobile Switching Center (MSC): Each base station is controlled by a switching office, called mobile switching center.

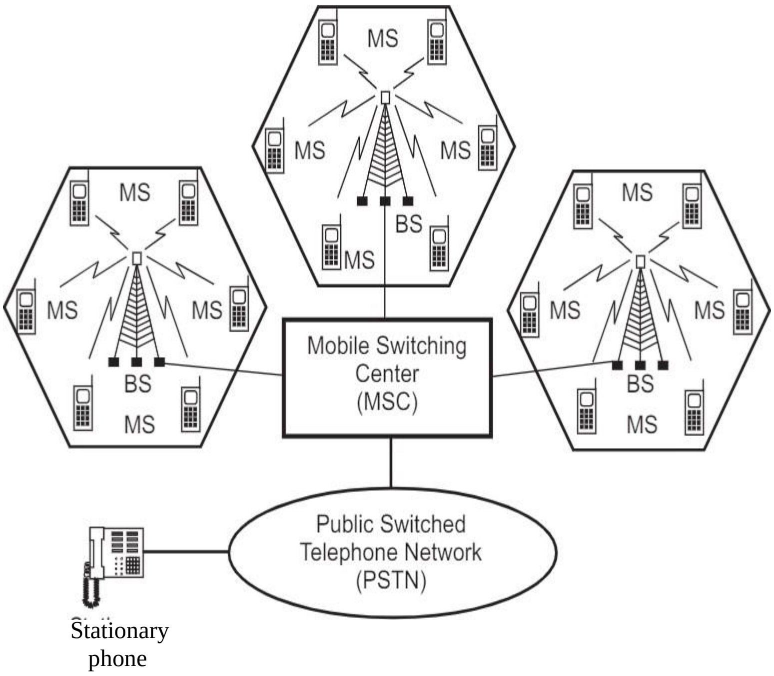

Fig. 5.1 Schematic diagram of a cellular telephone system

5.3 Cellular Concept and Frequency Reuse

In the early phase, mobile radio system normally used a high power transmitter with an antenna mounted on a tall tower. This approach gave very good coverage, but it was very difficult to reuse these same frequencies, therefore that the network capacity is low. As the demand for mobile service increased, achieving high network capacity by the same radio spectrum was more important than covering large areas.

In order to solve the capacity problem, the cellular concept was proposed in 1970. The fundamental principle of the cellular concept is to divide the coverage area into a number of smaller areas which are served by their own radio base station. Radio channels are allocated to these smaller areas in an intelligent way so as to minimize the interference and improve the performance, and cater to the traffic loads in these areas called cells. The groups of cells in smaller areas are known as clusters. As the population grows, cells can be added to accommodate that growth. Frequencies used in one cell cluster can be reused in other cells. Conversations can be handed off from cell to cell to maintain constant phone service as the user moves between cells.

The cellular concept employs variable low power transmitters, which allow cells to be sized according to the subscriber density and demand of a given area. As the population grows, cells can be added to accommodate that growth. Frequencies used in one cell cluster can be reused in other cells. Small cells will increase the network capacity, but on the other hand will increase the co-channel interference (CCI), therefore affect the quality of service (QoS). In order to achieve high capacity while satisfying quality of service expectations, a cellular architecture must be defined so as to be flexible to accommodate system growth. Fig. 5.2 shows the concept of cells in wireless and mobile networks.

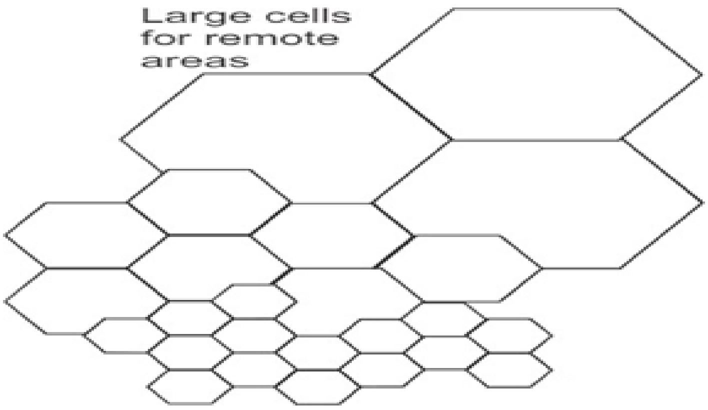

Fig. 5.2 Cellular concept in wireless and mobile networks

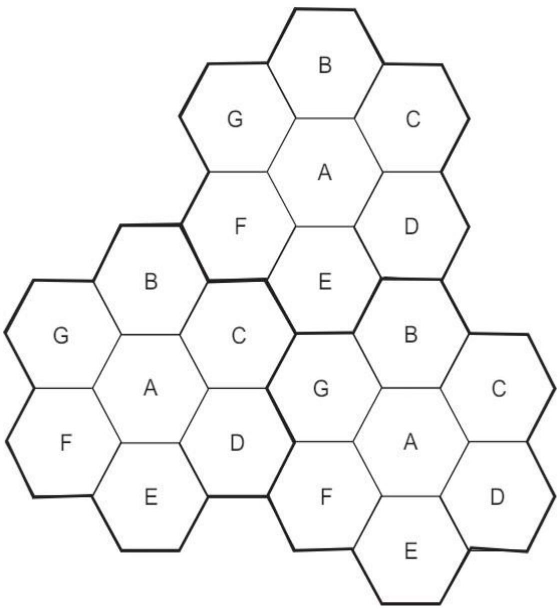

Fig. 5.3 Concept of frequency reuse

5.3.1 Frequency Reuse

Frequency reuse is the core concept of the cellular mobile radio system. The total available channels are divided into a number of channel sets (Actually, frequency reuse pattern is equally to the number of channel sets). Each channel set is assigned to a cell. Cells are assigned a group of channels that is completely different from neighbouring cell.

Fig. 5.3 illustrates the concept of frequency reuse. Cells with the same alphabet use the same channel set. The same set of channels can be reused in another cell provided that the reuse distance D is fulfilled. The reuse distance is the minimum separation of identical channels that have the same carrier frequency, at which there is acceptable interference:

$$D=\sqrt{3N}.R \qquad (1)$$

Where N is the number of channel sets (cells in a cluster), R is the radius of a cell.

5.3.2 Reduction of Interference

Reusing an identical frequency channel in different cells is limited by co-channel interference between cells, and the co-channel interference can become a major problem. One way to reduce co-channel interference (CCI) is to keep the separation between two co-channel cells by a sufficient distance. Another way for controlling CCI is to use directional antennas at the base station (BS), and we call it cell sectoring. The adjacent channel interference, coming from neighbouring channels and next channels, is another consideration in channel assignment. The adjacent channel interference depends on the separation of two adjacent channels, the characteristic of receiver filters, and the distance of two adjacent channel users. The near-end ratio interference can occur among the neighbouring channels. Therefore, if one channel is assigned to a cell, its adjacent channels cannot be assigned to the same cell and vice-versa.

5.3.3 Transmitting and Receiving

Basic operations of transmitting and receiving in a cellular telephone network are discussed in this section.

Transmitting involves the following steps:

- A caller enters a 10-digit code (phone number) and presses the send button.
- The MS scans the band to select a free channel and sends a strong signal to send the number entered.
- The BS relays the number to the MSC.

- The MSC in turn dispatches the request to all the base stations in the cellular system. The Mobile Identification Number (MIN) is then broadcast over all the forward control channels throughout the cellular system. It is known as paging.
- The MS responds by identifying itself over the reverse control channel.
- The BS relays the acknowledgement sent by the mobile and informs the MSC about the handshake.
- The MSC assigns an unused voice channel to the call and call is established.

Receiving involves the following steps:

- All the idle mobile stations continuously listens to the paging signal to detect messages directed at them.
- When a call is placed to a mobile station, a packet is sent to the callees home MSC to find out where it is.
- A packet is sent to the base station in its current cell, which then sends a broadcast on the paging channel.
- The called MS responds on the control channel.
- In response, a voice channel is assigned and ringing starts at the MS.

5.3.4 Mobility Management

A MS is assigned a home network, commonly known as location area. When an MS migrates out of its current BS into the footprint of another, a procedure is performed to maintain service continuity, known as Handoff management. An agent in the home network, called home agent, keeps track of the current location of the MS. The procedure to keep track of the user's current location is referred to as Location management. Handoff management and location management together are referred to as Mobility management.

Handoff: At any instant, each mobile station is logically in a cell and under the control of the cells base station. When a mobile station moves out of a cell, the base station notices the MSS signal fading away and requests all the neighbouring BSS to report the strength they are receiving. The BS then transfers ownership to the cell getting the strongest signal and the MSC changes the channel carrying the call. The process is called handoff. There are two types of handoff; hard handoff and soft handoff. In a hard handoff, which was used in the early systems, a MS communicates with one BS. As a MS moves from cell A to cell B, the communication between the MS and base station of cell A is first broken before communication is started between the MS and the base station of B. As a consequence, the transition is not smooth. For smooth transition from one cell (say A) to another (say B), an MS continues to talk to both A and B. As the MS moves from cell A to cell B, at some point the communication is broken with the old base station of cell A. This is known as soft handoff.

Roaming: Two fundamental operations are associated with location management; location update and paging. When a Mobile Station (MS) enters a new Location Area, it performs a location updating procedure by making an association between the foreign agent and the home agent. One of the BSS, in the newly visited Location Area is informed and the home directory of the MS is updated with its current location. When the home agent receives a message destined for the MS, it forwards the message to the MS via the foreign agent. An authentication process is performed before forwarding the message.

5.4 Wireless Network Topologies

Wireless network topology is defined as the configuration in which a mobile terminal (MT) communicates with other mobile terminals. Basically, there are two types of topologies used in wireless networks as follows:

Ad-Hoc Network Topology: Ad-hoc wireless networks do not need any infrastructure to work. Each node can communicate directly with other nodes, so no base station is necessary. These networks are primarily used by military and also in a few commercial applications for voice and data transmission. This topology is suitable for rapid deployment of a wireless network in a mobile or fixed environment.

Fig. 5.4 shows a single-hop, ad-hoc network where every user terminal has the functional capability of communicating directly with any other user terminal. Nodes within an ad-hoc network can only communicate if they can reach each other physically, i.e., if they are within each others radio range or if other nodes can forward the message.

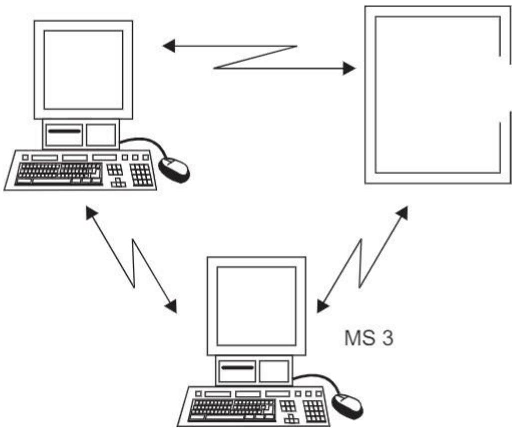

Fig. 5.4 Single hop ad-hoc network

In some ad-hoc networking applications, where users may be distributed over a wide area, a given user terminal may be able to reach only a portion of the other users in the network due to the transmitter signal power limitations. In this situation, user terminals will have to cooperate in carrying messages across the network between widely separated stations. These networks are called multi hop ad-hoc networks as shown in Fig. 5.5.

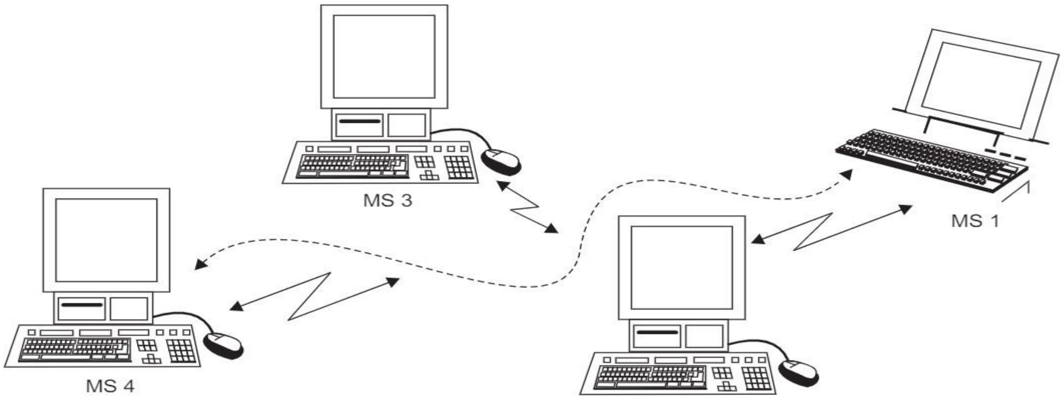

Fig. 5.5 Multi hop ad-hoc network

Infrastructure Network Topology: In this topology, there is a fixed infrastructure that supports the communication between the mobile terminals and between mobile and fixed terminals. This topology is often designed for large coverage areas and multiple base stations (BS) or access point (AP) operations. Fig. 5.6 shows the basic operation of an infrastructure network with a single base station. Base station (BS) serves as the hub of the network and mobile terminals are located at different positions at the ends of spokes. Any communication from one wireless station user to another comes through the base station. Thus, we can say that the hub is involved in managing the user access to the network.

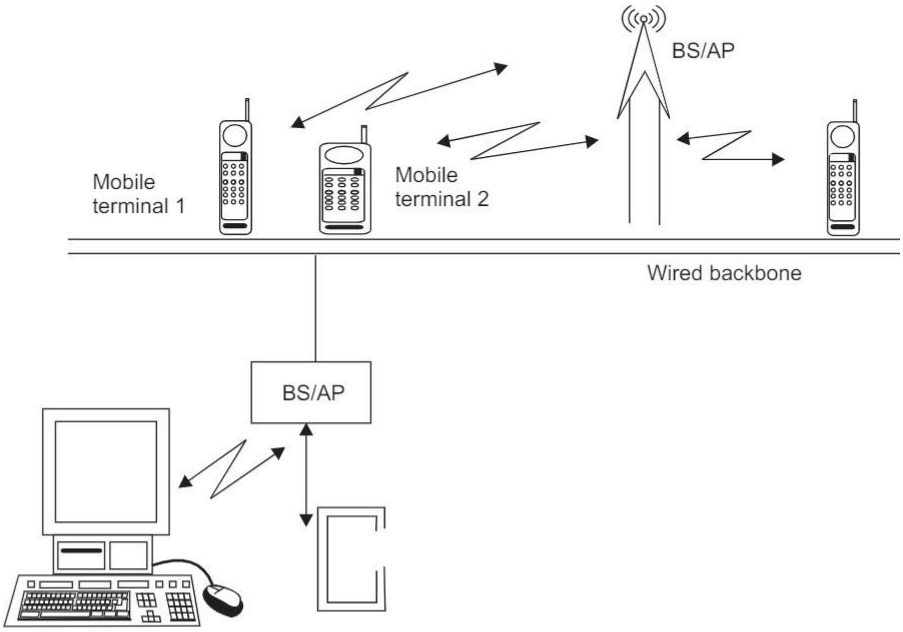

Fig. 5.6 Infrastructure network topology

5.5 First Generation (IG) Technology

IG stands for "first generation," refers to the first generation of wireless telecommunication technology, more popularly known as cellphones. A set of wireless standards developed in the 1980's, IG technology replaced OG technology, which featured mobile radio telephones and such technologies as Mobile Telephone System (MTS), Advanced Mobile Telephone System (AMTS), Improved Mobile Telephone Service (IMTS), and Push to Talk (PTT). Its successor,2G, which made use of digital signals, IG wireless networks used analog radio signals.

Through869-894 MHz, 30 KHz for each channel

Forward communication ⟶

824-894

BS

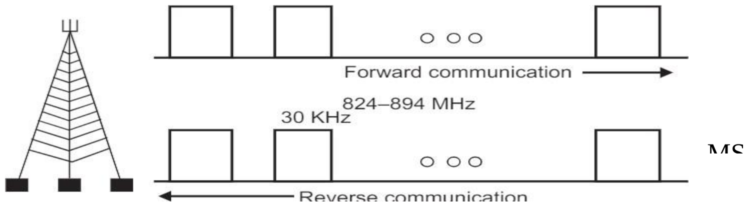

Fig. 5.7 Frequency bands used in AMPS system

IG, a voice call gets modulated to a higher frequency of about 150 MHz and up as it is transmitted between radio towers. This is done using a technique called Frequency-Division

Multiple Access (FDMA). In terms of overall connection quality, IG compares unfavorably to its successors. It has low capacity, unreliable handoff, poor voice links, and no security at all since voice calls were played back in radio towers, making these calls susceptible to unwanted eavesdropping by third parties.

The first generation was designed for voice communication. One example is Advanced Mobile Phone System (AMPS) used in North America. AMPS is an analog cellular phone system. It uses 800 MHz ISM band and two separate analog channels; forward and reverse analog channels. The band between 824 to 849 MHz is used for reverse communication from MS to BS. The band between 869 to 894 MHz is used for forward communication from BS to MS. Each band is divided in to 832 30-KHz channels as shown in Fig. 5.7. As each location area is shared by two service providers, each provider can have 416 channels, out of which 21 are used for control. AMPS uses Frequency Division Multiple Access (FDMA) to divide each 25-1MHz band into 30-KHz channels as shown in Fig. 5.8.

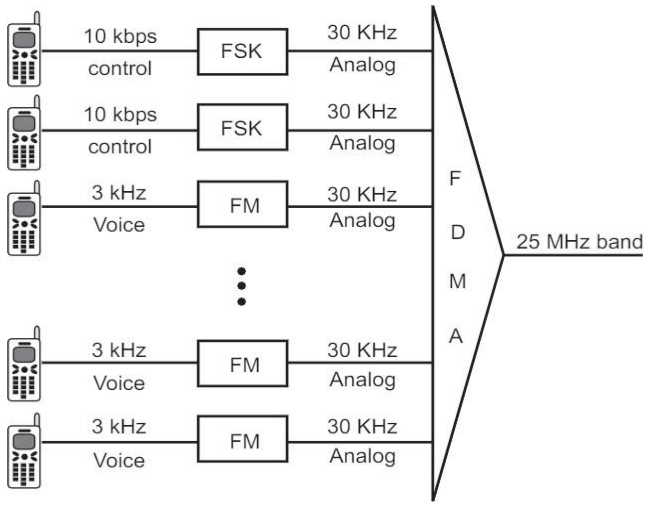

Fig. 5.8 FDMA medium access control technique used in AMPS

5.6 Second Generation (2G) Technology

2G is short for "second-generation" wireless telephone technology. It cannot normally transfer data, such as email or software, other than the digital voice call itself, and other basic ancillary data such as time and date. The first generation cellular network was developed for analog voice communication. To provide better voice quality, the second generation was developed for digitized voice communication. Nevertheless, SMS messaging is also available as a form of data transmission for some standards. Second generation 2G cellular telecom networks were commercially launched on the GSM standard in Finland in 1991. GSM service is used by over

2 billion people across more than 212 countries and territories. The ubiquity of the GSM standard makes international roaming very common between mobile phone operators, enabling subscribers to use their phones in many parts of the world.

2G technologies can be divided into Time Division Multiple Access (TDMA) based and Code Division Multiple Access (CDMA) based standards depending on the type of multiplexing used. 2G makes use of a CODEC (Compression-Decompression Algorithm) to compress and multiplex digital voice data. Through this technology, a 2G network can pack more calls per amount of bandwidth as a IG network. 2G cellphone units were generally smaller than IG units, since they emitted less radio power. Some benefits of 2G were Digital signals require consume less battery power, so it helps mobile batteries to last long. Digital coding improves the voice clarity and reduces noise in the line. Digital signals are considered environment friendly. The use of digital data service assists mobile network operators to introduce short message service over the cellular phones. Digital encryption has provided secrecy and safety to the data and voice calls. The use of 2G technology requires strong digital signals to help mobile phones work. If there is no network coverage in any specific area, digital signals would be weak. Three major systems were evolved as follows:

- 1S- 136 (D-AMPS)
- 1S- 95 (CDMA)
- Global System for Mobile (GSM)

D-AMPS: ID-AMPS is essentially a digital version of AMPS and it is backward compatible with AMPS. It uses the same bands and channels and uses the frequency reuse factor of 1/7.25 frames per second each of 1994 bits, divided in 6 slots shared by three channels. Each slot has 324 bits-159 data, 64 control, 101 error-correction as shown in Fig. 5.9. As shown in the Fig., it uses both TDMA and FDMA medium access control techniques.

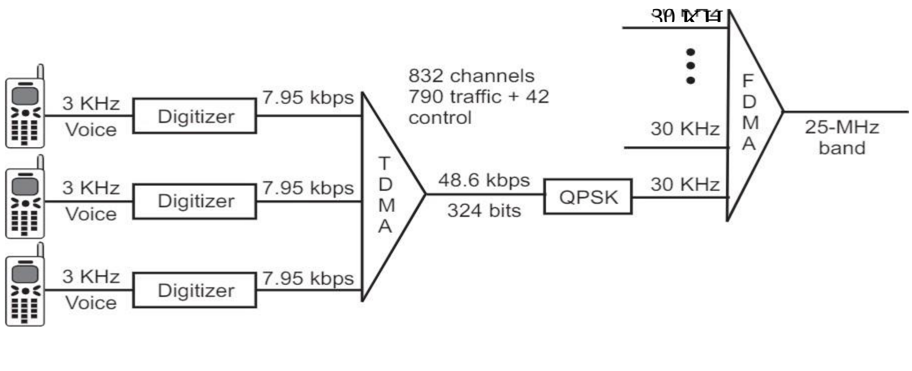

Fig. 5.9 DAMPS

IS-95 (CDMA): IS-95 is based on CDMA/DS-SS and FDMA medium access control techniques.

GSM: The Global System for Mobile (GSM) communication is a European standard developed to replace the first generation technology. Uses two bands for duplex communication.

Each voice channel is digitized and compressed to a 13Kbps digital signal. Each slot carries 156.25 bits, 8 slots are multiplexed together creating a FDM frame, 26 frames are combined to form a multiframe.

1 multiframe = 26 frames

For medium access control, GSM combines both TDMA and FDMA. There is large amount of overhead in TDMA, 114 bits are generated by adding extra bits for error correction. Because of complex error correction, it allows a reuse factor as low as 1/3.

5.7 Global System for Mobile (GSM) Communications

Most of the existing systems were operated at different frequencies and all were analog. In 1982, conference of European Posts and Telegraphs (CEPT) formed a study group named Group Special Mobile GSM to study development of a Pan European Public and Mobile Telephone System using ISDN. The responsibility of GSM was transferred to European Telecommunicators Standard Institute (ETSI) in 1989. And the Phase-I was published in 1990. GSM provided its subscriber with good quality privacy and security, it began its services in Germany in1991 and by 1993, 33 GSM networks were installed in 22 countries.

The first GSM system developed was GSM-900 (Phase 1). Now, GSM is known as Global Systems for Mobile Communications. Phase-I operates in 900 MHz band for voice only. Phase2 (introduced in 1995) which included facsimile, video and data communication services. After implementing 1800 MHz in Europe and 1900 MHz in North America in 1997, GSM-800 and GSM-1900 were created. GSM is a second generation (2G) cellular telephone system to solve the fragmentation problems inherent in IG cellular telephone system in Europe. All European countries were using different cellular telephone standards before implementing GSM. Thus, it was impossible for a subscriber to use a single telephone set throughout Europe.

GSM was the first totally digital cellular telephone system which used the services of SS7 signaling and integrated services digital network (And all digital data networks). GSM became the worlds most popular standard with 22-50 million subscribers for new cellular telephone and communication equipment.

5.7.1 GSM System Architecture

The system architecture of GSM is shown in the Fig. 5.10. It consists of three major subsystems that interact with each other and with the subscribers through specified network interfaces. The three subsystems are as follows:

- Mobile station (MS)
- Base station subsystem (BSS)
- Network and switching subsystem (NSS)

Mobile Station (MS): The MS consists of the physical equipment used by the subscriber to access a mobile network for offered telecommunication services. Functionally, the MS includes a Mobile Terminal (MT) and, depending on the services it can support, various Terminal Equipment (TE), and combinations of TE and Terminal Adaptor (TA) functions (the TA acts as a gateway between the TE and the MT). Various types of MS, such as the vehicle mounted station, portable station, or handheld station, are used.

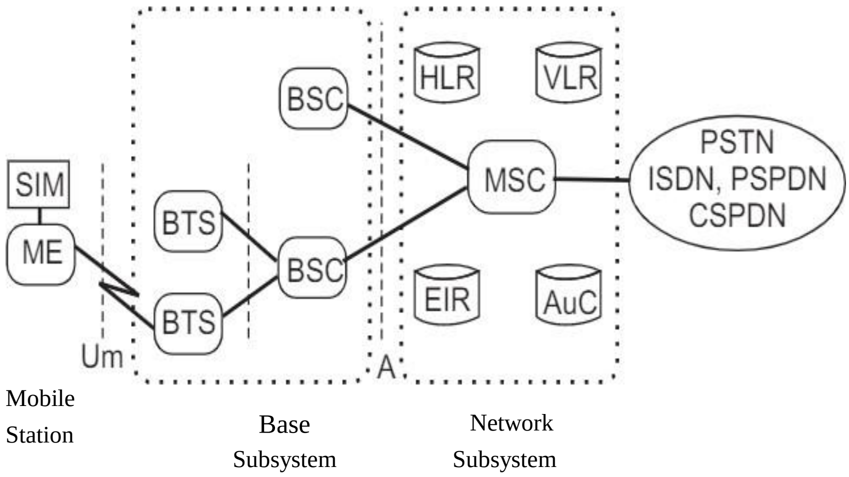

Fig. 5.10 GSM architecture

Basically, a MS can be divided into two parts. The first part is the Mobile equipment (ME) which contains the hardware and software to support radio and human interface functions. The second part contains terminal/ user- specific data in the form of a smart card known as Subscriber Identity Module (SIM), which can effectively be considered a sort of logical terminal.

The SIM card plugs into the first part of the MS and remains in for the duration of use. Without the SIM card, the MS is not associated with any user and cannot make or receive calls (except possibly an emergency call if the network allows). The SIM card is issued by the mobile service provider after subscription, while the first part of the MS would be available at retail shops to buy or rent. This type of SIM card mobility is analogous to terminal mobility, but provides a personal-mobility-like service within the GSM mobile network.

An MS has a number of identities including the International Mobile Equipment Identity (IMEI), the International Mobile Subscriber Identity (IMSI), and the ISDN number. The IMSI is stored in the SIM. The SIM card contains all the subscriber-related information stored on the users side of the radio interface.

Base Station Subsystem (BSS): The BSS is the physical equipment that provides radio coverage to prescribed geographical areas, known as the cells. It contains equipment required to communicate with the MS. Functionally, a BSS consists of a control function carried out by the base station controller (BSC) and a transmitting function performed by the BTS. The BTS is the radio transmission equipment and covers each cell. A BSS can serve several cells because it can have multiple BTSs. The BTS contains the Transcoder Rate Adapter Unit (TRAU). In TRAU, the GSM-specific speech encoding and decoding is carried out, as well as the rate adaptation function for data. In certain situations the TRAU is located at the MSC to gain an advantage of more compressed transmission between the BTS and the MSC.

Network and Switching Subsystem (NSS): The NSS includes the main switching functions of GSM, databases required for the subscribers, and mobility management. Its main role is to manage the communications between GSM and other network users. Within the NSS, the switching functions are performed by the MSC. Subscriber information relevant to provisioning of services is kept in the home location register (HLR). The other database in the NSS is the visitor location register (VLR). The MSC performs the necessary switching functions required for the MSS located in an associated geographical area, called an MSC area. The MSC monitors the mobility of its subscribers and manages necessary resources required to handle and update the location registration procedures and to carry out the handover functions. The MSC is involved in the interworking functions to communicate with other networks such as Public Switched Telephone Network (PSTN) and ISDN. The interworking functions of the MSC depend upon the type of the network to which it is connected and the type of service to be performed. The call routing and control and echo control functions are also performed by the MSC.

Home location register (HLR): The HLR is the functional unit used for management of mobile subscribers. The number of HLRs in a PLIMN varies with the characteristics of the PLMN. Two types of information are stored in the HLR: subscriber information and part of the mobile information to allow incoming calls to be routed to the MSC for the particular MS. Any administrative action by the service provider on subscriber data is performed in the HLR. The HLR stores IMSI, MS ISDN number, VLR address, and subscriber data.

Visitor Location Register (VLR): The VLR is linked to one or more MSCs. The VLR is the functional unit that dynamically stores subscriber information when the subscriber is located in the area covered by the VLR. When a roaming MS enters an MSC area, the MSC informs the associated VLR about the MS; the MS goes through a registration procedure. The registration procedure for the MS includes these activities:

- The VLR recognizes that the MS is from another MN.
- If roaming is allowed, the VLR finds the MS's HLR in its home MN.
- The VLR constructs a Global Title (GT) from the IMSI to allow signaling from the VLR to the MSs HLR via the PSTN /ISDN networks.
- The VLR generates a Mobile Subscriber Roaming Number (MSRN) that is used to route incoming calls to the MS.
- The MSRN is sent to the MS's HLR.

The information in the VLR includes MSRN, TMSI, the location area in which the MS has been registered, data related to supplementary service, MS ISDN number, IMSI, HLR address or GT, and local MS identity, if used. The NSS contains more than MSCs, HLRs, and VLRs. In order to deliver an incoming call to a GSM user, the call is first routed to a gateway switch, referred to as the Gateway Mobile Service Switching Center (GMSC). The GMSC is responsible for collecting the location information and routing the call to the MSC through which the subscriber can obtain service at that instant (i.e., the visited MSC). The GMSC first finds the right HLR from the directory number of the GSM subscriber and interrogates it. The GMSC has an interface with external networks for which it provides gateway function, as well as with the SS7 signaling network for interworking with other NSS entities.

Operation and Maintenance Subsystem (OMSS): The OMSS is responsible for handling system security based on validation of identities of various telecommunications entities. These functions are performed in the Authentication Center (AuC) and Equipment identity register (FIR).

The Auc is accessed by the HLR to determine whether an MS will be granted service. The EIR provides MS information used by the MSC. The EIR maintains a list of legitimate, fraudulent, or faulty MSS.

The OMSS is also in charge of remote operation and maintenance functions of the MN. These functions are monitored and controlled in the OMSS. The OMSS may have one or more Network Management Centers (NMCs) to centralize MN control. The Operational and Maintenance Center (OMC) is the functional entity through which the service provider monitors and controls the system. The OMC provides a single point for the maintenance personnel to maintain the entire system. One OMC can serve multiple MSCs.

5.8. Third Generation (3G) Technology

The third generation systems support high speed packet switched data (up to 2Mbps). In fact GPRS is considered to be a transition step from second generation cellular systems to third generation cellular systems.

The 3G systems are accepted world-wide and the subscriber is able to get the mobile services from anywhere in the world without replacing his handset or SIM card. The subscriber also gets the same environment and services in the visiting network as in his home network also being independent of the terminal. Apart from this, the modern generation cellular systems provide with the framework to build various kind of services (like VPN and conferencing) on the top of core cellular networks. Currently the 3G cellular systems are being evolved from the existing cellular networks. Despite the efforts of standardization, UNITS (Universal Mobile Telecommunication System) and CDMA-2000 are the two main 3G networks which are being used. Both these systems use CDMA technology. The UNITS system is being promoted by ETSI (European Telecommunication Standards Institute) and is a successor of GSM while CDMA2000 is successor of IS-95.

5.9 CDMA Technology

CDMA offers several advantages over FDMA and TDMA. Error control coding, spreading of the spectrum, soft handoffs and strict power control are some of those advantages. CDMA is primarily an air-interface and access technique that is based on direct sequence - spread spectrum (DS-SS). The air interface is significantly different in the case of CDMA compared with TDMA technique. The core fixed network infrastructure of CDMA supports the wireless interface is very similar to the structure of the GSM core network.

After 2000, third generation (3G) systems are being standardized all over the world currently by International Telecommunication Union (ITU) under the banner of International Mobile Telecommunications beyond 2000 (1MT-2000). Both IS-136 and IS-95 use CDMA as the air interface and the access method. In CDMA, all user data, the control channel and signaling information are transmitted on the same frequency at the same time. Also, CDMA employs powerful error control codes. The quality of voice is also improved and the multipath and fading problems are also reduced in CDMA technology.

Capacity of a Mobile Telecommunication System

In 1948, Claude Shannon discovered a theoretical limit on the data rate that can be achieved from any communication system. We will write it in its simplest form, as follows:

$$C = B \log_2 (1 + SINR)$$

Here, SINR is the signal to interference plus noise ratio, in other words the power at the receiver due to the required signal, divided by the power due to noise and interference. B is the bandwidth of the communication system in Hz, and C is the channel capacity in bits s^{-1}. It is theoretically possible for a communication system to send data from a transmitter to a receiver without any errors at all, provided that the data rate is less than the channel capacity. In a mobile communication system, C is the maximum data rate that one cell can handle and equals the combined data rate of all the mobiles in the cell.

$$SINR(dB) = 10 \log_{10} (SINR)$$

5.10 From Universal Mobile Telecommunication System (UMTS) To Long-Term Evolution (LTE)

(i) High Level Architecture of Long-Term Evolution (LTE)

In 2004, 3GPP began a study into the long term evolution of UNITS. The aim was to keep 3GPP's mobile communication systems competitive over timescales of 10 years and beyond, by delivering the high data rates and low latencies that future users would require. Fig.5.11 shows the resulting architecture and the way in which that architecture developed from that of UMTS.

In the new architecture, the evolved packet core (EPC) is a direct replacement for the packet switched domain of UMTS and GSM. It distributes all types of information to the user, voice as well as data, using the packet switching technologies that have traditionally been used for data alone. There is no equivalent to the circuit switched domain: instead, voice calls are transported using voice over IP. The evolved UNITS terrestrial radio access network (E-UTRAN) handles the EPC's radio communications with the mobile, so is a direct replacement for the UTRAN. The mobile is still known as the user equipment, though its internal operation is very different from before.

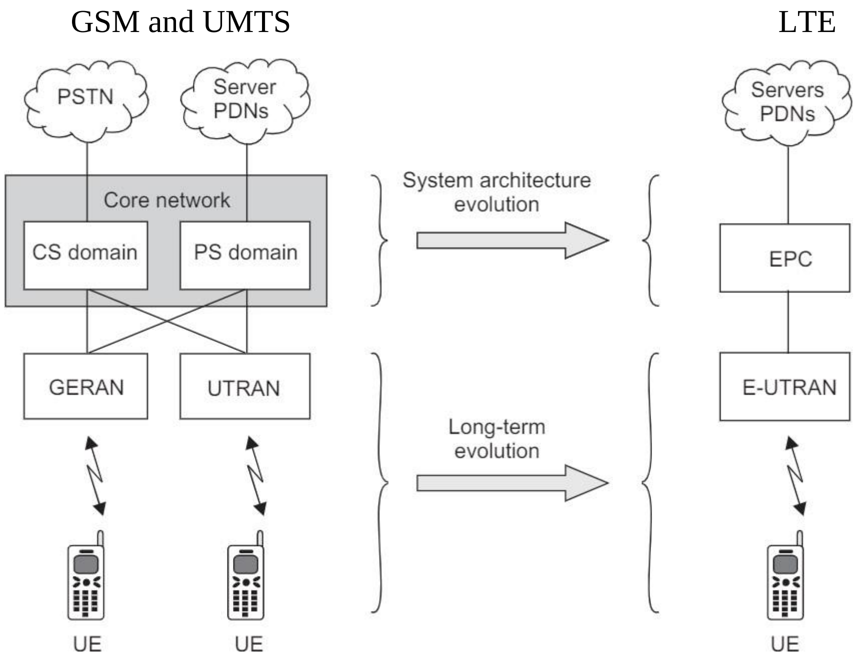

Fig. 5.11 Evolution of the system architecture from GSM and UMTS to LTE

The new architecture was designed as part of two 3GPP work items, namely system architecture evolution (SAE), which covered the core network, and long term evolution (LTE), which covered the radio access network, air interface and mobile. Officially, the whole system is known as the evolved packet system (EPS), while the acronym LTE refers only to the evolution of the air interface. Despite this official usage, LTE has become a colloquial name for the whole system, and is regularly used in this way by 3GPP.

5.11 Fourth Generation (4G) Technology

4G is short for "fourth-generation" wireless telephone technology. It is the latest technology which is started to be used in many countries. LTE or Long Term Evolution is the brand name given to the efforts of 3GPP 4th Generation technology development efforts mostly in Europe and UMB (Ultra-Mobile Broadband) is the brand name for similar efforts by 3GPP2 in North America.

The High Level requirements for a 4G technology were identified as:

- Higher spectral efficiency.
- Reduced cost per bit.
- Increased service provisioning by lowering the cost and increasing efficiency.
- Open interfaces as against closed technologies of the past.
- Power consumption efficiency.
- Scalable and flexible usage of frequency bands.

The technical specifications approved by 3GPP for the LTE project include the use of Orthogonal Frequency Division Multiplexing (OFDM) and advanced antenna technologies such as MIMO (Multiple Input Multiple Output). It specifies downlink peak speeds of 326Mbps and uplink peak speeds of 86Mbps, both in a 20 Mhz bandwidth. It also mandates the roundtrip latency between the base station and handsets to 10-milliseconds.

(i) LTE-A System Architecture

Fig. 5.12 gives a high-level description of the LTE-A network architecture. In the old GSM there were base transceiver stations (BTS), and base station controllers (BSC), and in UTRA networks. we have Node Bs and radio network controllers (RNC), and several different entities in the core network.

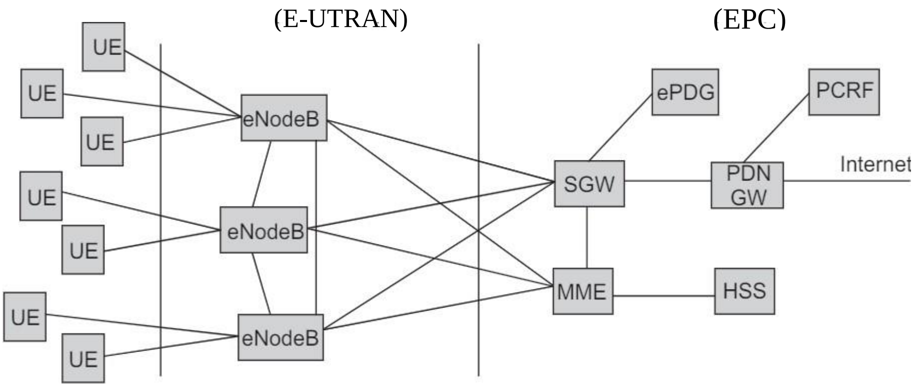

Fig.5.12 LTE system architecture

Radio Access Network   Core Network

(UTRAN)

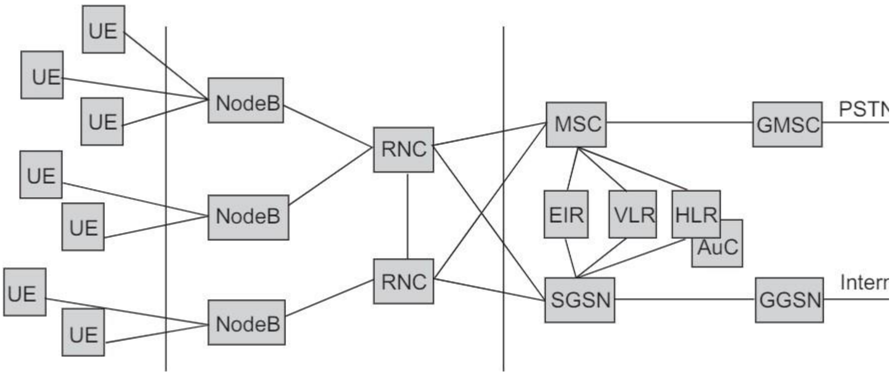

Fig. 5.13 ULTRAN system architecture

5.12Wireless LAN (WLAN)

To know about WLAN, first we need to know the definition of LAN, which is simply a way of connecting computers together within a single organization, and usually in a single site. Wireless Local Area Network (WLAN) links two or more devices using a wireless communication method. It usually provides a connection through an Access Point (AP) to the wider internet. This gives users the ability to move around within a local coverage area while still be connected to the network. Just as the mobile phone frees people to make a phone call from anywhere in their home, a WLAN permits people to use their computers anywhere in the network area. In WLAN, connectivity no longer implies attachment. Local areas are measured not in feet or meters, but miles or kilometers. An infrastructure need not be buried in the ground or hidden behind the walls, so we can move and change it at the speed of the organization.

The major standards for WLANs are IEEE 802.11 and HIPERLAN.

5.12.1 WLAN Specifications

The IEEE 802.11 specifications were developed specifically for Wireless Local Area Networks (WLANs) by the IEEE and include four subsets of Ethernet-based protocol standards: 802.11, 802.11a, 802.11b, and 802.11g.

802.11

802.11 operated in the 2.4 GHz range and was the original specification of the 802.11 IEEE standard. This specification delivered 1 to 2 Mbps using a technology known as phase-shift keying (PSK) modulation. This specification is no longer used and has largely been replaced by other forms of the 802.11 standard.

802.11a

802.1la operates in the 5 - 6 GHz range with data rates commonly in the 6 Mbps, 12 Mbps, or 24 Mbps range. Because 802.1la uses the orthogonal frequency division multiplexing (OFDM) standard, data transfer rates can be as high as 54 Mbps. OFDM breaks up fast serial information signals into several slower sub-signals that are transferred at the same time via different frequencies, providing more resistance to radio frequency interference. The 802. lla specification is also known as Wi-Fi5, and though regionally deployed, it is not a global standard like 802.11b.

802.11b

The 802.11b standard (also known as Wi-Fi) operates in the 2.4 GHz range with up to 11 Mbps data rates and is backward compatible with the 802.11 standard. 802.11b uses a technology known as complementary code keying (CCK) modulation, which allows for higher data rates with less chance of multi-path propagation interference The overall benefits include:

- Up to twice the data rate of conventional 11 Mbps 802.11b standard products.
- Greater WLAN coverage.
- Improved security over standard 802.11b.

802.11g

802.1lg is the most recent IEEE 802.11 draft standard and operates in the 2.4 GHz range with data rates as high as 54 Mbps over a limited distance.

Advantages of WLAN over Wired LAN

Installation: Wireless LANs are very easy to install. There is no requirement for wiring every workstation and every room. This ease of installation makes wireless LANs inherently flexible. If a workstation must be moved, it can be done easily and without additional wiring, cable drops or re configuration of the network.

Portability: If a company moves to a new location, the wireless system is much easier to move than ripping up all of the cables that a wired system would have snaked throughout the building.

It provide a useful complement to radio-based systems, particularly for systems requiring low cost, light weight, moderate data rates, and only requiring short ranges.

5.13 Bluetooth

Bluetooth is a standard used in links of radio of short scope, destined to replace wired connections between electronic devices like cellular telephones, Personal Digital Assistants (PDA), computers, and many other devices. Bluetooth technology can be used at home, in the office, in the car, etc. This technology allows to the users instantaneous connections of voice and information between several devices in real time. The way of transmission used assures protection against interferences and safety in the sending of information. Between the principal characteristics, must be named the hardiness, low complexity, low consume and low cost. The Bluetooth is a small microchip that operates in a band of available frequency throughout the world. Communications can realize point to point and point multipoint.

The standard Bluetooth operates in the band of 2,4 GHz. This band is available worldwide, however, the width of the band can differ in different countries.

5.13.1 Bluetooth Architecture — Piconets and Scatternets

Up to seven slaves can be active and served simultaneously by the master. If the master needs to communicate with more than seven devices, it can do so by first instructing active slave devices to switch to low-power park mode and then inviting other parked slaves to become active in the piconet. This juggling act can be repeated, which allows a master to serve a large number of slaves.

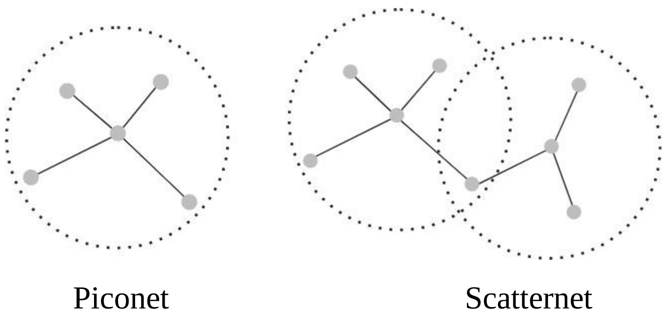

Fig. 5.14 Illustration of the concept of piconet and scatternet in bluetooth

Most envisioned Bluetooth applications involve local communication among small groups of devices. A piconet configuration consisting of two, three, or up to eight devices is ideally suited to meet the communication needs of such applications. When many groups of devices need to be active simultaneously, each group can form a separate piconet. The slave nodes in each piconet stay synchronized with the master clock and hop according to a channel-hopping sequence that is a function of the masters node address. Since channel-hopping sequences are pseudorandom, the probability of collision among piconets is small. Piconets with overlapping coverage can coexist and operate independently. None the less, when the degree of overlap is high, the performance of each piconet starts to degrade. In some usage scenarios, however, devices in different piconets may need to communicate with each other.

Bluetooth defines a structure called scatternet to facilitate interpiconet communication. A scatternet is formed by interconnecting multiple piconets.

5.14 Introduction – Satellite communication

The outer space has always fascinated people on the earth and communication through space evolved as an offshoot of ideas for space travel. In the area of satellite communications, the technology has been responsive to the imaginative dreams. Hence it is also expected that technological innovations will lead the evolution of satellite communications towards the visions of today. Satellites are specifically made for telecommunication purpose. They are used for mobile applications such as communication to ships, vehicles, planes, hand-held terminals and for TV and radio broadcasting. Satellites orbit around the earth Fig. 5.15. Depending on the application, these orbits can be circular or elliptical. Satellites in circular orbits always keep the same distance to the earth's surface.

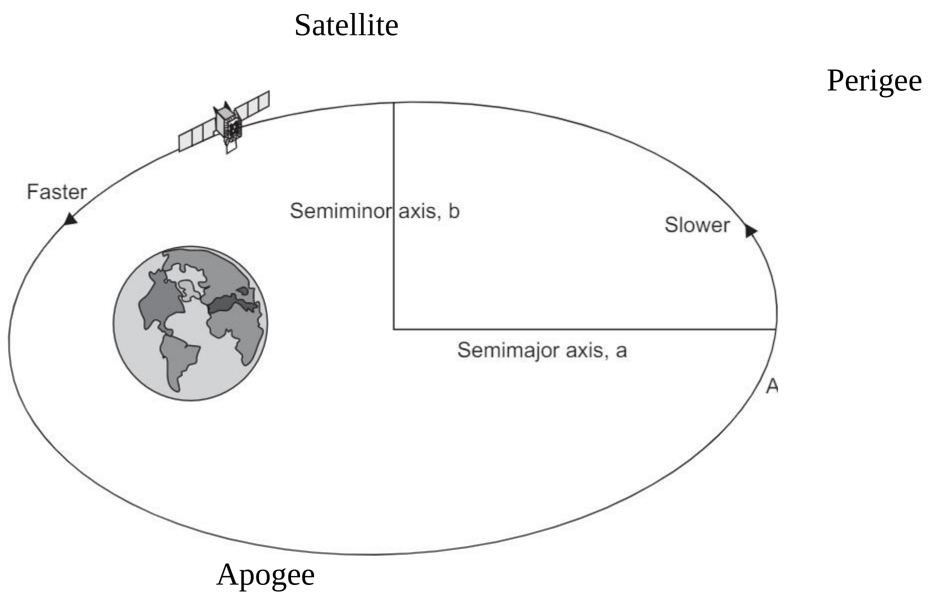

Fig. 5.15 Satellite orbit around the Earth

10,000 to 16,000 km above the Earth. The advantages of MEO are that they require smaller constellation than LEOs and provide opportunity for near-world-wide converge. However, the disadvantages of MEO are that they require tracking terminals, they operate in harsh space radiation environment like Van Allen belts, and they constitute a larger constellation than geostationary-orbit (GEO) satellites. MEO satellites use some civilian satellites of Globalstar and public satellites of the global positioning system (GPS).

GEOs are the most commonly used satellites. They are placed at 35,786 km above the Earth. Notable advantages of GEO satellites are that they are quasi-stationary (and do not require tracking terminals), they provide broad coverage areas, and they enable one to build a constellation over time. The disadvantages of GEO satellites are that they provide longer latency (e.g., 240 ms per round trip), their launch costs are higher than LEO and MEO satellites, and they provide no polar coverage. In addition, they contribute to orbit congestion over time, and they must maintain required spacing among themselves. Primary users of GEO are commercial communications satellites such as Intelsat and Eutelsat, and military communications satellites such as Wideband Global SATCOM (WCS) and Defense Satellite Communications System (DSCS) satellites.

Finally, there are highly elliptical-orbit (HEO) satellites. Their orbits are characterized with perigees of per aps 500 km and apogees up to 40,000 km above the Earth. The advantages of using HEO satellites are that they provides specialized coverages (e.g., the polar area) and that they can provide long coverage times with small constellations. The disadvantage of using HEO satellites are that they normally serve one hemisphere only, and they require tracking terminals. HEO satellites are employed primarily for surveillance systems, and some polar augmentation is provided by the Russian Molniya satellites.

5.15 Elements of Satellite Communication

The basic elements of a satellite communication system are shown in the Fig. 5.16. Basic elements are:

User. The user generates the baseband signal that proceeds through a terrestrial network and transmitted to a satellite at the earth station.

Satellite: The satellite consists of a large number of repeaters in the space that perform the reception of modulated RF carrier in its uplink frequency spectrum from all the earth stations in the present networks, amplifiers. They retransmit them back to the earth stations in the down link frequency spectrum. To avoid interference, downlink and uplink frequency spectrums should be separate and different.

Terrestrial network: This is a network on the ground which carries the signal from user to earth station. It can be a telephone switch or a dedicated link between the user and the earth station.
Earth Station: Its a radio station located on the earth and used for relaying signals from satellites. It governs all the activities and transmissions happening in the satellite communication.

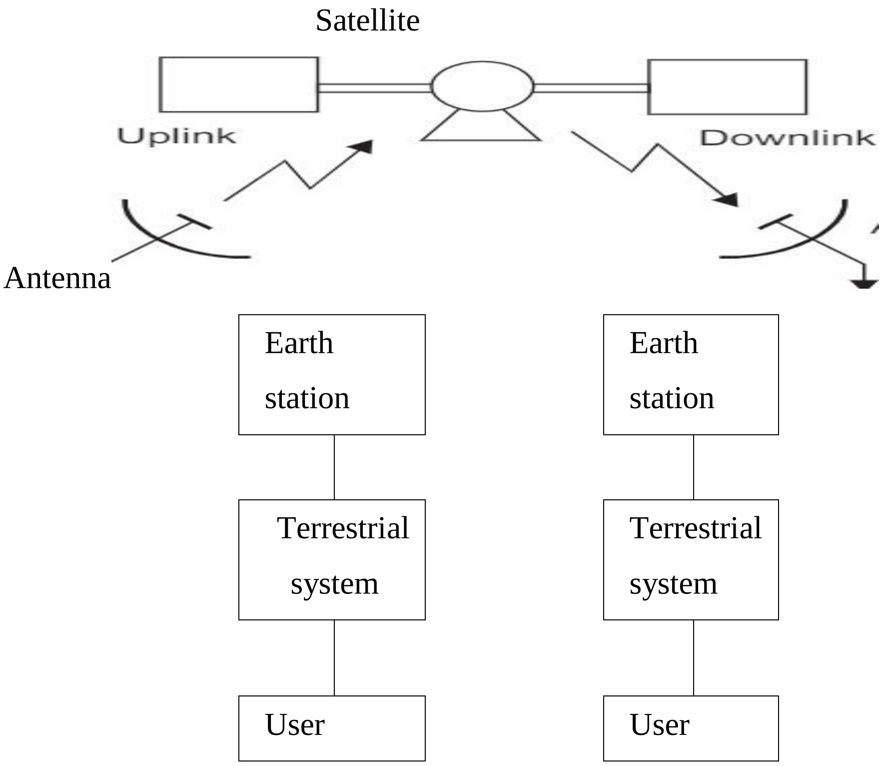

Fig. 5.16 Basic elements of a satellite communication system

5.16 Types of Satellites (Based On Orbits)

5.16.1 Geostationary Earth Orbit (GEO) Satellites

GEO satellites are synchronous with respect to earth. Looking from a fixed point from Earth, these satellites appear to be stationary. These satellites are placed in the space in such a way that only three satellites are sufficient to provide connection throughout the surface of the Earth. The orbit of these satellites is circular. There are three conditions which lead to geostationary satellites. Lifetime expectancy of these satellites is 15 years.

- The satellite should be placed 37,786 kms (approximated to 36,000 kms) above the surface of the earth.
- These satellites must travel in the rotational speed of earth, and in the direction of motion of earth, that is eastward.

- The inclination of satellite with respect to earth must be 00.

Geostationary satellite in practical is termed as geosynchronous as there are multiple factors which make these satellites shift from the ideal geostationary condition.

- Gravitational pull of sun and moon makes these satellites deviate from their orbit. Over the period of time, they go through a drag. (Earth's gravitational force has no effect on these satellites due to their distance from the surface of the Earth.)
- These satellites experience the centrifugal force due to the rotation of Earth, making them deviate from their orbit.
- The non-circular shape of the earth leads to continuous adjustment of speed of satellite from the earth station.

These satellites are used for TV and radio broadcast, weather forecast and also, these satellites are operating as backbones for the telephone networks.

5.16.2 Low Earth Orbit (LEO) Satellites

These satellites are placed 500-1500 kms above the surface of the earth. As LEO satellites circulate on a lower orbit, hence they exhibit a much shorter period that is 95 to 120 minutes. LEO systems try to ensure a high elevation for every spot on earth to provide a high quality communication link. Each LEO satellite will only be visible from the earth for around ten minutes.

Using advanced compression schemes, transmission rates of about 2,400 bit/ s can be enough for voice communication. LEOs even provide this bandwidth for mobile terminals with omnidirectional antennas using low transmit power in the range of 1W. The delay for packets delivered via a LEO is relatively low. Smaller footprints of LEOs allow for better frequency reuse, similar to the concepts used for cellular networks. LEOs can provide a much higher elevation in polar regions and better global coverage.

These satellites are mainly used in remote sensing and mobile communication services (due to lower latency).

Disadvantages:

- The biggest problem of the LEO concept is the need for many satellites if global coverage is to be reached.
- Several concepts involve 50—200 or even more satellites in orbit. The high number of satellites combined with the fast movements resulting in a high complexity of the whole satellite system.

- The short time of visibility with a high elevation requires additional mechanisms for connection handover between different satellites.
- One general problem of LEOs is the short lifetime of about five to eight years due to atmospheric drag and radiation.
- Other factors are the need for routing of data packets from satellite to if a user wants to communicate around the world.

5.16.3 Medium Earth Orbit (MEO) Satellites

MEO satellites can be positioned somewhere between LEOs and GEOs, both in terms of their orbit and due to their advantages and disadvantages. Using orbits around 10,000 km, the system only requires a dozen satellites which is more than a GEO system, but much less than a LEO system. These satellites move more slowly relative to the Earth's rotation allowing a simpler system design (satellite periods are about six hours). Depending on the inclination, a MEO can cover larger populations, so requiring fewer handovers.

Disadvantages:

- Due to the larger distance to the earth, delay increases to about 70—80 ms.
- These satellites need higher transmit power and special antennas for smaller footprints.

5.17 A Fiber-Optic Communication System

A generalized configuration of a fiber-optic communication system is shown in Fig.5.17. A brief description of each block in this Fig. will give us an idea of the prime components employed in this system.

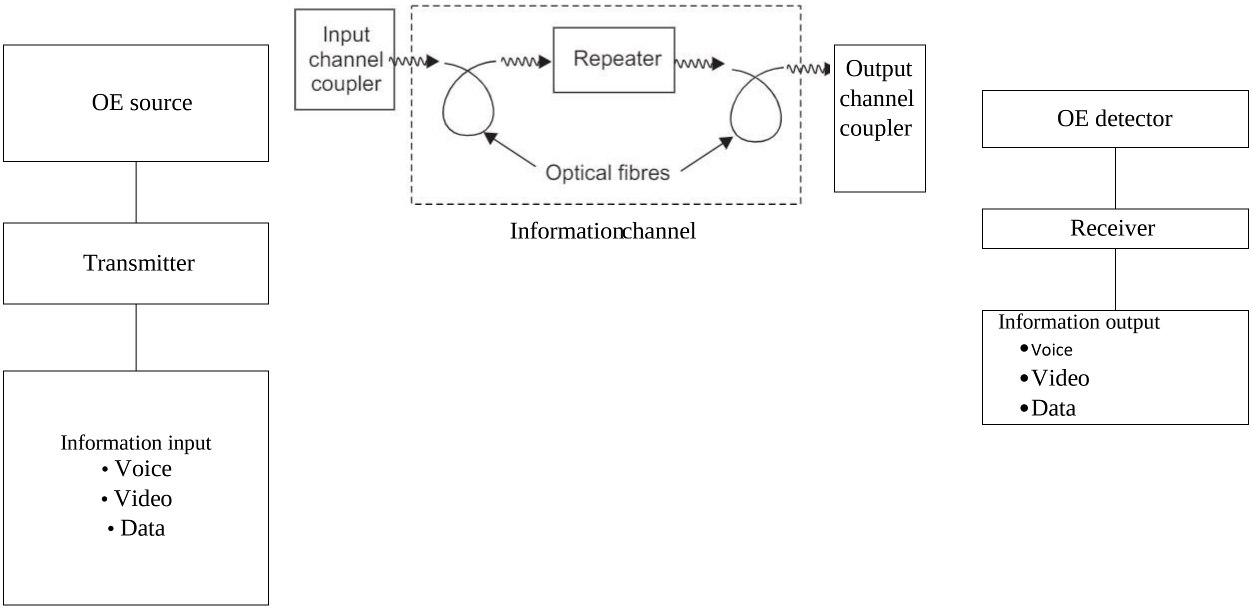

Fig. 5.17 Generalized configuration of a fiber-optic communication system

5.17.1 Information Input

The information input may be in any of the several physical forms, e.g., voice, video, or data. Therefore an input transducer is required for converting the non-electrical input into an electrical input. For example, a microphone converts a sound signal into an electrical current, a video camera converts an image into an electric current or voltage, and so on. In situations where the fiber-optic link forms a part of a larger system, the information input is normally in electrical form. Examples of this type include data transfer between different computers or that between different parts of the same computer. In either case, the information input must be in the electrical form for onward transmission through the fiber-optic link.

5.17.2 Transmitter

The transmitter (or the modulator, as it is often called) comprises an electronic stage which (i) converts the electric signal into the proper form and (ii) impresses this signal onto the electromagnetic wave (carrier) generated by the optoelectronic source.

The modulation of an optical carrier may be achieved by employing either an analog or a digital signal. An analog signal varies continuously and reproduces the form of the original information input, whereas digital modulation involves obtaining information in the discrete form. In the latter, the signal is either on or off, with the on state representing a digital 1 and the off state representing a digital 0. These are called binary digits (or bits) of the digital system.

The number of bits per second (bps) transmitted is called the data rate. If the information input is in the analog form, it may be obtained in the digital form by employing an analog-to-digital converter.

Analog modulation is much simpler to implement but requires higher signal-to-noise ratio at the receiver end as compared to digital modulation. Further, the linearity needed for analog modulation is not always provided by the optical source, particularly at high modulation frequencies. Therefore, analog fiber-optic systems are limited to shorter distances and lower bandwidths.

5.17.3 Optoelectronic Source

An optoelectronic (OE) source generates an electromagnetic wave in the optical range (particularly the near-infrared part of the spectrum), which serves as an information carrier.

Common sources for fiber-optic communication are the light-emitting diode (LED) and the injection laser diode (ILL)). Ideally, an optoelectronic source should generate a stable single frequency electromagnetic wave with enough power for long-haul transmission. However, in practice, LEDs and even laser diodes emit a range of frequencies and limited power. The favorable properties of these sources are that they are compact, lightweight, consume moderate amounts of power, and are relatively easy to modulate. Furthermore, LEDs and laser diodes which emit frequencies that are less attenuated while propagating through optical fibers are available.

5.17.4 Channel Couplers

In the case of open channel transmission, for example, the radio or television broadcasting system, the channel coupler is an antenna. It collects the signal from the transmitter and directs this to the atmospheric channel. At the receiver end again the antenna collects the signal and routes it to the receiver. In the case of guided channel transmission, e.g., a telephone link, the coupler is simply a connector for attaching the transmitter to the cable.

In fiber-optic systems, the function of a coupler is to collect the light signal from the optoelectronic source and send it efficiently to the optical fiber cable. Several designs are possible. However, the coupling losses are large owing to Fresnel reflection and limited light gathering capacity of such couplers. At the end of the link again amplifier is required to collect the signal and direct it onto the photo detector.

5.17.5 Fiber-optic Information Channel

In communication systems, the term 'information channel' refers to the path between the transmitter and the receiver. In fiber-optic systems, the optical signal traverses along the cable consisting of a single fiber or a bundle of optical fibers. An optical fiber is an extremely thin strand of ultra-pure glass designed to transmit optical signals from the optoelectronic source to the optoelectronic detector. In its simplest form, it consists of two main regions: (i) a solid cylindrical region of diameter 8-100 um Called the core and (ii) a coaxial cylindrical region of diameter normally 125 um called the cladding. The refractive index of the core is kept greater than that of the cladding. This feature makes light travel through this structure by the phenomenon of total internal reflection. In order to give strength to the optical fiber, it is given a primary or buffer coating of plastic, and then a cable is made of several such fibers. This optical fiber cable serves as an information channel.

For clarity of the transmitted information, it is required that the information channel should have low attenuation for the frequencies being transmitted through it and a large light-gathering capacity. Furthermore, the cable should have low dispersion in both the time and frequency domains, because high dispersion results in the distortion of the propagating signal.

5.17.6 Repeater

As the optical signals propagate along the length of the fiber, they get attenuated due to absorption, scattering, etc., and broadened due to dispersion. After a certain length, the cumulative effect of attenuation and dispersion causes the signals to become weak and indistinguishable. Therefore, before this happens, the strength and shape of the signal must be restored. This can be done by using either a regenerator or an optical amplifier, e.g., an erbium doped fiber amplifier (EDFA), at an appropriate point along the length of the fiber.

5.17.7 Optoelectronic Detector

The reconversion of an optical signal into an electrical signal takes place at the OE detector. Semiconductor p-i-n or avalanche photodiodes are employed for this purpose. The photocurrent developed by these detectors is normally proportional to the incident optical power and hence to the information input. The desirable characteristics of a detector include small size, low power consumption, linearity, flat spectral response, fast response to optical signals, and long operating life.

5.17.8 Receiver

For analog transmission, the output photocurrent of the detector is filtered to remove the dc bias that is normally applied to the signal in the modulator module, and also to block any other undesired frequencies accompanying the signal. After filtering, the photocurrent is amplified if needed. These two functions are performed by the receiver module.

For digital transmission, in addition to the filter and amplifier, the receiver may include decision circuits. If the original information is in analog form, a digital-to-analog converter may also be required.

The design of the receiver is aimed at achieving high sensitivity and low distortion. The signal-to-noise ratio (SNR) and bit-error rate (BER) for digital transmission are important factors for quality communication.

5.17.9 Information Output

Finally, the information must be presented in a form that can be interpreted by a human observer. For example, it may be required to transform the electrical output into a sound wave or a visual image. Suitable output transducers are required for achieving this transformation. In some cases, the electrical output of the receiver is directly usable. This situation arises when a fiber-optic system forms the link between different computers or other machines.

5.18 Introduction on 'Microwaves

'Microwaves' is a descriptive term finds its origin in the frequencies used for its communication. The term microwaves used to identify em waves in the frequency spectrum ranging approximately from 1 GHz (10^9 Hz) to 30 GHz. This corresponds to wavelengths from 30 cm to 1 cm. Sometimes higher frequencies (extending upto 600 GHz) are also called microwaves. These waves present several interesting and unusual features not found in other portions of em frequency spectrum. These features make 'microwaves' uniquely suitable for several useful applications.

A significant advantage associated with the use of microwaves for communications is their large bandwidth. A 10% bandwidth at 3 GHz implies availability of 30 MHz spectrum. This means all the radio, television and other communications that are transmitted in the frequency spectrum from DC to 300 MHz can be accommodated in a 10% bandwidth around 3 GHz. Since the lower frequency part of the radio spectrum is getting crowded, there is a trend to use more and more of microwave region (and beyond) for various different services. The high frequencies used in the microwave communication environment makes it very different compared to the low frequency communications. They differ in the types of equipment available and the approach to the circuitry and systems. They also differ from other radio applications in the use of antennas, which are highly directional with the microwave systems. Small antenna size and the property of reflection of microwave from metallic surfaces make it practical to operate radar systems at these frequencies.

At such high frequencies of operation, it is possible to focus the radio energy concentrated into a beam, with a much less bandwidth compared to low-frequency communication systems. There are other advantages associated with the small wavelengths at microwave frequencies. Unlike lower radio frequencies, these waves are not reflected and practically not absorbed by the ionosphere. Another reason for the microwaves to operate as such a high frequency is the availability of the spectrum in that range. The low frequency spectrum is generally used for omni directional (all directions) broad coverage systems and is not generally available (only low tens of kHz is licensed). Omni directional coverage systems generally include a transmitting antenna, which broadcasts in all directions. Cellular technology is one such system in which the base station, especially in center-excited systems, transmits in all directions. Since the transmission is not aimed at a single stationary mobile, cellular technology requires omni directional coverage. On the other hand, microwave communication is inherently a point-to point system, so it falls under the category of a highly directional communication system. At higher frequencies, frequency bandwidths of orders of MHz are available and thus one can efficiently handle large quantities of data, video and voice.

Microwave techniques are now being introduced in fast computer operations. Pulses with very small widths are used in high speed logic circuits. When the pulse width lies in the subnanosecond range, the major portion of the pulse spectrum is in the microwave region.

Microwaves are extensively used for information relay systems in communication, especially for line-of-sight transmission systems. They also find application in RADAR. The most common use of the microwave systems is to communicate over rough or inaccessible terrain. Besides their most common use in RADAR systems and point-to-point radio communications, microwaves are applied extensively in Research laboratories servicing microwave test equipment and components e.g., microwave oven which typically operates at 2.45 GHz. The study of microwave resonances in molecules has led to several useful devices e.g., non-reciprocal devices employing ferrites, solid state microwave amplifiers and oscillators called masers.

Microwave communication systems cover distances ranging from 15 miles to 4000 miles. Microwave can be categorized as short haul for intrastate communication and long haul for interstate communication systems. The channel capacity may range from 12 channels to as many as 22000 channels depending on the requirement. Traditional microwave systems used frequency division multiplexed channels for voice and employed non-coherent frequency modulation techniques. However, the recent advanced systems use pulse code modulated time division multiplexed voice channels. They generally use advanced modulation techniques such as phase shift keying (PSK) or quadrature amplitude modulation (QAM).

5.19 Microwave Communications

Microwave communications are widely used for telephone networks, in broad cast and television systems and several other communication application by services, railways, etc.

5.19.1 Frequency Modulated Microwave Communication System

FM microwave systems, when equipped with suitable multiplexing technology are capable of carrying hundreds of voice and data channels. In addition to point-to-point communications. the FM microwave systems can also be extended to broadcasting television audio signals.

The baseband input signal can be anything from a FDM voice channel to a TDM channel or from a composite video signal to a wideband data signal. The baseband signal is first applied to the pre emphasis network that, in general, provides extra amplification to high frequency baseband signals. When the signal coming out of the pre emphasis circuit is applied to the FM modulator, the low frequencies get frequency modulated by the Intermediate Frequency (IF) carrier and the high frequencies get phase modulated. This ensures a more uniform SNR (signal to noise ratio) throughout the frequency range. The IF frequencies are generally in the range of 60-80 MHz. The modulated output from the FM deviator is passed through the IF amplifier to the mixer. The mixer then converts the signal to microwave frequencies. Using the mixer instead of the multiplier preserves the modulation index and also limits the bandwidth. The output of the mixer is passed through the band pass filter to band limit the signal and then to the channel-combining network. Finally, the signal is fed to the transmitter antenna.

Fig. 5.18 shows the simplified transmitter block diagram of a microwave FM transmitter.

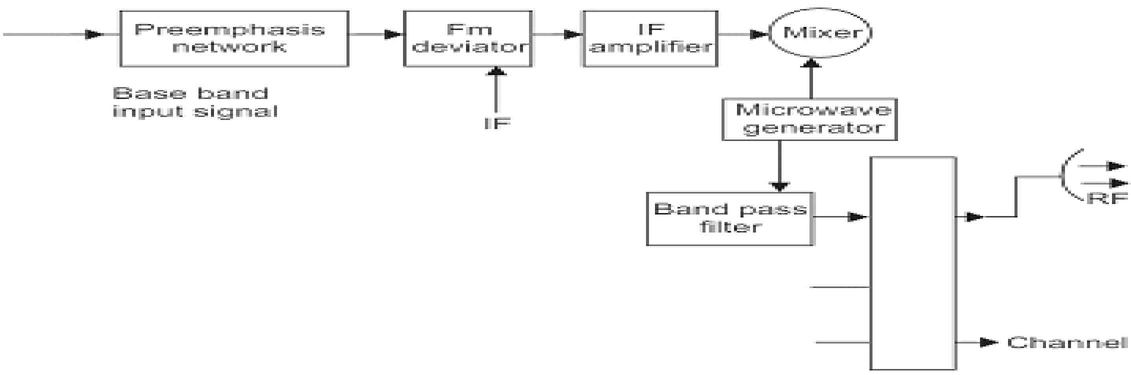

Fig. 5.18 Block diagram of FM transmitter

Fig. 5.19 shows the need for repeaters and how a virtual line of sight is maintained between the transmitter and the receiver using repeaters.

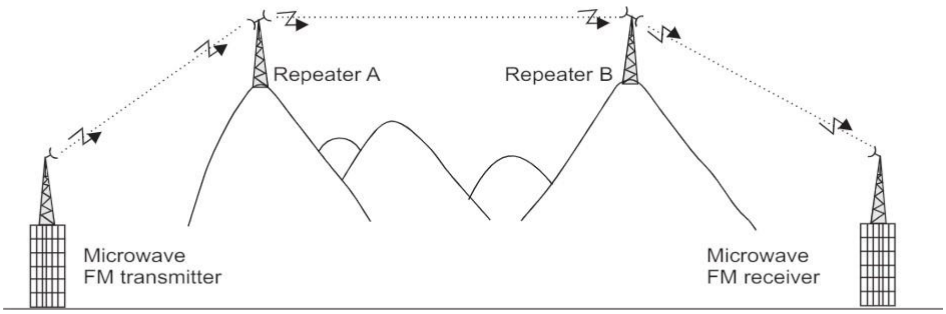

Fig. 5.19 Virtual line of sight for microwave FM transmission using Repeaters

If the distance between the transmitter and the receiver is less than the maximum distance that ensures the reliable reception of the FM signal, then the communication system does not need any other intermediate station. However, there should be a line of sight path maintained for reliable transmission and reception. If either if there two conditions is not met, then the system needs intermediate stations that can receive the signal, process it (possibly amplify) and retransmit the signals. These intermediate stations are called the repeaters, since their objective is to repeat the signal that they receive (possibly with some amplification) in the direction of the next repeater or the receiver. In Fig. 5.19, the transmitter and the receiver are not in direct line of sight with each other due to the obstructive intermediate terrain (which is caused by the mountains). However, by appropriately placing the repeaters, a virtual line of sight is achieved along the path transmitter-repeater A-repeater B-receiver.

In Fig. 5.20, the RF signal picked by the receiving antenna is passed to the channel separation network, which separates the individual channels. The bandpass filter then filters out any frequencies that fall outside the bandwidth of the required signal. The mixer employs the same RF oscillator frequency as used at the transmitter and converts the RF signal to the IF band. The FM detector demodulates the signal which is then passed to the de emphasis network. The de-emphasis network applies inverse functionality of the pre-emphasis network at the transmitting end, to finally restoring the original baseband signal. Fig. 5.20 shows the microwave FM receiver block diagram.

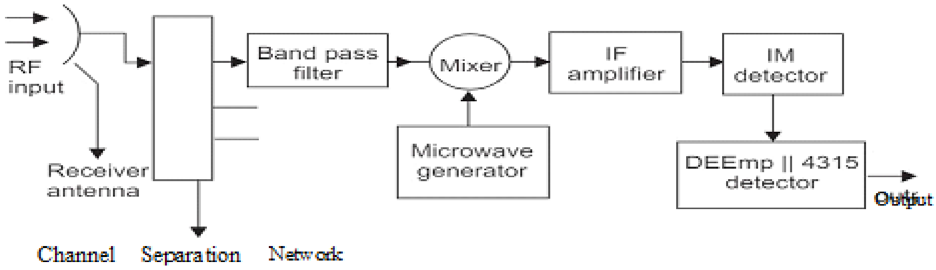

Fig. 5.20 Block diagram of FM receiver