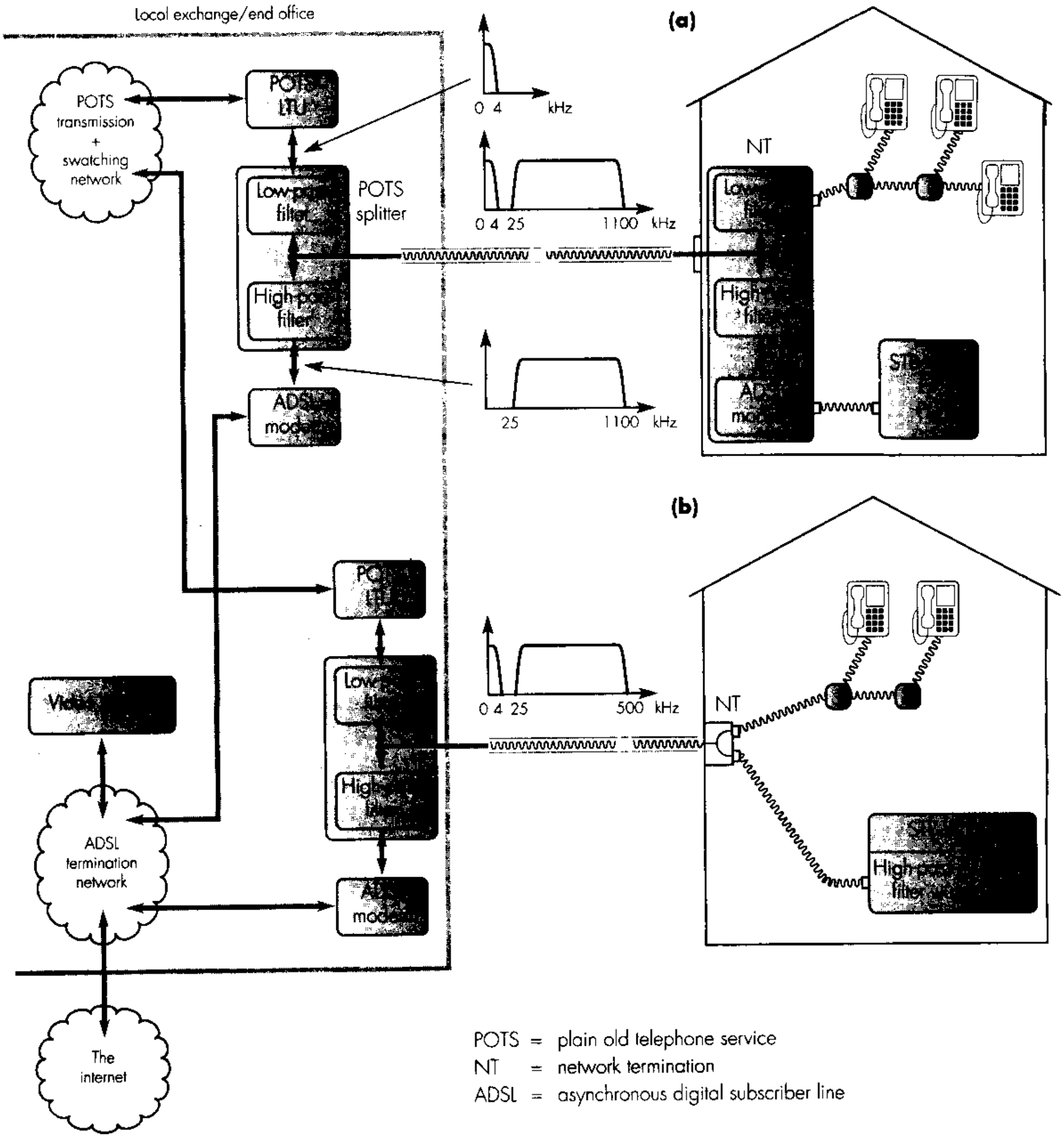


Figure 11.23 Connection alternatives: (a) ADSL with active NT; (b) ADSL-Lite with passive NT.

As we can see in part (a), with an ADSL installation the network termination (NT) at each customer premises is the same as that used in the LE/EO. This comprises an electrical circuit known as a **POTS splitter** and its role is to separate out the POTS and ADSL signals. This is done by means of two filters, a low-pass filter from 0–4 kHz that passes only the POTS signal and a high-pass filter from 25 kHz–1.1 MHz that passes only the forward and return ADSL signals. As we can see, having separated out the POTS signal, the existing customer wiring and connection sockets can be used to connect telephones to the NT. In the case of the ADSL signals, normally the ADSL modem is located within the NT and new wiring is used to connect the customer equipment to the NT. This can be a PC or the TV set-top box depending on the service that is being provided. Alternatively, the ADSL modem can be located within the customer equipment and the latter is then connected directly to the output of the high-pass filter.

As we can see in part (b), with an ADSL-Lite installation the existing (passive) NT and twisted-pair wiring is used. The telephone handsets are attached directly to this as they are responsive only to the low-frequency speech signal. The equipment using the ADSL-Lite line – typically a PC for Internet access – can also be attached to this same wiring. Integrated within the equipment (PC), however, is a high-pass filter and the ADSL-Lite modem. The advantage of this approach is the much simplified NT as it avoids the use of a POTS splitter and filters. Also, the existing wiring and sockets can be used to provide access to both services. To use the fast-access Internet service, the customer simply purchases and installs the line-termination board containing the high-pass filter and ADSL-Lite modem into the PC and informs the telco that they wish to use the fast-access Internet service. The telco then connects the customer line to the newer NT equipment at the LE/EO to provide this service without the need to install any new wiring or visit the customer premises.

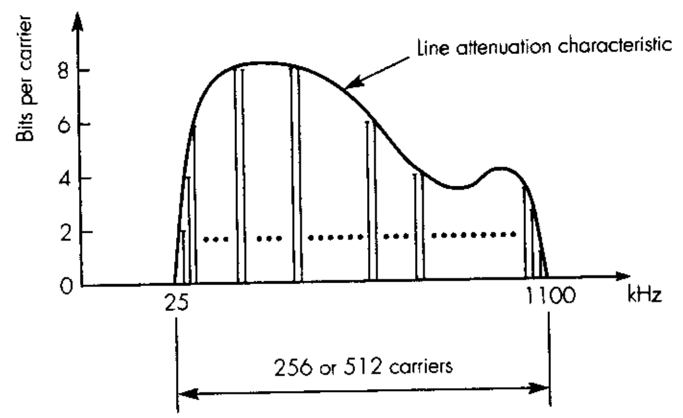
The disadvantage of this approach is that, in some instances, since the ADSL-Lite signal is carried over the whole in-house wiring, some interference can be experienced with the basic telephony service when the high bit rate service is being used concurrently. The main cause of the interference arises from the higher-frequency components in the ADSL-Lite signal being down-converted by some telephony handsets into speech-frequency signals and hence heard. This is one of the reasons why the upper frequency used with ADSL-Lite is limited to 500 kHz. In addition, if the existing in-house wiring is poor, then interference may also arise owing to external effects such as radio broadcasts. So in instances where interference is obtained, it is often necessary to install a low-pass filter into the sockets to which telephones are connected.

Modulation method

In the ANSI T1.413 standard, the modulation method used with ADSL modems is called **discrete multitone** (**DMT**). In practice this operates in the same way as COFDM. As we saw earlier in Section 11.4.2, with COFDM the bitstream to be transmitted is divided into fixed-length blocks. The bits in each block are then transmitted using multiple carriers each of which is separately modulated by one or more bits from the block. With this application, the number of carriers is either 256 or 512. However, as we show in Figure 11.24(a), those carriers that lie in the lower part of the frequency spectrum that are reserved for telephony are not used. Also, because with twisted-pair wire the level of attenuation associated with each carrier increases as a function of frequency, a non-linear allocation of bits per carrier is used. Typically, the lower-frequency carriers are modulated using multiple bits per carrier – for example 8-QAM – and the higher-frequency carriers use progressively fewer bits down to 1 bit (PSK), the number of bits per carrier being chosen so that optimum use is made of each carrier.

In addition, because of the relatively high levels of noise present on the lines – caused by the various telephony functions such as ringing, radio frequency signals from other lines, and lightning effects – in order to improve the raw bit error rate (BER) probability of each line, a forward error correction (FEC) scheme similar to that used with satellite and (and terrestrial) broadcast channels is used. As we saw earlier in Section 11.3.2, this involves the bitstream to be transmitted being segmented into 188-byte blocks each of which has 16 FEC bytes appended to it. Byte interleaving is then used to overcome longer noise bursts, the principles of which we showed in Figure 11.18(a) and (b).

(a)



(b)

Upstream: frequency band = 25–200 kHz, bit rate = 32–384/1000 kbps
Downstream: frequency band = 250–1100 kHz, bit rate = 640–1500/8000 kbps

Figure 11.24 Example DMT frequency usage: (a) bits per carrier allocation, (b) duplex frequency usage.

Duplex transmission

The ADSL baseband signal comprises a duplex bitstream of up to 8 Mbps in the downstream direction and up to 1 Mbps in the return direction. In the case of ADSL-Lite the bit rates are up to 1.5 Mbps downstream and up to 384 kbps upstream. In both cases, however, since a single twisted-pair line is used, a scheme must be employed to enable both bitstreams to be transmitted over the line simultaneously. In the case of both ADSL variants this is achieved using a technique known as **frequency division duplex (FDD)**. With this the bitstream in each direction is transmitted concurrently using a different portion of the allocated bandwidth and hence set of carriers. An example set of frequencies is given in Figure 11.24(b).

11.5.2 VDSL

Very-high-speed digital subscriber line (VDSL) is the most recent technology for providing high bit rates over existing unshielded twisted-pair access lines. It is intended for use over the twisted-pair section of fiber-to-the-kerb/curb installations with the VDSL modem located in the same cabinet as the ONU. As we saw in Figure 11.22, the maximum length of the twisted-pair section is set at 300 yards/meters and hence higher bit rates than those with ADSL can be achieved. Bit rates can be up to 20 Mbps in each direction when used in a symmetric configuration or up to 52 Mbps in an asymmetric configuration with a return path of up to 1.5 Mbps.

The technical details of VDSL are currently being decided but the modulation scheme is likely to be DMT. As we saw earlier, it is intended that the higher bit rate service should share the use of the access line with both POTS and basic rate ISDN. Hence the amount of bandwidth available for the higher bit rate service is less than that of an equivalent ADSL configuration.

The duplexing method is likely to be based on **time-division duplexing (TDD)**. Using TDD, instead of both the downstream and upstream signals being transmitted simultaneously by allocating each signal its own portion of the line bandwidth – as is the case with FDD – alternate time intervals are allocated for each direction of transmission. This approach means that the duration of each time interval can be varied to meet the particular configuration required. Also, since the whole of the usable frequency spectrum is used in both directions, filters are not required. As with ADSL, an active network termination is used in the customer premises.

Summary

In this chapter we have studied the principle of operation of the different types of broadcast television networks – cable, satellite, and terrestrial – and how digital TV and interactive services are provided with each of these networks. We have also looked at selected aspects of the technology associated with the high-speed modems that are used with the access networks of a PSTN to deliver high-speed Internet access and other services such as video-on-demand. The topics relating to the different types of broadcast television networks are summarized in Figure 11.25(a) and those relating to high-speed PSTN modems in Figure 11.25(b).

In the case of the different types of broadcast TV networks, first we considered the principle of operation of each network type and then proceeded to study how digital TV is supported and how interactive services are provided. As we saw, with cable networks interactive services are provided using cable modems while with satellite and terrestrial broadcast networks they utilize a separate return channel from, say, a PSTN or an ISDN. We then considered the principles behind the different types of digital subscriber line (DSL) technologies that are used in the high-speed PSTN modems to obtain high bit rates over the unshielded twisted-pair (UTP) lines in the access network. As we saw, these include asymmetric DSL (ADSL), ADSL-Lite, and very-high-speed DSL (VDSL).

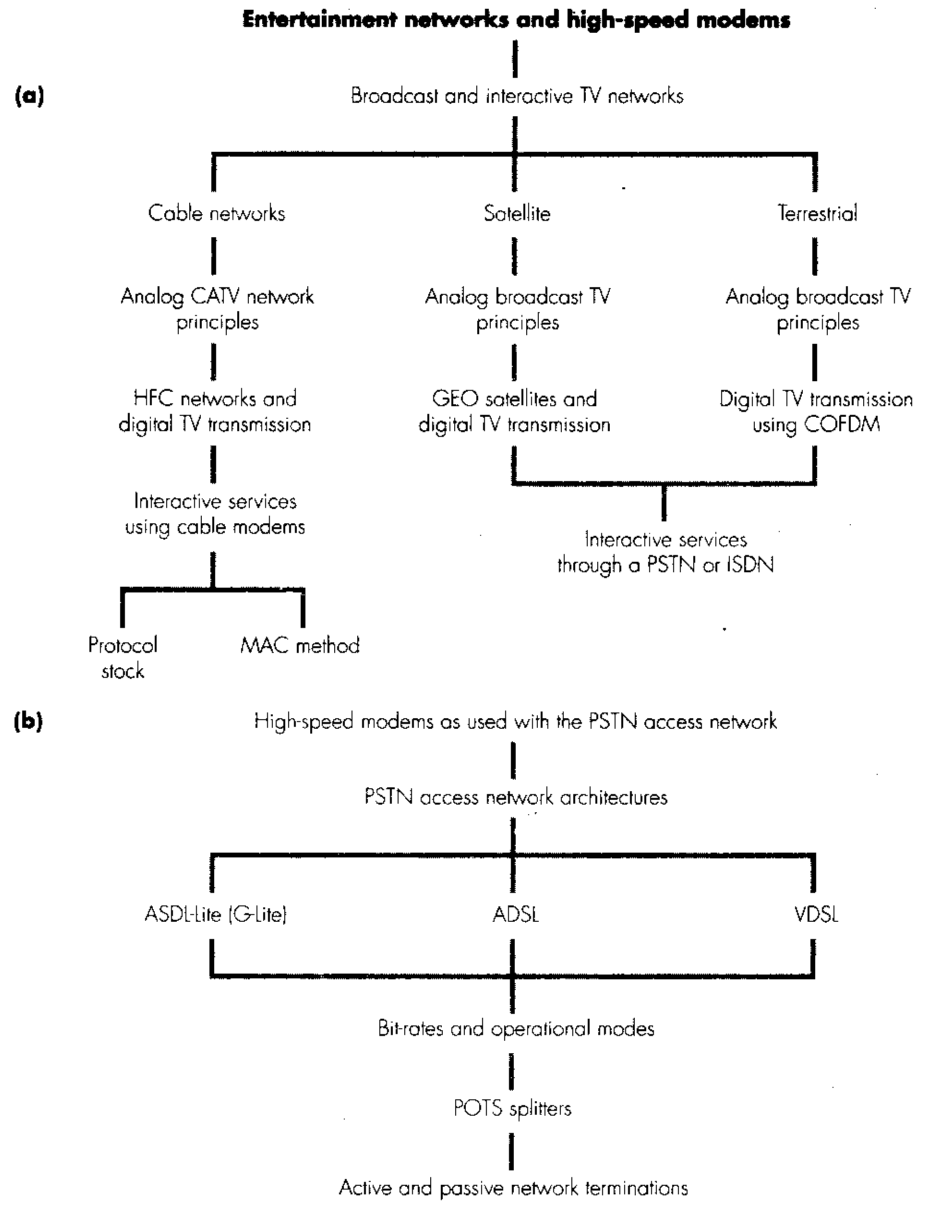


Figure 11.25 Entertainment networks and high-speed modems: (a) broadcast and interactive TV networks; (b) high-speed modems for use with the PSTN access network.

Exercises

Section 11.1

11.1 List the bit rate requirements for the (compressed) audio and video associated with the following entertainment applications:
(i) movie/video-on-demand,
(ii) interactive television.
State the reason why a return channel is needed with these applications and hence the bit rate of this.

11.2 State the minimum bit rate requirements of a high-speed modem that provides an asymmetric channel over PSTN access lines to support
(i) VCR-quality and
(ii) broadcast quality movie/video-on-demand.
Give another application for this type of channel.

Section 11.2

11.3 With the aid of the schematic diagram of a CATV distribution network shown in Figure 11.1, explain the meaning/use of the following:
(i) cable headend,
(ii) trunk and distribution coax,
(iii) trunk and distribution amplifiers,
(iv) trunk splitter,
(v) subscriber tap.

11.4 With the aid of the frequency usage diagrams shown in Figure 11.2, state for both an NTSC system and a PAL system,
(i) the bandwidth required for the baseband composite video signal with sound,
(ii) the bandwidth required for the modulated video and audio signals,
(iii) the meaning and use of frequency division multiplexing,
(iv) the role of the frequency translators, filters, and combiner in the cable headend,
(v) how a subscriber selects a particular TV program,
(vi) the range of frequencies of the coaxial cable bandwidth that are used.

11.5 In relation to the hybrid fiber coax network shown in Figure 11.3, explain the meaning/use of the following:
(i) a fiber node and the number of homes each serves,
(ii) bidirectional distribution amplifiers,
(iii) the utilization of the cable bandwidth in the downstream and upstream directions including the use of guard-bands and bandsplitting filters.

11.6 Explain the role of an RF modem including the modulation schemes used and the bandwidth available with a single 6/8 MHz band. State the additional applications (to broadcast TV) that these channels are used for.

11.7 In relation to the utilization of the upstream channel bandwidth in an HFC network, explain why the available cable bandwidth is divided into smaller subbands than those used for the downstream channels. Why are more robust modulation schemes used? Give some examples of typical bands and their bit rates.

11.8 In relation to the multiaccess channels available with an HFC cable distribution network use Figures 11.3 and 11.4 to explain the role of the following:
(i) cable modem,
(ii) cable modem termination system including the role of the Fast-Ethernet switch.

11.9 In relation to the protocol stack used in a CM and the CMTS shown in Figure 11.5, state:
(i) why a CM has an integral (Ethernet) repeater hub within it,
(ii) the role of the cable MAC layer,
(iii) the role of the SNMP, TFTP, and DHCP protocols.

11.10 With the aid of the protocol stack shown in Figure 11.5, describe the role of the following protocols during the configuration and management phases of a CM:
(i) the DHCP and the information obtained,
(ii) the TFTP and the information obtained,
(iii) the SNMP.

11.11 In relation to the utilization of the (shared) upstream channel bandwidth, explain in outline how the cable MAC in a CM obtains bandwidth to send a frame. Include in your explanation the role of:
 (i) the request and grant messages,
 (ii) the service identifier of the CM,
 (iii) the bandwidth allocation MAP,
 (iv) time synchronization and ranging.

11.12 With the aid of the timing diagram shown in Figure 11.6, explain the principle of operation of the cable MAC time synchronization procedure. Include the meaning/use of:
 (i) the SYNC management message,
 (ii) SYNC time-stamp,
 (iii) minislot and the power-of-two multiple associated with it,
 (iv) the relationship between the minislot counter and the SYNC time-stamp.

11.13 In relation to the timing diagram relating to the cable MAC ranging procedure shown in Figure 11.7, explain:
 (i) how the CM side determines when to send the first RNG-REQ message and the contents of the message,
 (ii) how the CMTS side computes the RTC of the CM from the received message and informs the CM side of this,
 (iii) how the returned RTC value is confirmed.

11.14 With the aid of the timing diagram relating to the cable MAC reservation access mode procedure shown in Figure 11.8, explain how the procedure works. Include in your explanation:
 (i) the need for a contention resolution procedure,
 (ii) the use of the DBS and DBE fields in the bandwidth allocation MAP and the meaning of the term "backoff window",
 (iii) an example computation performed by the CM,
 (iv) how a collision is detected by the CM and the actions it takes.

11.15 With the aid of Figure 11.9, state the meaning and role of the various header fields shown in the figure.

11.16 With the aid of the fragment header frame format and example shown in Figure 11.10, explain the fragmentation procedure carried out by a CM to transmit a user data frame that requires more minislots than have been granted. Include in your explanation the use of the EH-TYPE, EH-LEN, and EH-VALUE fields in each fragment header.

11.17 State the role of the following additional procedures relating to the cable MAC protocol:
 (i) piggyback requests,
 (ii) request/data regions,
 (iii) QoS support including the use of unsolicited grant, real-time polling, unsolicited grant with activity detection, and non-real-time polling.

11.18 With the aid of the packet formats shown in Figure 11.11, describe the operation of the downstream transmission convergence (DSTC) sublayer. Include in your description the meaning/use of
 (i) the MPEG transport packet format,
 (ii) the use of the payload identifier (PID) and PUSI bit in the packet header,
 (iii) how the DSTC in the CM determines the length of a MAC frame,
 (iv) stuff-bytes.

11.19 With the aid of the two schematic packet flows shown in Figure 11.12, describe the principle of operation of the downstream and upstream transmission convergence sublayers. In relation to the upstream direction, include the meaning/use of
 (i) a guard-band,
 (ii) a preamble sequence,
 (iii) the forward error control field.

11.20 With the aid of the network topology shown in Figure 11.13, explain the motivation for cable operating companies linking their regional HFC networks together to form an intranet. Describe the principle of operation of a cable intranet.

11.21 State the application domains of a multichannel (M) and a local (L) multipoint distribution system (MDS). Hence, with the aid of the schematic diagrams shown in Figure 11.14, explain the principle of operation and operating frequencies of both systems.

Section 11.3

11.22 With the aid of the network schematic shown in Figure 11.15(a), explain the principle of operation of a geostationary satellite broadcast TV network. Include the meaning of the terms:
(i) geosynchronous,
(ii) geostationary earth orbit (GEO).

11.23 In relation to a satellite's position, use the diagrams shown in Figure 11.15(b) to explain the meaning of
(i) angle of elevation,
(ii) azimuth.

11.24 With the aid of the frequency bands shown in Figure 11.16 relating to early analog TV transmissions, state:
(i) the bandwidth of each modulated TV channel,
(ii) the guard-band between adjacent channels,
(iii) why different frequency bands are used for the uplink and downlink.

11.25 Describe the principle of operation of a satellite dish including the role of the low-noise block/converter (LNB/C). With the aid of Figure 11.17(a), state the difference and advantages of an offset-focus antenna compared with a prime-focus antenna.

11.26 With the aid of the block schematic diagram shown in Figure 11.17(b), state the meaning/use of the following:
(i) satellite intermediate frequency,
(ii) transponder subsystem,
(iii) channel filter,
(iv) frequency converter,
(v) power amplifier,
(vi) signal combiner,
(vii) command and telemetry subsystem.

11.27 With the aid of the block schematic diagrams of the (baseband) satellite digital channel interface shown in Figure 11.18, explain the role of:
(i) the RS coding block,
(ii) the byte interleaver,
(iii) the convolutional encoder including the meaning of puncturing,
(iv) QPSK modulation.

11.28 State the following for the downlink of the DBS and DVB-S digital TV transmissions;
(i) the allocated bandwidth,
(ii) the number of channels and the bandwidth per channel,
(iii) the symbol rate and raw bit rate of a channel,
(iv) the useful bit rate per channel,
(v) typical applications of this.

11.29 Explain briefly the following forms of interactivity with satellite broadcast transmission. State an application in each case:
(i) local interaction,
(ii) anonymous response,
(iii purchase request.

Section 11.4

11.30 With the aid of the diagrams relating to terrestrial TV broadcast transmissions shown in Figure 11.19, discriminate between a multi-frequency network and a single-frequency network.

11.31 Explain the meaning of the following terms relating to the broadcast channel of a terrestrial broadcast TV network:
(i) multipath,
(ii) wavelength,
(iii) multipath dispersion/delay spread,
(iv) intersymbol interference.

11.32 With the aid of the diagrams shown in Figure 11.20, explain the principle of operation of COFDM transmission. Include the role of:
(i) the symbol mapper,
(ii) the generation of each transmitted symbol,
(iii) the guard interval.

11.33 With the aid of the diagrams relating to COFDM in Figures 11.20 and 11.21, explain the implications of:
(i) using orthogonal carriers on the spacing between adjacent carriers,
(ii) adding a guard interval between symbols,
(iii) the relationship between the guard interval and the symbol period.

11.34 Assuming a guard interval of 50 μs and a usable channel bandwidth of 7 MHz, derive the number of carriers that would be used.

11.35 Define the origin of 2K and 8K in the 2K/8K specifications for digital video broadcasting-terrestrial (DVB-T).

11.36 With the aid of the 2K/8K frame formats shown in Figure 11.21, explain the meaning/use of the following relating to receiver synchronization:
(i) a frame,
(ii) continual pilots,
(iii) scattered pilots,
(iv) TPS pilots.

11.37 With reasons, estimate the usable bit rate that is available with an 8 MHz broadcast channel assuming the 2K specification, and 16-QAM modulation per carrier. Allow for loss of bit rate caused by the guard interval and the channel interface overheads quantified in Example 11.1. State the number of digital TV programs the channel will support.

Section 11.5

11.38 State the meaning, bit rate, and use of the following PSTN high-speed access technologies:
(i) IDSL,
(ii) HDSL,
(iii) SDSL,
(iv) ADSL-Lite,
(v) ADSL,
(vi) VDSL.

11.39 With the aid of the schematic diagram of a typical modern access network architecture shown in Figure 11.22, state the length of twisted-pair cable with each of the following:
(i) FTTH,
(ii) FTTK/C,
(iii) FTTCab,
(iv) direct-to-building.

Hence state the maximum length of twisted pair cable that can be used with ADSL.

11.40 With the aid of the access network architecture shown in Figure 11.23(a), describe how the POTS and high-speed interactive services are provided with an ADSL installation. Include in your description the role of the low-pass and high-pass filters in the POTS splitter and the ADSL modem.

11.41 With the aid of the access network architecture shown in Figure 11.23(b), describe how the POTS and high-speed interactive services are provided with an ADSL-Lite installation. Include in your description the advantages of using a passive network termination (NT) and one of the potential drawbacks of this.

11.42 In relation to the discrete multitone (DMT) modulation method used with ADSL modems, state:
(i) the number of carriers per symbol that are used,
(ii) the reason why multilevel modulation is not used with all carriers,
(iii) how duplex transmission is obtained.

11.43 State the following for a VDSL installation:
(i) the type of access network and the location of the VDSL modem,
(ii) typical bit rates,
(iii) how duplex transmission is obtained.