

# THE ARCHITECTURE OF JAN GECSEI VIDEOTEX SYSTEMS





# **THE ARCHITECTURE OF VIDEOTEX SYSTEMS**



**Jan Gecsei**

*Université de Montréal*

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## 4

# Delivery Media



## 4.1 THE TELEPHONE NETWORK

The public telephone system is the best-established and most extensive communication network we know. There are some 300 million telephones in the world, 6 million in New York City alone, and practically every household in North America has access to a telephone. In principle at least, every phone in the world can be connected with every other. The cost of locally using a phone is well within the reach of the average person in the industrialized world.

The telephone network can be thought of approximately as a hierarchy of exchanges (switching offices), concentrators, and toll offices, interconnected by communication lines of different capacity. Generally the characteristics of these lines depend on their position in the hierarchy: at higher levels, links have higher bandwidth, are multiplexed, and span longer distances. Subscribers' phones are connected to local exchanges (lowest-level exchanges) through dedicated two-wire circuits called *local loops*.

The original purpose of the telephone system was, of course, communication of analog speech signals, and not transmission of digital data. Consequently, the bandwidth of a typical switched voice-grade circuit is about 3000 Hz (frequency range from 300 to 3400 Hz). However, this limited bandwidth applies only to end-to-end circuits in the network, that is, from phone to phone. Individual parts of the system can often carry much higher data rates. The end-to-end bandwidth is artificially limited in order to exploit

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### Modems

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Function \	Dedicated 2-way	Shared 1-way	Shared 2-way
Bit, byte synchronization	✓	✓	✓
Error protection	✓	✓	✓
Data identification continuity (page, magazine)	N.A. (only demanded pages sent)	✓	✓
User addressing	N.A. (done in access machine)	✓ (In addressable systems only)	✓
User command handling	✓	Local function in terminal	✓

Figure 4.1 Delivery protocol functions in different media.

better (i.e., to multiplex) the long-haul circuits. Thus, for instance, the local loop itself has a bandwidth of almost 1 MHz, and could therefore easily carry a digital voice circuit of 64 kb/s. But the extension of such circuits throughout the network would require expensive upgrading of the whole system. And since videotex, in order to be viable, must be cheap, those videotex systems that rely on the telephone network for delivery use it as it is. However, there is a trend toward the digitalization of the telephone network, as will be discussed later.

### Modems

The most common way to use the switched telephone network for digital transmission is through devices called *modems*. The function of modems is to transform binary signals into a form suitable for transmission within the available bandwidth. Since the bandwidth does not extend down to 0 Hz, the circuit would not transmit well the dc levels corresponding to binary 0's and 1's. Instead, most modems employ a frequency modulation technique with four distinct frequencies used to carry 0's and 1's in both directions.

Low speed modems, such as those typically used for videotex, work in *asynchronous* mode. That is, each eight-bit character is bracketed between a start bit and a stop bit used to re-synchronize the bit-clock of the receiving modem. Thus, individual characters can be followed by pauses of any length.

Modems are available for a range of standardized transmission rates from 75 b/s to 9600 b/s. Speeds up to 1200 b/s (approximately 120 char/s) through switched circuits are attainable with relatively inexpensive modems; higher rates require specially designed

modems, coding techniques, and, eventually, conditioned and/or dedicated (leased) lines. We point out that when the switched network is used, the physical circuits involved in the connection may be different from one call to another (except for the local loop).

Again for obvious economic reasons, low cost modems are a must for videotex. Fortunately, 1200 b/s is an acceptable speed for most picture-coding techniques, with the exception of photographic coding. (This is no surprise: in effect, image-coding methods for videotex were originally conceived with this limited bandwidth in mind!) At that rate, transmitting a full alphanumeric page takes less than 10 seconds, about 0.5 s per line, which is decidedly higher than the reading speed of an average person. About a minute is needed to build up a photographic image on the screen; this is decreased to 15 s at 4800 b/s, a quite acceptable delay.

### Data Rates

In two-way videotex a reverse channel must exist to transmit user commands to the service computer. The bandwidth required for this is much less than it is in the forward direction; in most systems 75 b/s is used (150 b/s in certain trials in Canada). A CCITT recommendation (V.23) exists for the communication between computers and user terminals. This recommendation in effect specifies full duplex asynchronous communication at 1200/75 b/s in the forward and reverse directions, respectively. Most existing systems use modems complying with V.23. The provision for full duplex communication is important, however: it permits a command to be sent before a page transmission is completed in order, for example, to shorten the waiting time for the next selection, or to block the transmission if the page is of no interest to the user.

The 1200/75 b/s system is sufficient for data retrieval applications in which the user input is generated by typing and sending a few characters. But in other circumstances (such as local editing of messages in an intelligent terminal and sending of the entire message at once), rates of 1200 b/s may be needed in both directions. This is completely within the possibilities of the switched telephone network, and suitable modems are currently available.

Higher transmission rates are required for photographic and quasiphotographic image coding. For example, Captain uses 3600 b/s, and the British Telecom is experimenting with 6800 b/s for its Picture Prestel service (not yet publicly available).

Some form of flow control must be used in order to prevent overflowing of the receiver's buffers. In Telidon, control character DC3 is used to request the service computer to stop transmission, and DC1 is used to resume transmission.

There is much discussion of the merits and drawbacks of the telephone as a videotex delivery vehicle (see Link Research Memoranda, 1980). One of the original motivations behind Prestel was to improve the utilization of the network in off-peak hours (evening). Although this rationale is entirely valid for home applications (the initially targeted marketplace), it is almost entirely invalid for business applications, most of which coincide with peak telephone traffic. The main arguments about the suitability of the telephone as a videotex delivery vehicle are summarized below.

4.2 INT

Digital



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#### Advantages:

1. It is a well-established system with very high penetration
2. It has ports (user entry points)
3. It has switching and addressing capability
4. It covers large geographical areas
5. It offers full duplex two-way communication
6. It has computerized functions similar to those required for videotex: automatic user identification, billing, programmable access restrictions, and facility to broadcast some messages.

#### Disadvantages:

1. It has a low data rate
2. It was not designed for the bursty traffic of videotex—i.e., long user sessions may be costly
3. It prevents normal use of the telephone (although proposals exist for use of a single telephone line for simultaneous voice and data transmission).

## 4.2 INTEGRATED SERVICES DIGITAL NETWORKS (ISDN)

Although many of today's public communication and mass media services are based on analog transmission technologies (telephone, radio, television), digital transmission is making fast and steady progress. The main reasons for this are that digital information is easier to protect against distortion and errors, and that computer technology can be readily applied to build and control sophisticated data networks. On a different level, the need for cooperation of distant computers has led to computer networks in which there is little place left for analog information.

### Digital Carriers

All information services reaching the public, including television, can be coded and transmitted in digital form. Pulse coded modulation (PCM) transducers, called *codecs*, are currently available to digitally encode acoustic information, and a growing number of long-distance links carry telephone traffic in digital form. In the U.S., there are nearly 160 million km of T-carrier links (1.5 Mb/s) and about 250,000 digitized local loops installed. Figure 4.2 shows some commonly used digital data rates and carriers. Bell System plans a switched digital capability over the public switched network, and a large number of digital exchanges and toll offices are already installed and working in most Western countries. Cable companies are introducing into the customers' homes very large bandwidth connections (up to 500 MHz), which, though presently used mostly for

Multiples of 1.2 Kb/s:		
	1.2	} Used over voice-grade lines with modems
	2.4	
	4.8	
	9.6	
	19.2	
Multiples of 56 Kb/s (= PCM voice channel):		
	56	
	112	
	224	
T1 carrier	1.544 Mb/s	( $\approx 24 \times 56$ )
T2 carrier	6.312	( $4 \times T1$ )
T3 carrier	44.736	( $7 \times T2$ )
T4 carrier	281	( $6 \times T3$ )

Figure 4.2 Data rates commonly used in the U.S.

television, are excellent carriers of digital information. In addition, public data networks and computer networks are already in current use.

### Service Integration

The idea of ISDN (see Dorros, 1981) is to unify this emerging infrastructure into a public, digital, end-to-end telecommunications network providing a wide range of applications through standardized interfaces. ISDNs are not yet common, nor is it clear what all the services carried will be like. What *is* clear is that even traditional services could be provided more economically and flexibly through a single unified digital medium than through separate and mixed media and networks (such as telephone, cable, and telex).

ISDN planners submit that the new network is relatively independent (say, up to the transport layer) of its future applications. The commodity offered to customers would be units of digital channel capacity. Each customer will "consume" as much capacity as needed. Channel capacity would be delivered through standardized interfaces. Some interface capacities currently planned by the Bell System are:

- 1.544 Mb/s for large business customers
- 144 kb/s for small business customers (sufficient for simultaneous voice and data)
- 80 kb/s for residential customers.

Cable systems (discussed in section 4.3) usually divide their bandwidth into 6-MHz slots; these can be used to carry digital traffic to a number of homes.

The obvious implication for videotex is that ISDN can serve as a convenient delivery system that is tailored to the real needs of the application in question, and not vice versa.

Although truly nationwide ISDN is still perhaps 10 years away, significant local implementations are being realized. One of them is the IDA project of the Manitoba Telephone Company, described in Chapter 6. Another major project is the ISDN service

4.3 CA

Physical



to be introduced in London in 1983. Users will have access to a 64 kb/s voice channel (useable also for data transmission) and an independent 8 kb/s data channel. Both of these will provide highly enhanced telephone and videotex services (see Childs, 1981). Another development is the recently announced Local Area Data Transport (Handler, 1982), which is in essence an X.25-based packet-switching network accessible through the local telephone loop.

### 4.3 CABLE SYSTEMS

The growing popularity and penetration of television in the 1950's brought about an increasing demand for more channels and better reception. Reception problems were observed in both rural and urban areas: in the former, due to the distance from the transmitters; in the latter, because of multipath reception and because there were many sources of noise. Community antenna television systems (CATV)—or simply cable TV—offered a solution to such problems. Today a considerable fraction of television owners in North America is serviced by cable. In Canada about 60% of all households have the cable installed, and the service is easily available (the cables passing nearby) to another 20%. In the U.S., cable penetration is about 28% and is rapidly growing. In Western Europe cable penetration varies widely between countries. According to Ball (1981) the leader is Belgium, with 75%. West Germany, France, and the U.K. have 35%, 1%, and 14% penetrations, respectively.

It was soon realized that video programming is not the only kind of information that can be carried (and sold) to customers through cable. Data can be superimposed onto the TV signal, as will be described later in this chapter. Additional possibilities are offered for full field data transmission on unused television channels. The next step is to consider the cable as a broadband, ISDN-type transmission medium with certain parts of the frequency spectrum allocated to purely digital (usually packet-based) data services that have nothing to do with the TV signal. Since packets can be addressed, individual sub-channels can be established for communicating with selected users or user groups. Finally, the system can be made interactive by incorporating reverse channels from the users to the cable head; the result is *two-way* CATV. Such systems are in actual operation, offering a variety of informational and other services and approaching what might be called "local" ISDNs.

#### Physical Structure

Current cable television systems use *coaxial cable* as a transmission medium. The topology is usually a three-level tree structure, as shown in Figure 4.3. The root of the tree is the head-end, or *hub*, which feeds the main trunk with the appropriate signals. This trunk is the backbone of the distribution system. Amplifiers must be inserted every 0.5–1.0 km in order to counter signal attenuation. Some of these amplifiers, called *trunk bridgers*, serve also as branching points for *distribution feeders*; each such feeder can serve 300–500 subscribers. Feeders consist physically of the same kind of coaxial cable

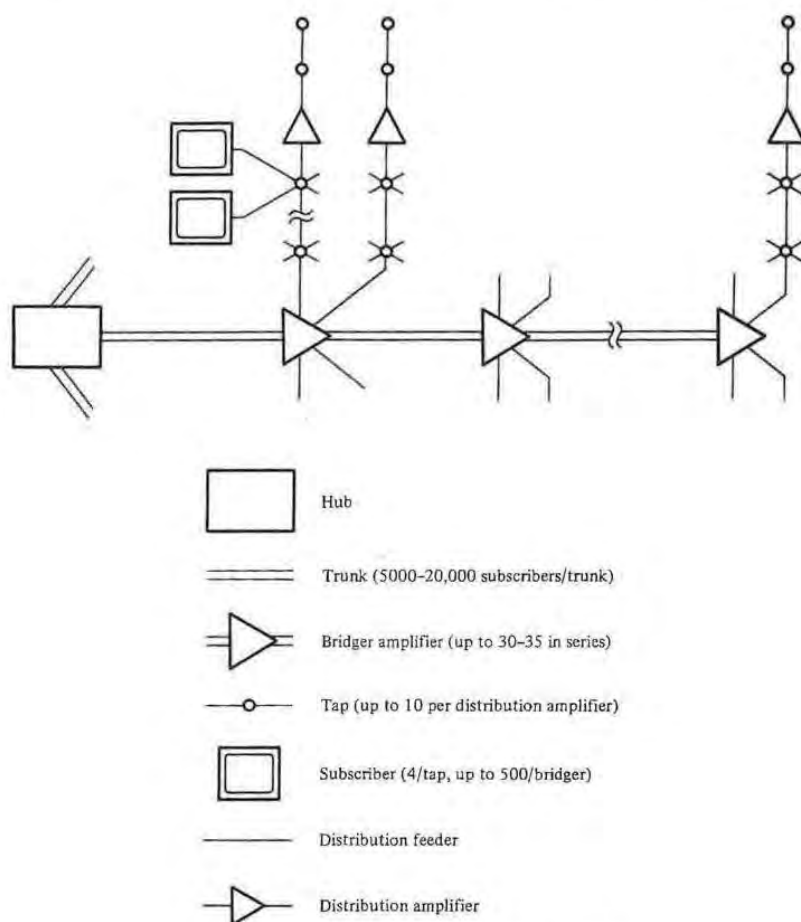


Figure 4.3 Structure of a typical CATV system.

and amplifiers as the main trunk. Individual users are connected to the feeder in branching devices called *directional couplers* or *taps* (4-8 users per coupler).

About 80% of cables installed in Canada are aerial cables; the remaining 20% are installed underground. The cost of installation of one km of cable is between \$5000 and \$10,000, depending on the factors such as the cable's bandwidth and whether the cable is above ground or buried.

The geographical span and the number of subscribers of such CATV systems is limited by the maximum number of amplifiers that can work in tandem in order to keep signal distortion to a reasonable level; a typical number is 30-35. These limitations can be partly relieved by using multiple hubs; this amounts to a star-like topology.

Two-Wa

Splitting

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### Two-Way Operation

Recent interest in interactive cable-based services (and in the potential revenues for operators and service providers) has motivated research into methods of upgrading existing CATV systems towards two-way operation. Presently there are about 400 cable operators in Canada. About 10% of the systems are "two-way compatible"—that is, they have physical provisions for the additional equipment required. But there are very few truly operational two-way systems. Examples of such systems are Cablesystems Engineering's system in London, Canada (see Allora-Abbondi, 1979), and Cox's Indax system (see Gates and Tjaden, 1982). Some of these systems will be described later.

Conversion to two-way operation fortunately does not always require replacement of the cable or addition of another one; the same medium can conduct signals both ways. This effect is achieved by splitting the cable's bandwidth and using one part for downstream, and the other for upstream communication. The main physical change that has to be made is to upgrade the amplifiers for bidirectional operation. The new devices consist essentially of two amplifiers with duplex filters, one used for each direction of transmission.

In addition to requiring physical modifications, upgrading to two-way traffic causes a number of further potential problems. The most important one may be the accumulation of noise from upstream traffic; in effect, a single faulty user terminal generating inappropriate signals or frequencies can jam the whole system. One solution is to cut off the noisy branch at the trunk bridge. This can be done by remotely controlling the bridgers by appropriate messages from the head end. Newer two-way designs incorporate a generalized remote control and monitoring facility, applicable to individual user terminals as well. Such a facility is used to implement functions such as statistics-gathering, pay television, burglar and fire alarms, and disconnection of the terminal if a bill is not paid on time.

### Splitting the Bandwidth

Modern coaxial cables transmit signals in a frequency range of up to 500 MHz. The useful part of this range is from 5 MHz up. This is an enormous bandwidth, corresponding to more than 100,000 analog voice circuits. In one-way CATV, the bandwidth is allocated to as many as 60 television channels, spaced at 6 MHz intervals and for the most part unused.

In two-way systems the split between the upstream and downstream bands is typically at 50 MHz (but sometimes at 150 MHz). The upper part of the spectrum is used for downstream transmission (thus including the complete VHF television and FM bands). Upstream transmission is between 5 and 35 MHz. Although the above split is not fixed by any formal convention, it is used as a de facto standard by all North American systems. However, except for the allocation of TV channels and FM broadcast bands, there is no further consensus on the subject of subdivision and multiplexing methods for the above two main bands. This absence of standards is similar to the situation in ISDN. A

e feeder in branch-

remaining 20% are  
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set of conventions to facilitate future interworking of digitized parts of CATV systems was proposed by O'Brien (1981).

### **Transmission Techniques**

Advanced services offered on one-way and two-way CATV rely on digital communication techniques. There follows a brief list of issues that must be addressed in such system design. Since these issues are not videotex-specific, we do not treat them in detail here (see Tanenbaum, 1981).

**Addressability.** It should be remembered that addressability is applicable even in one-way systems. Addressability permits control information or messages to be sent selectively to individual terminals. A common application is in pay TV, in which microprocessor-controlled terminals receive authorization and supplementary information to descramble selected TV signals. Another form of addressability is applied to cut off noisy branches in bridges in two-way systems.

**Multiplexing.** Two basic techniques are used to split and share the bandwidth of a cable: FDM (frequency division multiplexing) and TDM (time division multiplexing). The former is used for analog TV signals, and allots 6-MHz intervals per channel. TDM is applicable only to digital traffic and is at the base of the packet-switching technology commonly used in data networks. Most systems use elements of both FDM and TDM: for example, assigning a 6-MHz slot for digital traffic and subdividing the slot into a number of sub-channels, each carrying perhaps a 64-kb/s digital bit stream, which itself can be packetized.

**Modulation.** Analog and digital signals to be transmitted must be modulated onto carrier waves whose frequency is determined by the underlying FDM scheme. The functioning is somewhat similar to that of modems described earlier.

**Access conflicts.** Since two-way cable is a shared medium, provisions must be made to allocate to each user separate bandwidth (in the form of dedicated frequency or time intervals) in the upstream direction. Alternatively, if a common upstream channel is used, access conflicts must be detectable and resolvable. One commonly used method is the "carrier sense multiple access/collision detection" (CSMA/CD). Its underlying principle is that each transmitter tries to transmit its message in an empty time slot. If a conflict (simultaneous transmission) occurs, the transmitters will repeat their messages after a random delay. Another class of procedures is based on polling. Generally the same methods as those used in local area computer networks are applicable here.

### **Characteristics of Cable-Based Videotex Delivery Systems**

The characteristics of such delivery systems are:

- high bandwidth
- a "box" (cable converter) that resembles a videotex keypad

### **4.4 FIBE**

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- in the case of one-way CATV, useability for interactive services, e.g., in combina-  
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- possible upgrading to two-way of most existing systems (90% of which are one-  
way)
- limited geographical extent
- no switching capability at present
- possibility of connecting local cable systems into large networks by using satellite  
links.

#### 4.4 FIBER OPTICS

There is much discussion about the potential of fiber optics as a replacement for coaxial cable or microwave links. We briefly mention this technology because of its potential as a delivery medium for videotex.

Fiber optics are fabricated from highly transparent glass material capable of functioning as optical waveguides. The carrier of information is light that is generated by a light-emitting diode or a diode laser. Analog or digital signals are amplitude-modulated onto the light wave. A photodiode is usually employed at the receiving end to convert the incoming light intensity into an electrical signal. Fibers are packaged into cables, each containing a variable number (1–24) of fibers.

At present it is not clear whether—and when—fiber optics will become a viable alternative to cable (see Metz, 1981). The situation is analogous to that involving the replacement of mechanical disks in computers by new electronic memories, such as magnetic bubbles or charge-coupled devices. Disks represent a well-entrenched technology, and experience shows that in order to be replaced by newer, exploratory technologies, these technologies have to be significantly superior in terms of both cost and performance. Marginal disadvantages are not likely to win out against inertia resulting from investment in well-proven technologies. So far, fiber optics technology has been unable to demonstrate an overall superiority over cables. Therefore, it is no surprise that cable companies are hesitating to move ahead with large-scale replacement. A more detailed analysis would involve the following facts:

1. The bandwidth of the fiber optics medium itself (like that of the coaxial cable) is much higher than that of the coupling equipment (amplifiers, modulators, taps).
2. A single fiber today can carry five to six TV channels (as opposed to 54 in modern cables). However, the distance required between amplifiers is much larger with fibers (10–20 km) than with cable (0.5–1 km). Digital transmission rates of more than 1 Gb/s (over a single fiber) have been demonstrated in field test operations in Japan and Germany.
3. The major reason for the limited bandwidth of entire analog transmission systems is the nonlinearity of the light source. Thus, present technology is better suited for digital transmission (in which signal distortion is not critical).
4. The cost of production of fibers is decreasing, whereas cables require materials such as copper and aluminum, whose cost cannot but increase in the future.

5. Current cost-effective uses of fiber optics in the U.S. include medium-distance links having few or no repeaters and no taps (branching). A typical example is the link between a satellite receiver station and the cable head-end. At the present stage, application for cable trunks and distribution feeders would be uneconomical due to the high cost of branching contacters (taps). One foreseeable application is in "mini-ISDN" systems (see Mini-Hub, 1981) for the distribution of video and digital services in high-rise apartment buildings (in which each customer would have a direct connection with a local head-end in the building).

Fiber optic links are used or planned in several countries (U.S., Japan, France) as high-speed trunk lines in telephone networks. They seem to be gaining ground mainly in short- and medium-distance applications (e.g., within a large city) not requiring repeaters.

Fiber optics cables are being used in project ELIE. This is an ISDN-type system being tried in Manitoba, Canada (see Chang, 1982).

#### 4.5 DATA TRANSMISSION OVER THE TV VIDEO SIGNAL (DOV)

The idea of piggybacking digital information on (analog) television and even FM radio signals is not new. A number of schemes have been devised to take advantage of unused portions of the frequency spectrum of the video signal. One proposal used a "flashing dot" displayed in the corner of the TV screen. These light signals were detected by a photodiode and used to drive a teletype.

DOV techniques in use today are based on different principles. Transmission takes place during the *unused time intervals* of the TV signal, and the received information is usually displayed in readable or graphical form on the screen. The unused times occur normally during the *vertical blanking interval* (VBI) between successive fields of picture information; an extension of the method, called *full-field* transmission, transmits only data (no picture information), while keeping the infrastructure of synchronizing (sync) pulses. The VBI technology originates in attempts to provide captioning and subtitling of TV programs. Since DOV is an important videotex-specific delivery method useable in both over-the-air and cable transmission, we will discuss it in considerable detail.

##### Principles of TV Transmission

There are three main standards used for color TV transmission: NTSC, PAL, and SECAM (Figure 4.4). For the following explanation, neither specification of the particular standard nor the presence of colors is essential. The TV picture is drawn on the inner face of the picture tube by an electron beam that sweeps across the picture area in a sequence of horizontal scan lines controlled by horizontal sync pulses. The intensity of the beam as it hits a given point determines the luminosity of that point. This intensity information is basically what is transmitted in analog form by a (black and white) TV signal. When the last scan line is completed, the beam returns to the top of the screen

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System	Lines/frame	Frames/s	Video band width MHz	Countries	Bit rates used Mb/s
NTSC	525	30	4.2	USA Canada Japan	5.73 (BS-14) (and many others)
PAL	625	25	5.5*	Western Europe except France	6.9 (U.K.)
SECAM	625	25	6*	Eastern Europe and France	6.2 (Didon)

\*Can be 5, 5.5, or 6 MHz

Figure 4.4 Comparison of TV standards and teletext bit rates.

and scanning starts anew. If this process is repeated quickly enough, the viewer has the impression of seeing the whole image at once; the effect of movement is achieved by slight changes in subsequent images, as in the projection of films.

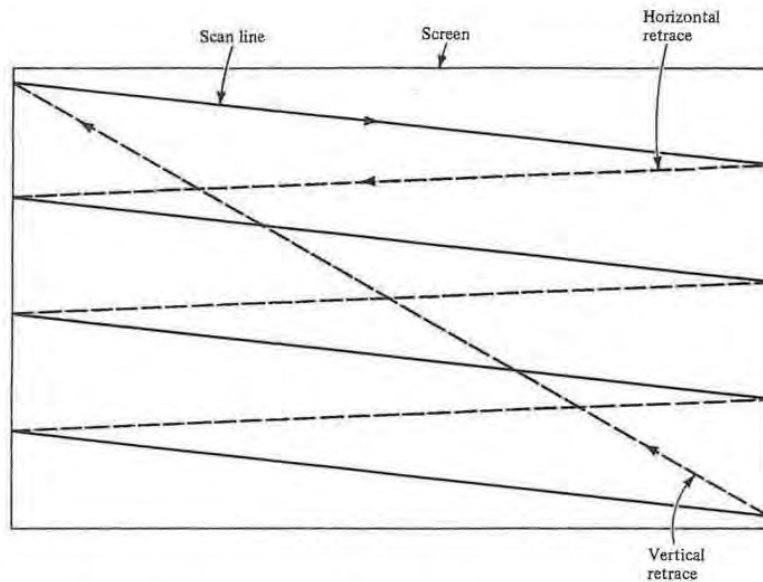
In order to obtain better picture quality a full TV image (frame) is composed of a sequence of two interlaced *fields*. This allows a doubling of the rate at which images are presented, and thereby significantly reduces objectionable flicker. If we think of the lines of a frame as consecutively numbered, then the two fields will contain even-numbered and odd-numbered lines, respectively. However, the lines in each field are usually numbered separately; we adopt this convention here as well. Figure 4.5 illustrates the composition of a field.

The exact timing of the movement of the beam across the screen (that is, the times of horizontal and vertical retraces) is controlled by synchronizing pulses. While the beam is returning to start a new line or field, its intensity must be sent to the blanking (black, invisible) level. Hence the term VBI. Note that although horizontal retraces are also blanked, they are too short to carry very much data.

### Data over Video

Strictly speaking, transmission of picture information is suppressed during the vertical retrace interval and also during the interval in which the first few scan lines appear in each field. These scan lines are normally not displayed on the visible area of the screen, but they can be seen as a black bar between two frames when the receiver is out of vertical synchronization. Data bits are modulated onto some of these invisible lines. The term VBI denotes collectively all lines that do not carry picture information.

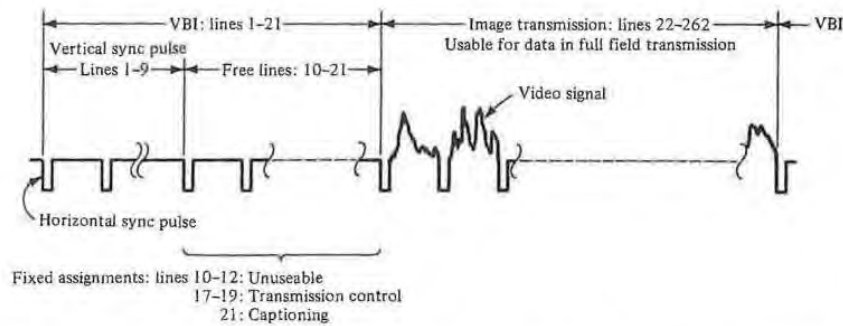
Two remarks are appropriate at this point. First, the sequence of horizontal sync pulses is not interrupted through the vertical beam retrace. The first few lines of the VBI are used for the vertical sync pulse (which in reality consists of a sequence of pulses); only the subsequent lines are available for data. Figure 4.6 indicates the timing of a typical field. Second, the above-mentioned blank lines between fields are not to be confused with the so-called *overscan* lines, which do carry picture information, but are usually



**Figure 4.5** Composition of a TV field. A frame consists of two interlaced fields.

also invisible. The purpose of these overscan lines is to assure full coverage of the screen by the image in spite of variations and aging of the TV sets.

A somewhat simplified form of a TV signal between two horizontal sync pulses is illustrated in Figure 4.7 (note that a line carrying data is called a *data line*). In most systems a straightforward coding is used, with two signal levels corresponding to 0 and 1, respectively.



**Figure 4.6** Simplified timing diagram of an NTSC field. VBI lines 13-16 and 20 are potentially available for data transmission (data lines).

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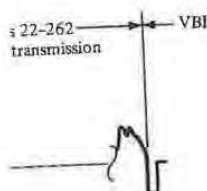




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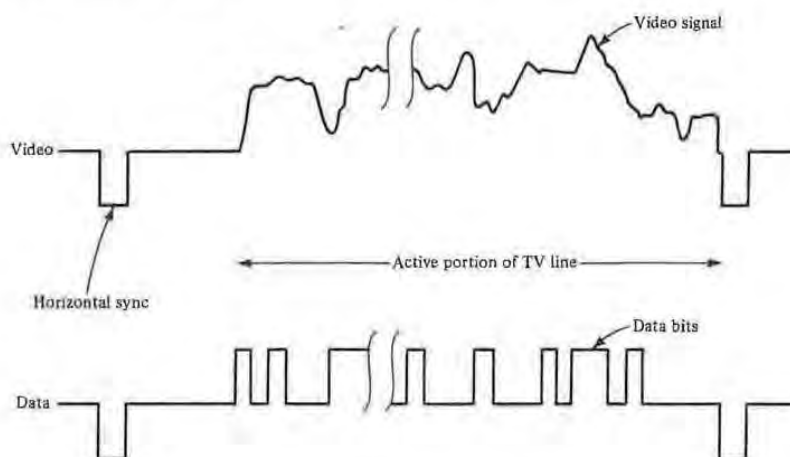


Figure 4.7 Timing of video lines and data lines.

In full-field transmission all available lines are data lines and no picture whatsoever is transmitted. This approach is particularly feasible in cable-based systems that have large channel capacity that is typically only partly used. These conditions make it possible to dedicate one or more entire channels to data transmission. In countries where TV is broadcast mostly over the air, the VBI technique is preferable since it permits simultaneous transmission of picture and data. Of course, if everything else is kept constant, the resulting effective data rate is proportional to the number of data lines in the signal.

### Data-Line Assignment

The number and assignment of data lines in the VBI is subject to informal conventions and varies in different countries and different systems. There is no internationally adopted standard in this matter. This does not represent a problem for decoder design because the proper data lines are usually recognized by examining the waveforms and not by counting the scan lines.

Some lines of the VBI are occupied for purposes other than data transmission, such as controlling the quality of the TV signal (compensation for color variations), channel and program source identification, and transmission of test patterns (gray scale and color values). The remaining data lines can be used for program-related data (such as subtitling and captioning), teletext data (to be displayed on the screen), and independent applications, such as broadcast facsimile, not tied to the program or screen.

In NTSC, the VBI consists of the first 21 lines of each field (25 lines in PAL). According to current Canadian regulations, lines 15, 16, 20, and 21 are available for

data; line 21 is reserved for closed captioning. The U.K. teletext originally used lines 17 and 18 (this was later extended to four lines), and, in a CBS trial in 1979 involving the U.K. and Antiope technologies, lines 13 and 16 were used.

In certain television receivers, electron beam blanking depends on the TV signal's being at black level. If data were inserted in these lines, dotted diagonal lines would faintly appear across the screen. More modern receivers electronically blank the electron beam during VBI time. As older receivers are retired from service, more VBI lines will become available for teletext.

### Transmission Rates

The *instantaneous bit rate*,  $B$ , is the speed (in Mb/s) at which bits are transmitted during the periods when data are sent. It is determined by a number of system parameters:

1. The video bandwidth  $W$  (MHz) of the transmission medium (including the receiving equipment). If two signal levels are used for coding, the maximum obtainable rate is  $B_{\max} = 2W$ . For North America, this yields  $B_{\max} = 2 \times 4 \text{ MHz} = 8 \text{ MHz}$ . (Note that without the restriction to two signal levels, a channel can carry an arbitrarily high bit rate as long as the signal-to-noise ratio is high enough.)
2. Acceptable error rates. The observed bit error rates in a given system increase as the transmission rate approaches the above limit. Although various theoretical models exist for this dependence, they do not entirely cover practical situations, and error statistics must be determined empirically, usually in field trials. These tests can also cover the influence of the technology of the receiving equipment.
3. Error detection and correction methods used (see below).
4. Evaluation of the psychological effect of various error types (such as loss of character, displaced lines, mixup in page numbers) on the user.
5. The value of  $B$  should be a multiple of the TV line frequency.

Within the above constraints, the bit rate should obviously be maximized. Practically used values of  $B$  are between  $0.8W$  and  $1.4W$ . The U.K. teletext rate is 6.9 Mb/s (too large for NTSC). In North America numerous tests were and are being conducted at various rates between 3 and 6 MHz. The bit rate recommended in the France-Canada-CBS joint standard proposal (discussed in the next chapter) is 5.72 Mb/s.

The *effective bit rate*,  $F$ , is the average number of bits transmitted over an extended period of time.  $F$  is given by

$$F = B \times (\text{fraction of the data lines in the TV signal}) \\ \times (\text{portion of the TV line carrying data bits}).$$

For example in the U.K. teletext,

$$F = 6.9 \times (2/312.5) \times 0.81 = 35.7 \text{ kb/s}.$$

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Further parameters related to the effective bit rate are the effective character rate ( $F/8$ ) and the useful character rate,  $U$ . The latter is the average rate of useful characters, which are those characters remaining after overhead information in a data line (such as addressing and error control) is discounted. (Evidently, the designation "useful" is subject to interpretation: is a display attribute character overhead or useful?) From  $U$ , the line and page rates are easily obtained. In U.K. teletext (40 characters per display row, 24 rows per page, 40 useful characters out of 45 per data line, 2 data lines per field), the page rate works out to 4.13 pages/s. Thus the average waiting time in a 160-page teletext cycle is about 20 seconds.

Transmission rates for full field operation are calculated similarly. Taking 300, instead of 2, lines in each field will give some 600 pages/s. Rates attainable in NTSC are slightly reduced due to the smaller bandwidth of NTSC.

The following rule of thumb can be used both in Europe and U.S.: for each scan line devoted to teletext in a TV frame, the transmission rate is one page per second.

### Error Handling in DOV

A number of DOV system characteristics enter into consideration in the design of suitable error strategies. First, the basic system is one-way. Therefore the forward data flow cannot be interrupted for retransmission of erroneous packets of information. Although much (but not all) information is cyclically retransmitted, the cycle time is too long to be relied upon systematically for error correction. As a result, forward error correction techniques are used.

Further considerations touch upon error probabilities and statistics, which are investigated in numerous field tests and other experiments. The principal parameters having influence on the occurrence of errors are the transmitter power, conditions of TV reception (especially in urban areas, in which waves reflected from buildings, hills, etc., cause the received signal to be the vector sum of a multiplicity of signals arriving over many paths), bit transmission rates, and the implementation of the receiving equipment. One important finding from a European field test (see Blineau, 1980) is that most errors are single bit errors and not bursts.

There is a fundamental difference between European television reception and North American television reception. In most European countries there are but two or three programs transmitted over hundreds of repeaters. Nearly everyone can receive at least one good signal for each program. In addition, television receivers are substantially more expensive. Thus, the proportionate cost of a quality antenna is less. Furthermore, most European stations are UHF. Since UHF wavelengths are shorter than VHF wavelengths, UHF antennas are less expensive, have higher gain, and are more effective in discriminating against ghosts (faint shifted images appearing on the screen due to multipath propagation). In the U.S., the situation is opposite in almost every respect. There are over 1000 stations in the U.S., and almost no repeaters; nearly everyone is certain to receive at least one poor signal. Most transmitters are VHF, requiring larger, more expensive, less directional, and lower-gain antennas. Because color receivers are so inexpensive, a quality antenna installation may exceed the cost of the receiver. Thus,



Americans are accustomed to purchasing a color receiver with "rabbit ears" and expecting perfect reception.

Furthermore, U.S. rules on ignition and electrical motor brush noise are much less stringent than are European rules. One need only have a teenage daughter with a hair drier to know that errors caused by motor noise destroy more than one bit. Watching the television screen with this kind of interference yields broad bands of bursty noise.

A particularly troublesome case is that of close-in ghosts. These are caused by reflections from structures very close to the transmitting antenna. The result is not a separate ghost image, but rather a blurring or smearing of the image. This defocusing of the picture is undesirable but by no means catastrophic. The picture is usually perfectly watchable. However, the consequences for teletext data could be disastrous. This phenomenon of close-in ghosts is a serious but mostly unappreciated threat to the fortunes of teletext in the U.S. The threat is so severe that the EIA Teletext Committee formed a task force to study possible solutions to the problem.

Different types of errors and their consequences are more or less tolerable by the user. Each coding system has specific points of vulnerability that have to be carefully protected against error. More sophisticated coding schemes, such as Telidon, are generally more vulnerable than are simpler ones; as a consequence, all data sent in broadcast Telidon are covered by an error-correcting code, whereas only the address part of the U.K. teletext is protected by such a code.

### ***Technical Criteria Used to Assess Reception Quality***

In order to assess the performance of a given teletext system installation, some easily testable criteria must be established. One such criterion is the bit error probability and related measures of burstiness. However, such error statistics do not give a direct indication of the subjective quality of reception. A given error level may yield quite different results with different coding schemes and error strategies. Specialized equipment is also required for such measurements.

Croll (1977) describes a set of simple criteria suitable for judging teletext reception (and encompassing the entire system from the transmitter to the receiver's screen). They are (in order of decreasing stringency):

- no errors received in 10 seconds of transmission
- no visible errors in each of three consecutive new acquisitions of one page
- no errors remaining after two writes of one page (each character of a page is error-free in at least one of two consecutive receptions)
- about half of the characters correct for each new acquisition of one page.

It is suggested by Croll that complying with the second or third criterion should yield acceptable reception quality.

**Eye height.** Another method commonly used to judge the quality of received teletext signals is the so-called *eye height* test. As will be discussed in Chapter 9, the

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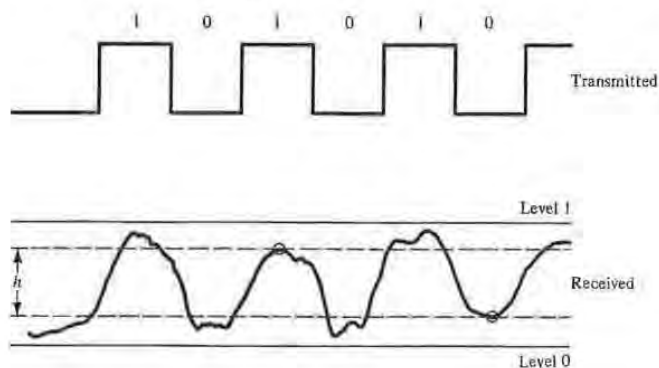
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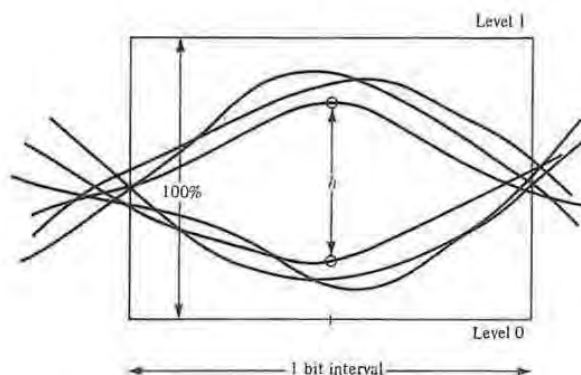
he quality of received ssed in Chapter 9, the

waveform obtained after demodulation of data line is more or less deteriorated, as shown in Figure 4.8(a). This deterioration is due to factors such as intersymbol interference and noise. Intersymbol interference is the smearing of one logic signal into the time space occupied by another. Principal causes of such interference are bandwidth limitations and multipath propagation. An important parameter that has impact on the occurrence of decoding errors is the difference,  $h$ , between the lowest received value for a 1 and the highest received value for a 0 (over some period of time).

The value of  $h$  (as a percentage of the distance between the 0 and 1 reference values) can be measured directly by displaying the received signal. That is, waveforms in individual bit periods are displayed superimposed on a screen, creating the typical



(a)



(b)

Figure 4.8 (a) Deterioration of received signal; (b) display of eye and determination of eye height  $h$ .



eye-shaped pattern shown in Figure 4.8(b). The value of  $h$  is read in the middle of bit intervals. Under normal receiving conditions the eye height is about 60–80%, but most receivers are capable of handling values as low as 25% without too many errors. Note that other attributes of the eye, such as eye width and shape, are also significant (for more details, see Lucky and Saltz, 1968).

### Error Detection and Correction

Current DOV systems use combinations of various error correction and detection techniques. See Peterson and Weldon (1972) for a comprehensive treatment of error-correcting codes. Vertical parity checks (one parity bit per character) permit the *detection* of an odd number of errors in each individual character. A combination of vertical parity and horizontal (longitudinal) parity (or checksum) enables the *correction* of any single error in a data block. The commonly used (8,4) Hamming encoding provides for the automatic correction of any single error and for detection of all multiple-bit errors in groups of four bits. Hamming codes have high redundancy and they are therefore used mostly on sensitive information, such as addressing and packet sequencing.

Figure 4.9 shows a block of 7-bit characters, each accompanied by a vertical parity bit. Appended to the end of the block is a longitudinal parity character,  $C$ . Parity bit  $p_i$  is generated by the transmitter in such a way that the number of 1's in the transmitted group of eight bits is, say, odd (even parity systems are also used). For example, if the character to be transmitted is 0110001,  $p_i$  will be 0. At the receiving end, the parity is recalculated from the received character bits and checked against the received  $p_i$ ; if the two are different, the character is considered to be erroneous (although it may be that only  $p_i$  is in error). If the two bits are equal, the character is considered to be correct (although it may contain an even number of errors that cannot be detected by simple parity checks). However, two (four, six, etc.) errors in a character are generally much less likely than is a single error; this is why parity checks work well most of the time.

Bits in the parity character are generated in a similar way as above, one for each line in the data block shown in Figure 4.9. If a single error occurs in the data block, it can not only be detected, but also corrected. This correction is done by inverting the bit at the intersection of the column (character) and line in which the error is detected. A potential problem with longitudinal parity, especially in larger data blocks (e.g., of 1024 characters) is the increased probability of multiple errors in a line. Solutions include inserting parity words at shorter intervals (e.g., after every 32 characters) or using multiple check bits, called collectively *checksums*, at the end of the block. As a direct extension of the parity method,  $n$  check bits for a line might represent the sum modulo  $2^n$  of a line ( $n = 1$  for even parity).

**Hamming codes.** Another form of multiple parity checks used for error correction is found in Hamming codes. In the variant commonly used to protect control infor-

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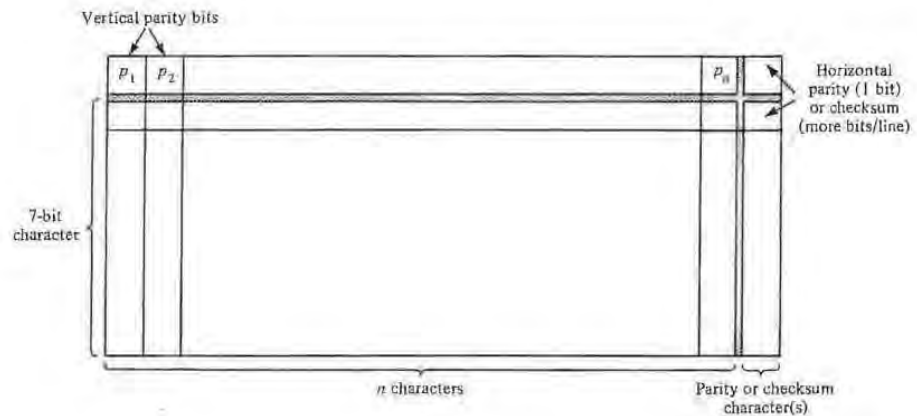


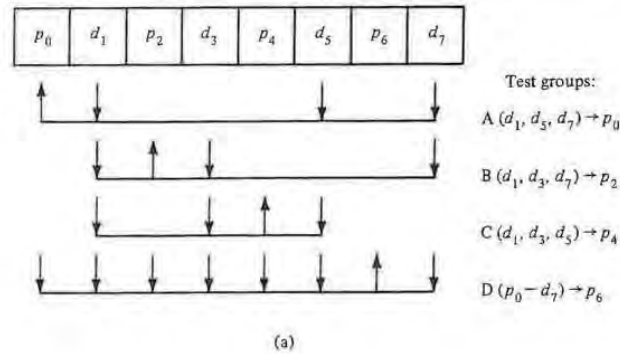
Figure 4.9 Horizontal and vertical parity and checksums.

information in DOV systems, and called the (8,4) Hamming code, four check bits are used to protect four data bits in each byte. The parity checks apply to different groups of data bits in such a way that each possible outcome of the parity checks singles out a unique data bit which must be in error (assuming that only one error occurred in the transmission of the whole byte). Figure 4.10(a) shows a Hamming-encoded byte;  $d$  and  $p$  are data and parity bits respectively. Groups of data bits used to generate parity bits are also shown. The same groups, including the parity bit, are, at reception, subject to separate parity tests  $A$ ,  $B$ ,  $C$ , and  $D$ . Note that  $p_6$  is the ordinary parity involving all bits; it is used to discriminate the case in which only one error is present. One can see, for example, that bit  $d_5$  contributes to the formation of parities  $p_0$ ,  $p_4$ , and  $p_6$ ; therefore, if  $d_5$  is received with error, parity checks  $A$ ,  $C$ , and  $D$  will fail. Figure 4.10(b) summarizes all possible cases and the corrective actions to be taken (for example, inversion of the data bit in question).

### General Data Format in DOV

Figure 4.11 illustrates the general format of a data line transmitted in DOV. In the terminology of the Open Systems Interconnection model, the data line is composed of two parts: Delivery Protocol Control Information (DPCI) and Delivery Service Data Unit (DSDU). Also shown in the figure are some related terms used in teletext jargon.

DSDU signifies information that is transferred to the higher (presentation and application) level protocols. DPCI groups all control information needed for the correct functioning of the delivery protocol. The bit and character synchronization sequences



A	B	C	D	Result
0	0	0	0	No error
1	0	0	0	
0	1	0	0	
1	1	0	0	
0	0	1	0	More than one error, reject
1	0	1	0	
0	1	1	0	
1	1	1	0	
0	0	0	1	data bits OK
1	0	0	1	data bits OK
0	1	0	1	data bits OK
1	1	0	1	$d_7$ in error
0	0	1	1	data bits OK
1	0	1	1	$d_5$ in error
0	1	1	1	$d_3$ in error
1	1	1	1	$d_1$ in error

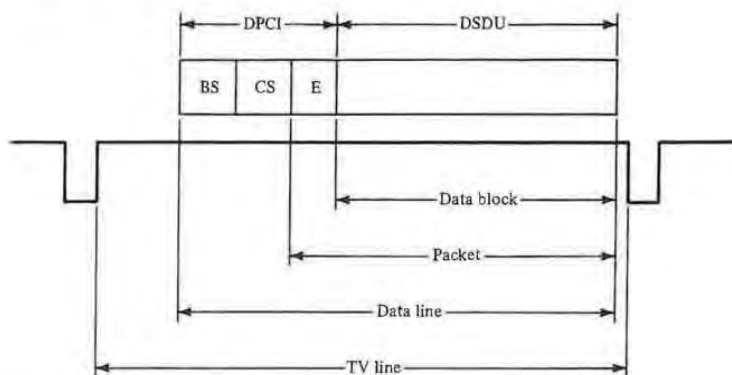
0: Parity check OK  
1: Parity check fails

(b)

**Figure 4.10** (a) Generation of parity bits  $p_0, p_2, p_4, p_6$  from data bits  $d_1, d_3, d_5, d_7$  in (8,4) Hamming code; (b) error correction in (8,4) Hamming code.

invariably occur at the beginning of the data line; they usually consist of fixed bit patterns serving to establish bit and character synchronism.  $E$  denotes collectively all error detection and correction bits that actually may be spread out over the whole line. The other elements of DPCI may change from one system to another; they will be illustrated by the examples in the next chapter.

s:

 $\rightarrow p_9$  $\rightarrow p_2$  $\rightarrow p_4$  $\rightarrow p_6$ 

BS: Bit synchronization  
 CS: Character synchronization  
 E: Error correction bits  
 DPCI: Delivery Protocol Control Information  
 DSDU: Delivery Service Data Unit

**Figure 4.11** General format of DOV data line.

n (8,4) Hamming code;

st of fixed bit pat-  
 ollectively all error  
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 / will be illustrated



# THE ARCHITECTURE OF VIDEOTEX SYSTEMS

JAN GECSEI

In this new book **Jan Gecsei** focuses on the technical aspects of television-based videotex systems. Videotex, a recent development combining advances in computers, telecommunications, and consumer electronics, offers easy access to a variety of information services both to the public at large and to business customers.

*Based on the ISO Open Interconnection model (OSI) and divided into five parts, the book:*

- provides an introduction to videotex and background material about similar systems and computer networks;
- treats the communications media and networks used in videotex (corresponding to OSI layers 1-5);
- discusses the presentation level (layer 6), treating in detail the image-coding options in current use, their impact on terminal design, and the related problems of national and international standardization;
- covers the application level—deals with databases for videotex and teletext, gateways, service computers, and service providers' equipment;
- touches upon themes important for the future of videotex: alternative methods of interfacing with the user, telesoftware (seen as the key to distributed processing in videotex), and methods of performance evaluation.

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