DOCUMENT FACSIMILE

In the Hush-A-Phone Case in 1956, the United States Courts of Appeals for the District of Columbia ruled that the telephone could be used in ways that were "privately beneficial if not publicly detrimental." The interpretation placed upon this was that it would be legal if the facsimile signal could be converted into sound and introduced into the telephone handset with the sound being recovered at the other end and then used to produce a paper copy. This was subject to the facsimile signal not interfering with the telephone switching, control, and billing systems, nor overloading the telephone circuit.

Until 1962, telephone companies prohibited any form of transmission other than voice over the telephone network with one exception. This exception was the transmission of news photographs which had been allowed since 1935 due to the availability of the telephoto coupling coil. However, the speed was restricted to 45 scans/min and a scanning density of 96 lines/in. which required 24 min to send one page. Subsequently the transmission of fingerprints was deemed to be "in the public interest" and specialized equipment based upon new photo equipment was developed for use by law enforcement agencies. However, the transmission of business or personal documents remained forbidden.

In 1962, AT&T introduced the Dataphone Data Set 602A to provide facsimile communication over the telephone network. Unfortunately, this did not provide the facsimile terminal with sufficient control over the control logic and no control at all over the modem. The introduction of the acoustic coupling placed the control of the whole signal in the hands of the terminal manufacturer. During 1966, Xerox introduced the Xerox/Magnavox Telecopier which used a frequency shift form of frequency modulation (FM) with "white" represented by 1500 Hz and "black" by 2450 Hz

In the early 1960s, document facsimile terminals had been developed by a number of manufacturers; these were usually incompatible with each other due to the use of different parameters. It was recognized by the manufacturers that a significant market for facsimile would only exist when compatibility was provided. It was at this stage that the International Telephone and Telegraph Consultative Committee (CCITT) began work on producing standards for facsimile terminals. In 1993 a reorganization in the International Telecommunications Union (ITU) resulted in the CCITT being renamed the International Telecommunications Union–Telecommunications Standardization Sector (ITU-T). For simplicity, ITU-T will be used hereafter.

The first type of facsimile terminal defined by the ITU-T was referred to as Group 1 and was defined in ITU-T Recommendation T.2 (2). These terminals transmit an A4 page in 6 min using frequency modulation with a "white" signal corresponding to 1300 Hz and a "black" signal corresponding to 2100 Hz. The page was scanned vertically at 3.85 lines/mm at a rate of 180 lines per minute. At this time the technology still used rotating drums at the transmitter and the receiver, and consequently the Recommendation also defined the other parameters necessary to maintain synchronization, and so on. Exact details of the other parameters can be found in Ref. 2. The "white" and "black" frequencies specified in Recommendation T.2 are different from those used by the Xerox/Magnavox Telecopier because of the slightly different characteristics of the telephone networks in Europe.

Although Recommendation T.2 was agreed in 1968, implementation of terminals conforming to it was fairly limited, specifically because there was a requirement to decrease the transmission time. This led to the adoption of ITU-T Recommendation T.3 (3) in 1976, which defined Group 2 facsimile terminals. These terminals transmitted an A4 page in 3 minutes using amplitude modulation/vestigial sideband modulation system with a carrier frequency of 2100 Hz. The "white" signal corresponded to the maximum carrier level and the "black" signal to the minimum carrier level (at least 26 dB below "white") or no carrier. The reduction in transmission time was achieved by increasing the scanning line frequency to 360 lines per minute. Exact details of the other parameters can be found in Ref. 3.

Group 2 terminals were produced in significant numbers, and with advances of technology the use of drum-type transmitters and receivers began to be replaced by flat-bed scanners and printers. With flat-bed scanners and printers, the paper is physically moved across the scanning or recording mechanisms.

In 1980 the ITU-T adopted Recommendation T.4 (4) which defines the technical characteristics of Group 3 facsimile terminals.

The definition of Group 3 is that it incorporates means for reducing the redundant information in the document signal prior to the modulation process and can achieve a transmission time of about 1 min for a typical type script A4 size page over a telephone circuit. Group 3 terminals predominate in the market today with effectively no Group 1 and Group 2 terminals in use. The exact definition of all groups of facsimile terminal can be found in ITU-T Recommendation T.0 (5).

GROUP 3 FACSIMILE TERMINAL OPERATION

A simple block diagram of a Group 3 facsimile terminal is shown in Fig. 1. The transmitting terminal scans the document and the output from the scanner is passed to a coder. This coder compresses the information; and its output is passed to the modulator, from which it is transmitted over the telephone network. The modulator converts the digital information into an analog form suitable for transmission over the telephone network. At the receiver the analog signals received from the telephone network are converted back to digital form by the demodulator. These digital signals are then passed through a decoder, from which the original information is recovered and then printed or displayed.

The basic modulation/demodulation system used provides a data signaling rate of 4800 bit/s with a fall-back to 2400 bit/s (6).

Group 3 terminals are sometimes referred to as "digital" facsimile; however, it should be noted that in this context the term "digital" applies to the scanning and printing methods and not the network over which the terminal operates. The

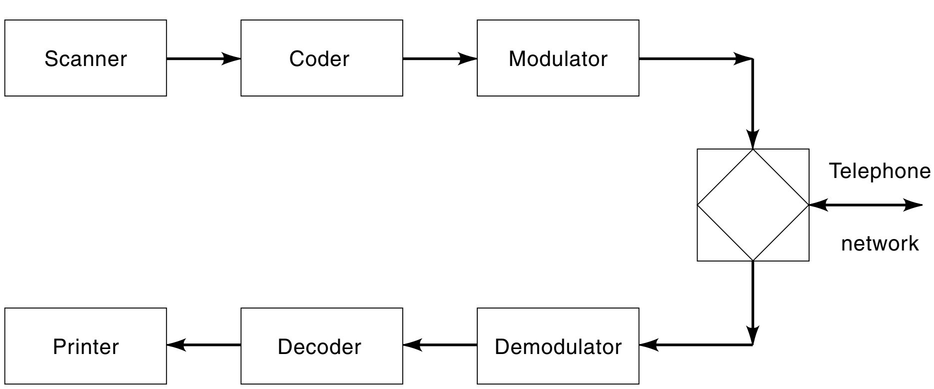

Figure 1. Simplified block diagram of a Group 3 facsimile terminal.

scanning process quantizes each picture element into either "black" or "white" while the printing process generates only "black" or "white."

CODING SCHEME

The document is scanned from the top left to the bottom right of the page. Across the width of the page each line is subdivided into 1728 picture elements (pels). In the vertical direction (i.e., down the page), the document is scanned at 3.85 lines per mm. At this scanning density an A4 page (297 mm long) produces approximately 1145 lines. Without any compression, the volume of data to be transmitted is 1728×1145 bits—that is, about 1.98 Mbits. At 4800 bit/s this corresponds to a transmission time for the page of over 6 min. The scanned data contains redundancy, and therefore it is possible to reduce the amount of information to be transmitted. The reduction in the amount of data depends upon the content of the original document, but for a typical page of type script it is by a factor of about 10.

The redundancy reduction method is based upon the work by D. A. Huffman (7), and the scheme adopted by ITU-T is known as the "modified Huffman" and operates in the following way. Examination of a scanned line shows that the frequency of occurrence of certain runs of pels of the same color along the scanning line are much more common than others. If a binary code is transmitted corresponding to the length of each run instead of transmitting the pels directly, the number of bits to be transmitted can be reduced. Based on the probability distribution of run lengths, it is possible to optimize the allocation of codes by associating the shortest codes with the most frequently occurring run lengths. A convenient analogy is Morse code where the most commonly occurring letter—that is, "E" is allocated the shortest code, namely a "dot." Figure 2 shows the result of the coding process on the output of the scanner. Full details of the coding scheme are contained in Ref. 4.

With redundancy reduction, the effect of transmission errors is increased, resulting in the decoded received information giving false run lengths. The modified Huffman coding scheme resynchronizes, although the correct run lengths are shifted relative to their correct position. To provide resynchronization for the coding irrespective of errors, a unique "End Of Line" (EOL) code is included at the end of each line (4). This code enables the receiver to determine whether a line has been received in error since the decoded information between two successive EOLs should correspond to 1728 pels. The code chosen for EOL is one that is not simulated by the coding of the image. Figure 3 shows the effect of a single error on a scan line.

SCANNING SYSTEMS

The two most commonly used types of scanning systems are charge coupled devices (CCD) and contact image sensors (CIS).

CCD Scanners

In this type of scanner the area of the page being scanned is illuminated, typically using a fluorescent lamp and a size-reduced image of the page is focused on to a CCD chip. The CCD has 1728 photosensors in a straight line. The distance between the scanning line and the CCD chip needs to have an optical path length of typically 30 cm; mirrors can be used to reduce the physical separation. A stepper motor moves the page over the scanner.

The photosensor elements consist of a light-sensitive resistor in parallel with a capacitor which is fully charged before each line is scanned. If the part of the page focused on to a particular photosensor is "white," the resistor has a low value and the capacitor voltage is drained off. If the image is "black," then the resistor has a high value and the capacitor is not discharged. The scanning line is read by inspecting the

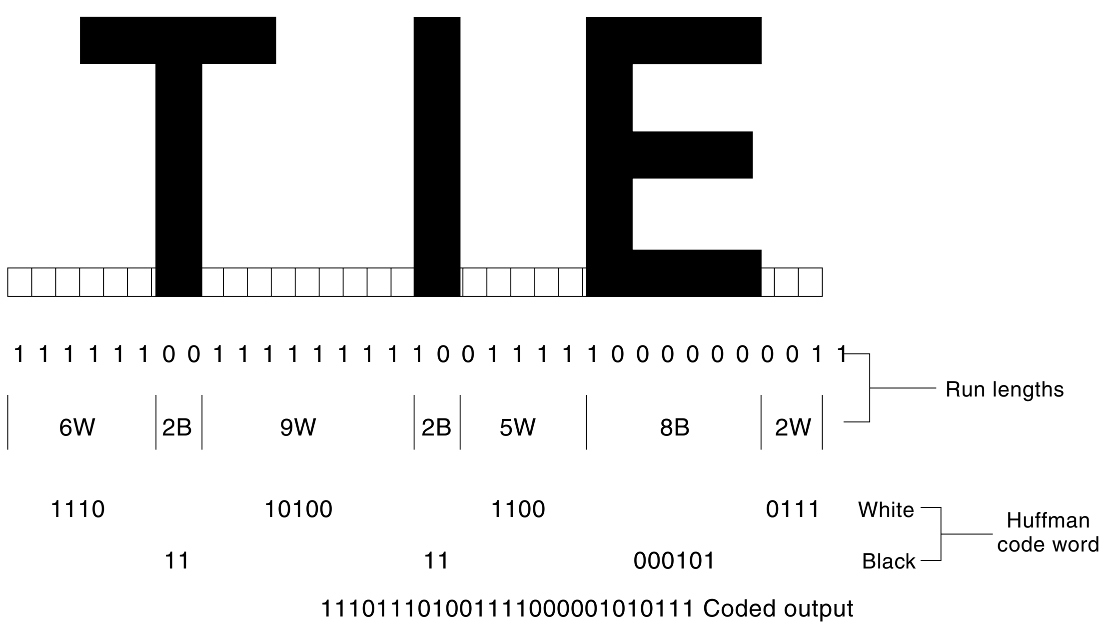

Figure 2. Result of run length coding process.

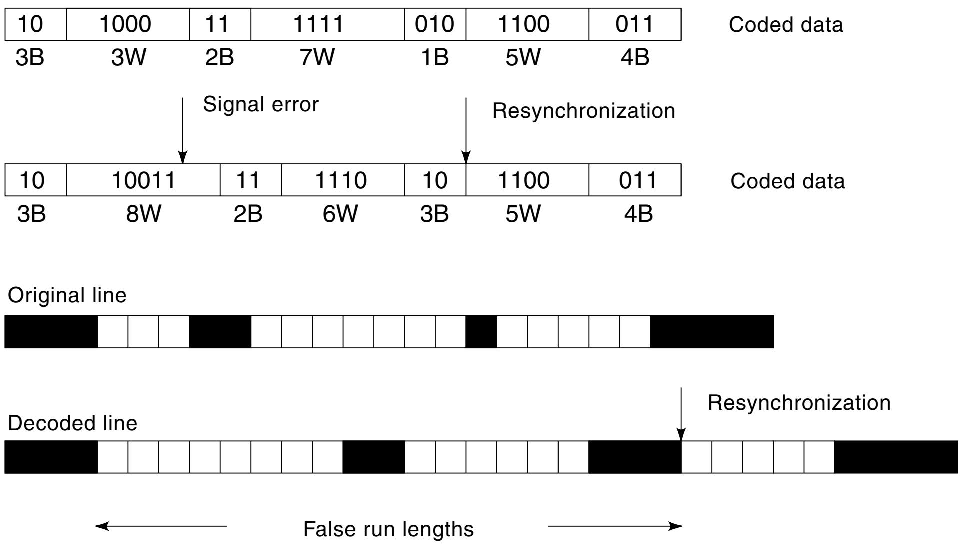

Figure 3. Effect of an error on a single-coded scan line.

current pulse into each capacitor as the photosensor is charged for the next line.

CIS Scanners

Contact image sensor (CIS) scanners include all the scanning elements in a block which is in "contact" with the page being scanned. There are two basic types of CIS scanners: one using an optical arrangement to focus the image and the other which is in full contact with the page being scanned.

In the former type, a narrow bar containing rod lens fiber optics is mounted between the page and the photosensors. The page is illuminated either by a fluorescent lamp or by light-emitting diodes (LED) built into the bar.

With the "full contact" type of CIS, a small window is provided in each sensor element through which an LED illuminates the page. The light is reflected back from the page on to the sensor. A thin transparent coating keeps the page a small distance away from the sensor elements.

RECORDING METHODS

A number of different recording methods are used, and the basic principles of the most commonly used ones are given in the following paragraphs.

Thermal Recording

Thermal recording was the most popular (and cheapest) method of recording for many years. Thermal paper consists of a base paper impregnated with a colorless compound which turns "black" when heated above a particular threshold. The recording mechanism consists of a line of tiny styli (usually 1728 per line) which are in contact with the surface of the paper. The individual styli are heated or not, dependent upon whether the corresponding pel is "black" or "white."

The disadvantage of thermal recording is that over several years the action of heat and light can cause degradation in the copy quality; also, the copy can be affected by storage in plastic folders. Consequently, thermal copies are not considered as being archival by some users.

The advantages of thermal recording are that it is cheap and that the printing system is physically small and reliable (the printer lasts the life of the terminal).

Plain-Paper Recording

Demand for facsimile messages to be recorded on plain paper resulted in plain paper recording becoming almost as common as thermal recording. In general, plain paper recording mechanisms are physically larger than thermal ones. Various plain-paper recording techniques are in use today; these are summarized in the following sections.

Ink Jet Recording. The ink jet recording concept is to place ink on the paper where a "black" pel is to be recorded. In the facsimile field, various techniques can be used; however, most terminals utilizing this method use a piezoelectric crystal which changes shape when a voltage is applied to it. This change of shape is used to force ink from the reservoir through the nozzle on to the paper.

The advantage of this method of recording is that it uses plain paper requiring no special treatment. The disadvantage lies in the problems of making sure that the ink stays liquefied and that the nozzles remain clear over the range of normal office environments.

Thermal Transfer Recording. With this method, a thermal transfer film is placed between a thermal head and the recording paper. The thermal head is the same type as used for thermal recording. Where a "black" pel is required on the paper, the appropriate element on the thermal head is heated and the ink from the film is transferred to the paper. The film and the recording paper move at the same rate so they are used in the same quantities. The used film is stored on a take-up reel and is replaced when a new roll of recording paper is put into the terminal. Because the used film contains a negative version of all the messages received, there is the potential for a loss of confidentiality.

Laser Beam Recording. Laser beam recording systems operate in basically the same way as xerographic type office copiers except that, instead of directly imaging the copy on to the photosensitive drum, the received facsimile signal is used to modulate a laser beam which records the received image on the drum.

In a typical implementation, the beam from the laser is swept across the drum by a rotating polygonal mirror with each face of the mirror making one recording line. Focusing lenses are used to keep the spot in focus along the recording line, and the drum rotates the equivalent of one recording line for each sweep of each mirror face.

The photosensitive drum is initially charged and those parts exposed to the laser beam have the charge neutralized. Toner is then deposited on to the parts of the drum which correspond to the "black" pels on each recording line. The toner is then transferred from the drum on to the paper, where it is subsequently fixed by heat and/or pressure.

Light-Emitting Diode (LED) Recording. This type of recording is essentially the same as the laser beam method except that the laser and rotating mirror are replaced by an LED array. Each LED in the array is focused on to the photosensitive drum using a fiber-optic lens. This type of recording system is more reliable than the laser beam because the rotating mirror has been removed.

GROUP 3 COMMUNICATION PROTOCOLS

A detailed specification of the Group 3 facsimile protocol can be found in ITU-T Recommendation T.30 (8).

A Group 3 facsimile call consists of five separate and consecutive phases as follows:

1. Phase A: call establishment, which can be either manual or automatic
2. Phase B: pre-message procedure for identifying and selecting the required facilities
3. Message transmission
4. Phase D: post-message procedure including end of message and confirmation and multidocument procedures
5. Phase E: call release

In phases B, D, and E, the signals between the two terminals are sent in a high-level data link control (HDLC) format at 300 bit/s using the modulation system defined in ITU-T Recommendation V.21 (upper channel) (9).

In phase C, the message is sent on a line-by-line basis using the modulation system defined in ITU-T Recommendation V.27*ter* (6). At the receiver, each line takes a finite time to record and it is possible that the time taken to transmit the line could be less than the recording time. The basic requirement is that all terminals must be able to record a line in 20 ms; however, as technology has progressed, the vast majority of terminals can now achieve 5 ms or 10 ms per line. As an example, an all "white" line is coded as "Make up" code 00110101 + "Terminating" code 010011011 (4) + EOL 000000000001—that is, 29 bits, which takes 6.04 ms to transmit at 4800 bit/s. Consequently the transmitter has to insert some redundant bits to allow the receiver to keep up. These redundant bits are known as "fill" bits. In the case of this example, the number of the fill bits is equivalent to a duration of 13.96 ms. The digital identification signal (DIS) from the called terminal indicates its recording time so that the appropriate number of fill bits are inserted when necessary.

As phase C utilizes a different modulation system from that used in phases B, D, and E, an indication must be given to the receiver when the modulation system will be changed—that is, at the end of the image data. This indication is provided by the "return to control" (RTC) signal which is sent at the end of the message. The RTC signal corresponds to six consecutive EOL signals.

Signal Sequence in a Typical Facsimile Call

The sequence of signals in a typical facsimile call is summarized in the following paragraphs. The example used is for the case when the calling terminal wishes to transmit a message. For simplicity the example considers only the standard signals and the sending of a single page.

The calling terminal dials the number of the destination terminal which detects the incoming ringing, answers the call, and sends a sequence of signals indicating its capabilities. The first signal transmitted is the "called station identification" (CED), which is a 2100 Hz tone and is used to indicate a nonspeech terminal. This is followed by the "digital identification signal" (DIS) which indicates all the standardized capabilities which are available at the receiver.

Recommendation T.30 (9) includes the capability to send standardized optional signals before DIS. These optional signals are "nonstandard facilities" (NSF) and "called subscriber identification" (CSI).

The NSF frame indicates any proprietary features that the terminal may include. Most manufacturers include such features as a means of providing differentiation between their and other manufacturers' products while still maintaining the basic level of capability. The CSI frame indicates the identity of the called terminal, normally by its international telephone number.

The transmitter checks the DIS signal to ensure that the parameters which it wishes to use to send the message are available at the receiver. If they are, then it responds with the "digital command signal" (DCS), which specifies the precise parameters chosen. This signal is immediately followed by a modem training signal and a "training check frame" (TCF). The training signal is sent at the highest data signaling rate that is available in both terminals. The TCF signal enables the receiver to determine whether or not the connection is likely to support the rate chosen. Assuming that the quality of the connection is satisfactory, the receiver responds with the "confirmation to receive" (CFR) signal. The transmitter then sends a short retraining sequence followed by the message.

At the end of the message, the transmitter sends the "end of procedure" (EOP) signal indicating that the document has been sent and implicitly asks for a response indicating whether the received quality is acceptable. If the quality is acceptable, then the receiver sends a "message confirmation signal" (MCF). Following receipt of MCF, the transmitter sends the "Disconnect" (DCN) signal to indicate to the receiver that it should clear the connection. Additional signals are defined to enable the receiver to indicate that the received copy quality is either acceptable "retrain positive" (RTP) or unacceptable "retrain negative" (RTN), but retraining the modem might improve subsequent messages.

GROUP 3 ERROR CORRECTION MODE

In the basic mode, Group 3 terminals do not have an error correction mechanism. If a received scan line is detected as being in error, different techniques are used to conceal the error. These include printing the previous line again, printing an all "white" line, printing the line as received up to 1728 pels, or omitting the line. The choice of which technique is used is an implementation matter and is not standardized.

The ITU-T has standardized an error correction mode (ECM), and the procedure differs only slightly from the basic mode of operation. Full details of the error correction mode can be found in Annex A (4) and Annex A (8).

The significant area of difference is in phase C, where the coded information is put into HDLC frames, with each frame consisting of 2048 bits (256 bytes) instead of being transmitted as a continuous series of bits. Each page can consist of a block of up to 256 frames, with each frame numbered sequentially numbered from 0 to 255; if the page is longer than this, it is sent as a series of partial pages. After sending each block of 256 frames, the transmitter stops and requests confirmation of satisfactory reception. If the received document has no errors, the receiver sends MCF; but if some of the received frames contain errors, it sends the partial page request (PPR) signal indicating the number(s) of the frames required to be corrected. The transmitter then resends only these frames. The use of ECM requires the inclusion of a page memory—that is, 256 frames each of 256 bytes or 64 bytes.

The modified Huffman and modified READ coding schemes defined in Ref. 4 both provide mechanisms to enable the receiver to detect and restrict the effect of errors caused by noise on the line. With ECM, such mechanisms are not necessary because the protocol corrects any such errors. This means that the image can be coded as one long block of data, thus reducing the number of bits to be sent because no redundancy is required. This allows the use of a full two-dimensional coding scheme referred to as modified modified READ (MMR) and is defined in ITU-T Recommendation T.6 (10). This coding scheme was originally developed for Group 4 terminals.

The basic technical characteristics of Group 3 can be summarized briefly as follows.

BASIC AND OPTIONAL FEATURES FOR GROUP 3

Basic Features

Resolution. 8 pels/mm horizontally (approximately 203 pels/in) × 3.85 lines/mm vertically (approximately 98 lines/in.) (4)

Coding Scheme. Modified Huffman (4)

Protocols. Recommendation T.30 (8)

Data Rate. 2400/4800 bit/s (4,6)

Optional Features

As well as the basic features outlined above, a number of optional features have also been standardized by ITU-T. These are summarized in the following paragraphs.

Scanning Density. Vertical scanning densities of 7.7 lines/mm (approximately 196 lines/in), 15.4 lines/mm, 200 lines/in., 300 lines/in., 400 lines/in. for higher-quality reproduction (4). The vertical inch-based densities are used with identical horizontal inch-based densities. The inch-based densities are included to provide compatibility with computer peripheral equipment.

Coding Schemes. A number of optional-based coding schemes are defined, and those current at the time of writing are briefly outlined below.

The "modified READ" scheme reduces the redundancy in both the vertical and the horizontal directions; hence it is sometimes called a "two-dimensional scheme." It gives a lower transmission time because of the two-dimensional redundancy reduction. With modified READ coding, the position of a changing picture element on one line is coded relative to a corresponding changing picture element on the preceding line. Details of the READ coding scheme can be found in Ref. 4. The term "READ" coding is derived from "relative address" coding.

Several color-coding schemes have been defined. In this context the word "color" is used to cover both color and grayscale images.

One optional continuous-tone color mode is defined in Annex E of Ref. 4, and the method for the transmission of color images is based upon ITU-T Recommendations T.42 (11) and T.81 (12). The former Recommendation defines a device independent interchange data representation (including a color space, the white point, illuminant, and gamut range used) and is a subset of that specified in Ref. 12. ITU-T Recommendation T.81 defines a progressive coding scheme which is applicable to a wide range of applications not just facsimile and includes both lossy and lossless compression. This Recommendation was developed jointly with the Joint Photographic Experts Group (JPEG) of ISO/IEC, and the text is identical with ISO/IEC International Standard 10918-1. The coding scheme is sometimes referred to as the "JPEG" scheme.

Another optional color mode is defined in Annex G of Ref. 4. In this mode, the data representation method is defined in ITU-T Recommendation T.43 (13), and the images are encoded using a lossless compression scheme as defined in ITU-T Recommendation T.82 (14) with the color representation, bit-plane decomposition, and coding methods as defined in Ref. 11. Recommendation T.82 defines three types of coding methods: (1) single-progression sequential coding, (2) progressive-compatible sequential coding, and (3) progressive for bilevel images. These methods were produced jointly between the ITU and ISO/IEC by a joint bilevel experts group (JBIG), and the scheme is sometimes referred to as the "JBIG" scheme. Associated with Ref. 14 is ITU-T Recommendation T.85 (15), which defines an application profile for the use of the single-progression coding method. At the time of writing, the other two methods had not been specified for use with facsimile.

A third optional coding scheme is defined in Annex H of Ref. 4 which refers to the coding scheme in ITU-T Recommendation T.44 (16). The coding scheme operates on the principle of separating the image data into layers based upon the importance of the data relative to its importance to the total content of the document. A three-layer model is used which identifies three basic types of data. The first type is for data which are associated with continuous-tone images requiring high color but intermediate to low spatial resolutions. The second type is for bilevel data which are associated with high detail text requiring low color but high spatial resolutions. The third type is for multilevel data associated with multilevel colors of text (or line art) requiring high color but intermediate to low spatial resolutions. Each of the layers is compressed and transmitted separately. Full details of the coding scheme are in Ref. 16.

Data Signaling Rates. Advances in modem technology and associated increases in data signaling rate on the switched telephone network are reflected in the range of optional rates defined for Group 3. Those defined are:

- 9600 bit/s with fall-back to 7200 bit/s using the modulation system defined in ITU-T Recommendation V.29 (17).
- 14,400 bit/s with fall-back to 12,000, 9600, and 7200 bit/s using the modulation system defined in ITU-T Recommendation V.17 (18). The fall-back rates of 9600 bit/s and 7200 bit/s of the V.17 modulation system are not compatible with that of Ref. 17.
- 33,600 bit/s with fall-back in integral multiples of 2400 bit/s to 2400 bit/s using the modulation system defined in ITU-T Recommendation V.34 (19). These fall-back rates are not compatible with either those in Ref. 18 or those in Ref 17. With this modem, the pre-message and post-message procedures use the modem control channel instead of the V.21 system (9). The former operates at a data signaling rate of 2400 bit/s. Details of the operation are contained in Annex F of Refs. 8 and 19.

Security Capabilities. To provide secure transmission of facsimile messages including authentication of sender and recipient and encryption of the message, two optional schemes are defined. One uses a key management system based upon the exchange of a one-time key (referred to as the HKM system), and the other is based upon the use of public keys (referred to as the "RSA" system). The fundamental principles of the public key system were defined by Diffie et al. (20) and Rivest et al. (21). The HKM system is a fixed-key, zero-knowledge cipher one in which sender and receiver use different secret 64-digit random numbers. The system generates an asymmetric relationship between sender and receiver in a one-time registration process using a series of modular arithmetic calculations using 9 five-digit prime numbers. These primes are selected from a common set of 19. A similar set of calculations is used to encrypt and transfer a session key to be used by both sender and receiver in a symmetrical cipher. The system provides implicit authentication of sender and receiver. The security of the system depends on the unfeasibility of computing the random cipher string used to encrypt the session key.

The RSA system is a fixed-key zero-knowledge asymmetric one in which the sender and receiver use different but related keys, only one of which must be kept secret. In the standardized system, the default is that the "public" key is not associated with a certificate issued guaranteeing its authenticity. However, as an option, such a certificate may be used to confirm the validity of the public key of the sender. These certificates are issued by a "trusted third party." The system uses a modular arithmetic calculation of the order of 10 to the power of 400 to encrypt and transfer a session key to be used by both sender and receiver in a symmetrical cipher. The security of the system is based on the premise that it is computationally infeasible to factorize large numbers (of the order of 400 digits) that are the product of two large prime numbers, each consisting of 200 digits.

Full details can be found in ITU-T Recommendation T.36 (22) and Annexes G and H of Ref. 8, respectively.

Miscellaneous Features. A number of features are defined to provide capabilities such as selective polling of documents, use of passwords for transmission or reception, and subaddressing. Details of all such capabilities are contained in Ref. 8.

"Nonfacsimile" Modes. A number of nonfacsimile modes have been defined; in this context, "nonfacsimile" means that the message is sent using a format other than one of the facsimile coding schemes.

Several files of transfer modes are defined covering basic transfer mode (BTM), document transfer mode (DTM), and binary file transfer (BFT). See also ITU-T Recommendation T.434 (23) and electronic data interchange (EDIFACT); details are in Annex B of Ref. 4.

A coded character mode enables text messages to be sent, details are in Annex C of Ref. 4. Two mixed modes are defined: The first is based upon dividing the page into horizontal stripes as defined in Annex D of Ref. 4, and the second is based upon Processable Mode 26 as defined in ITU-T Recommendation T.505 (24).

GROUP 4 FACSIMILE TERMINALS

Group 4 terminals were defined by ITU-T in 1979, and a brief definition is that they are terminals that "provide essentially error-free communication over digital networks." The ITU-T Recommendations became available in 1983 and defined three classes of Group 4 terminal:

Class 1. Facsimile transmission and reception only

Class 2. Facsimile transmission and reception plus reception of basic Teletex and mixed mode documents

Class 3. Facsimile transmission and reception plus generation, transmission, and reception of basic Teletex and mixed-mode documents.

Teletex was a service defined by the ITU-T to enable text processing terminals to communicate (see Ref. 25). The inclusion of the references to Teletex arose because of the expectation that its use would become significant. The market did not accept Teletex, and in 1995 it was deleted from the ITU-T list of services. In 1996, references to Teletex were removed from the ITU-T Recommendations covering Group 4.

The technical characteristics of Group 4 are slightly different from those of Group 3. The basic horizontal and vertical resolutions are 200 pels/in. Full details of the terminal characteristics are contained in ITU-T Recommendation T.563 (26). The coding scheme defined in Ref. 10 is used because the Group 4 protocols include error correction.

The communication protocols are based upon the concept of the open systems interconnection (OSI) model. The first version of the session level protocol is more correctly called an "OSI-type" protocol, since it is not fully in conformance with the OSI model. This version is defined in ITU-T Recommendation T.62 (27). Subsequently, a second version of the session level protocol was defined in ITU-T Recommendation T.62*bis* (28) for use with ITU-T Recommendation X.215 (29) and X.225 (30), which are fully OSI-compatible. The transport level protocol is defined in ITU-T Recommendation T.70 (31). The communication application profile and document application profile are defined in ITU-T Recommendations T.521 (32) and T.503 (33), respectively.

The technical characteristics for Group 4 terminals were agreed during 1983 but the growth in the use of Group 4 has been minimal.

BASIC AND OPTIONAL FEATURES FOR GROUP 4

Basic Features

Resolution. 200 pels/in. (horizontally) × 200 pels/in. (vertically)

Coding Scheme. Modified modified READ (10)

Protocols. Recommendations T.62 (27) or T.62bis (28), T.70 (31), T.503 (33), and T.521 (32)

Data Signaling Rate. Up to 64 kbit/s (26)

Optional Features

As well as the basic features outlined above, a number of optional features have also been standardized by the ITU-T. These are summarized in the following paragraphs.

Scanning Density. 240 pels/in. (horizontally) × 240 pels/in. (vertically), 300 pels/in. (horizontally) × 300 pels/in. (vertically), and 400 pels/in. (horizontally) × 400 pels/in. (vertically).

Coding Scheme. The same optional color and gray-scale coding schemes defined for Group 3 are defined for use with Group 4 also.

Miscellaneous Features. The same features have been defined as for Group 3 to provide capabilities such as selective polling of documents, use of passwords for transmission or reception, and subaddressing. Details of all such capabilities are contained in Ref. 33.

"Nonfacsimile" Modes. The same file transfer capabilities have been defined as for Group 3, and details are in Annex B of Ref. 26. For Group 4, only one form of mixed mode has been defined; this is the Processable Mode 26 (20).

GROUP 3 TERMINALS ON THE INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

In 1991, proposals were made to define an option for Group 3 to specify a mode capable of operating at 64 kbit/s over the ISDN. The basic characteristics of the terminals remaining the same as for standard Group 3 except that the protocols are modified slightly to take advantage of the full-duplex link provided by the ISDN.

The principle area of difference between Group 4 and the Group 3 ISDN terminals is the protocols. The OSI protocols

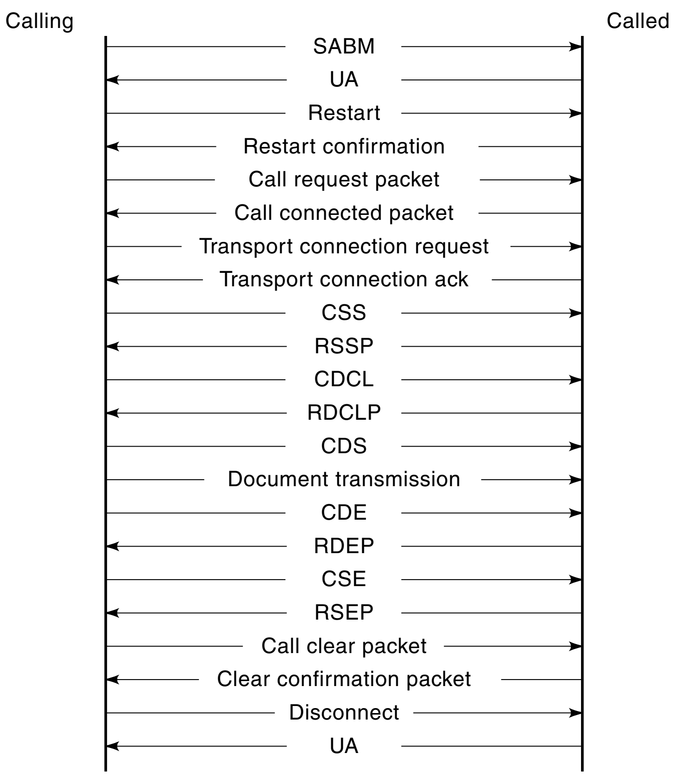

Figure 4. Signal exchange between terminals using OSI protocol.

are based upon packet switching principles—that is, where the terminals negotiate with their local packet switching node not directly with each other. The propagation delay between the terminals and the associated nodes is short because they are physically close together. The ISDN is a circuit-switched network; that is, once the connection is established, any negotiation is between the terminals directly. As it is necessary to establish each layer in the seven-level model before proceeding to a higher one, the propagation delay has a significant impact upon the overall communication time.

In order to quantify the extra time added by the OSI protocols, consider Fig. 4, which shows the signals exchanged between two terminals. A typical value for the propagation delay on a connection using one satellite hop is 300 ms. The pre-message commands and responses take 3.9 s (13 × 300 ms), and the post-message commands and responses take 2.4 s (8 × 300 ms).

For nontechnical reasons, the ITU-T agreed on two different options for Group 3 terminals to operate on the ISDN. One is based upon the OSI-type protocols and is defined in Annex F of Ref. 4, and the other is based on the Group 3 protocol and is defined in Annex C of Ref. 8. These are commonly referred to as G3F and G3C, respectively. The difference between Group 3F and Group 4 terminals is that the document application profile (33) specifies the use of the basic Group 3 resolution and coding scheme.

The purpose of the G3C protocol is to overcome the burden of the OSI protocols and uses the basic Group 3 protocol defined in Ref. 8 modified to remove the negotiation associated with the modulation system. The result is shown in Fig. 5. Using the same propagation delay as above, the pre-message exchanges take 0.6 s and the post-message exchanges take

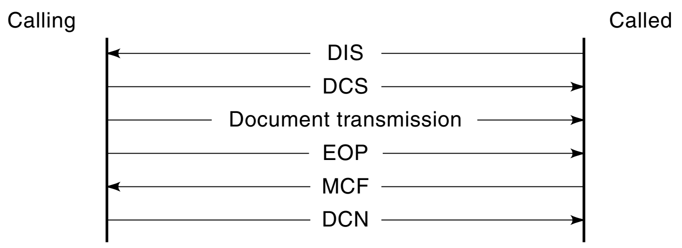

Figure 5. Signal exchange between terminals using modified Group 3 protocol.

0.6 s. The abbreviations used in Figs. 4 and 5 are defined in Table 1.

NETWORKS

When Group 3 was first standardized, the only widespread network available was the Public Switched Telephone Network. As technology has advanced, other networks have become available based upon digital technology. Reference has already been made to the ISDN, but other networks—specifically mobile networks—have evolved. Most wireless digital networks have a data transmission rate of less than 16 kbit/s, which will not support many of the higher data signaling rates standardized for Group 3 terminals. Techniques have been developed to enable terminals connected to mobile networks to interwork with those connected to the telephone network. The techniques used involve the demodulation and remodulation of the Group 3 signal, such that the voice-band signals are converted into digital signals suitable for transmission over the digital network. Communication between the mobile and fixed networks can be carried out either in real time or in a store and forward mode.

In the real-time case, the facsimile message is transmitted between the two terminals before the call is cleared. The advantage of this method is that confirmation of the message delivery is provided prior to the call being cleared.

In the store and forward case, the terminal communicates with the network, the message is stored within the network, and the originating terminal clears the call. Storage of messages in the network imposes a burden on the network operator as well as introducing complications regarding charging and confirmation of message delivery.

More detailed information on facsimile transmission over digital mobile networks can be found in Ref. 34.

The ITU-T has defined a number of Recommendations covering real time facsimile communication over packet switched public data networks. These defined in Recommendations X.5 (35), X.38 (36), and X.39 (37).

The European Telecommunications Standards Institute (ETSI) has defined a set of standards for communication over the GSM cellular network using both the transparent (real time) and nontransparent (store and forward) systems in GSM 03-45 (38) and GSM 03-46 (39).

Table 1. Abbreviations Used in Figs. 4 and 5

Abbreviation	Description
ACK	Acknowledgment
CDCL	Command Document Capability List
CDCLP	Command Document Capability List Positive
CDE	Command Document End
CDS	Command Document Start
CSE	Command Session End
CSS	Command Session Start
DCN	Disconnect
DCS	Digital Command Signal
DIS	Digital Identification Signal
EOP	End of Procedure
MCF	Message Confirmation
RDEP	Response Document End Positive
RSEP	Response Session End Positive
RSSP	Response Session Start Positive
SABM	Set Asynchronous Balanced Mode
UA	Unnumbered Acknowledgment

PC FACSIMILE

Advances in technology have resulted in the development of boards suitable for installation inside a personal computer (PC) to enable the PC to emulate a facsimile terminal. Facsimile messages can then be produced on a PC using a word-processing application and subsequently transmitted without the necessity of the document being printed and scanned. Such messages appear to the recipient to be of a higher quality, because there is no degradation due to the scanning system. Similarly, such devices can receive facsimile messages and display them on the screen, enabling the message to be retained in soft copy form or printed out.

ITU-T Recommendations T.31 (40) and T.32 (41) define interfaces for the control of a modem chip on a PC facsimile board or, alternatively, an external modem. A more complex alternative is offered by ITU-T Recommendation T.611 (42), which defines a control/command language across an application and communication interface.

For terminals located on a local area network, the subaddressing capability enables facsimile messages to be passed automatically from a server to the recipient. ITU-T Recommendation T.33 (43) contains details of how the subaddress can be used to perform this routing.

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FADING CHANNELS. See MULTIPATH CHANNELS.