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SERIES I: INTEGRATED SERVICES DIGITAL NETWORK

ISDN user-network interfaces – Layer 1 Recommendations

B-ISDN user-network interface – Physical layer specification: 51 840 kbit/s operation

ITU-T Recommendation I.432.4

(Previously CCITT Recommendation)

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ITU-T RECOMMENDATION I.432.4

B-ISDN USER-NETWORK INTERFACE – PHYSICAL LAYER SPECIFICATION: 51 840 kbit/s OPERATION

Summary

This Recommendation covers Physical Layer characteristics for transporting Asynchronous Transfer Mode (ATM) cells at a nominal bit rate of 51 840 kbit/s over Category 3 Unshielded Twisted Pair (UTP) cabling at the S_B reference point of the B-ISDN User Network Interface (UNI). The maximum distance is approximately 100 m. This specification may be used to take advantage of existing building wiring.

Functionality is presented in terms of Physical Media Dependent (PMD) and Transmission Convergence (TC) sublayers, and both Synchronous Digital Hierarchy (SDH)-based and cell-based formats are included.

This Recommendation is part of the I.432-series Recommendations, and includes references to Recommendation I.432.1 on general characteristics, and Recommendation I.432.2 on Transmission Convergence sublayer aspects.

Source

ITU-T Recommendation I.432.4 was prepared by ITU-T Study Group 13 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 15th of February 1999.

Keywords

Asynchronous Transfer Mode (ATM), Broadband Integrated Services Digital Network (B-ISDN), User Network Interface (UNI).

FOREWORD

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Recommendation I.432.4

B-ISDN USER-NETWORK INTERFACE – PHYSICAL LAYER SPECIFICATION: 51 840 kbit/s OPERATION

(Geneva, 1999)

1 Scope

This Recommendation covers Physical Layer characteristics for transporting Asynchronous Transfer Mode (ATM) cells at a nominal bit rate of 51 840 kbit/s over Category 3 Unshielded Twisted Pair (UTP) cabling at the S_B reference point of the B-ISDN User Network Interface (UNI). The maximum distance is approximately 100 m. This specification may be used to take advantage of existing building wiring.

Functionality is presented in terms of Physical Media Dependent (PMD) and Transmission Convergence (TC) sublayers, and both Synchronous Digital Hierarchy (SDH)-based and cell-based formats are included.

2 Background

This Recommendation was previously contained in Recommendation I.432 (as published in March 1993) along with characteristics now published as Recommendation I.432.1 [1] on general characteristics that contain characteristics which are relevant to all B-ISDN transmission systems at the UNI.

This Recommendation contains only those characteristics that are specific to transmission systems operating at 51 840 kbit/s. Information on other bit rates can be found in other Recommendations of the I.432-series.

3 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

[1] ITU-T Recommendation I.432.1 (1999), *B-ISDN user-network interface – Physical layer specification: General characteristics.*

[2] ISO/IEC 11801:1995, *Information technology – Generic cabling for customer premises.*

[3] ISO/IEC 8877:1992, *Information technology – Telecommunications and information exchange between systems – Interface connector and contact assignments for ISDN Basic Access Interface located at reference points S and T.*

[4] ITU-T Recommendation I.432.2 (1999), *B-ISDN user-network interface – Physical layer specification: 155 520 kbit/s and 622 080 kbit/s operation*.

[5] ITU-T Recommendation G.707 (1996), *Network node interface for the synchronous digital hierarchy (SDH).*

[6] ITU-T Recommendation I.361 (1995), *B-ISDN ATM layer specification*.

[7] ITU-T Recommendation G.826 (1996), *Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate*.

[8] ITU-T Recommendation I.610 (1995), *B-ISDN operation and maintenance principles and functions*.

4 Definitions and abbreviations

4.1 Definitions

None.

4.2 Abbreviations

This Recommendation uses the following abbreviations:

AIS	Alarm Indication Signal
ATM	Asynchronous Transfer Mode
AU	Administrative Unit
BER	Bit Error Ratio
BIP	Bit Interleaved Parity
B-ISDN	Broadband Integrated Services Digital Network
CEC	Cell Error Control
EDC	Error Detection Code
ISO/IEC	International Organization for Standardization/International Electrotechnical Commission
LCD	Loss of Cell Delineation
LSB	Least Significant Bit
MIC	Media Interface Connector
NEXT	Near End Crosstalk
OAM	Operations, Administration and Maintenance
PL	Physical Layer
PM	Physical Medium
PMD	Physical Medium Dependent
POH	Path Overhead
ppm	parts per million
PSN	PL-OAM Sequence Number
QAM	Quadrature Amplitude Modulation
RDI	Remote Defect Indication
REB	Remote Errored Blocks
REI	Remote Error Indication

RL_r	Return Loss at the receiver interface
RL_t	Return Loss at the transmitter interface
SDH	Synchronous Digital Hierarchy
SOH	Section OverHead
TC	Transmission Convergence
UNI	User Network Interface
UTP	Unshielded Twisted Pair

5 Reference configuration

Refer to Recommendation I.432.1 [1].

6 Characteristics of the Physical Medium Dependent (PMD) sublayer

6.1 PMD characteristics at S_B for 51 840 kbit/s

6.1.1 Bit rates

Bit rate (data rate) refers to the logical bit rate for data (expressed in kbit/s). Encoded line rate (symbol rate) refers to the modulation rate of the electrical signal on the media (expressed in Mbaud).

The nominal bit rate is 51 840 kbit/s.

In the absence of a valid clock derived from the network, the transmitter at the customer side should use a free-running transmit clock that operates at the nominal bit rate with a tolerance of ±100 ppm.

6.1.2 Bit rate symmetry

Interfaces are symmetric, i.e. the bit rates are the same in both transmit and receive directions.

6.1.3 Bit Error Ratio (BER)

The BER should not exceed 10^{-10}.

Measurement of BER is normally performed out-of-service. In-service measurements based upon different parameters, e.g. Block Errors, Background Block Errors, etc., is under study.

6.1.4 Timing

6.1.4.1 SDH-based

In normal operation, timing for the transmitter is traceable to the timing received from the network clock. The tolerance under fault condition is 51 840 kbit/s ± 100 ppm.

6.1.4.2 Cell-based

At the customer side at the interface S_B reference point, the cell-based Physical Layer may derive its timing from the signal received across the interface or provide it locally from a clock in the customer equipment.

6.1.5 Medium characteristics

The reference channel model as described in ISO/IEC 11801 [2] is defined to be a link consisting of 90 metres of Category 3 cable, 10 metres of Category 3 flexible cords, and four Category 3 connector pairs internal to the link. The reference channel includes the cable, patch cords, and all connection hardware.

The reference channel attenuation and Near End Crosstalk (NEXT) loss, and characteristic impedance should meet the Category 3 performance limits defined in ISO/IEC 11801 [2].

6.1.6 Transmitter functionality

The PMD sublayer functionality is shown in Figure 1. Any implementation that produces the same functional behaviour for the transmitter is equally valid. The transmit function scrambles and encodes the bit stream received from the Transmission Convergence sublayer into an equivalent Quadrature Amplitude Modulation (QAM) encoded symbol and then into a modulated signal for presentation to the transmission medium.

As shown in Figure 1, the symbol stream from the encoder is divided into two paths, a_n and b_n, where n designates the n^{th} symbol period. The two symbol streams are sent to passband in-phase and quadrature shaping filters, respectively. The output of the in-phase filter and the negative of the output of the quadrature filter are summed into a single signal, the result passed through a low-pass filter, and then transmitted onto the twisted pair cable.

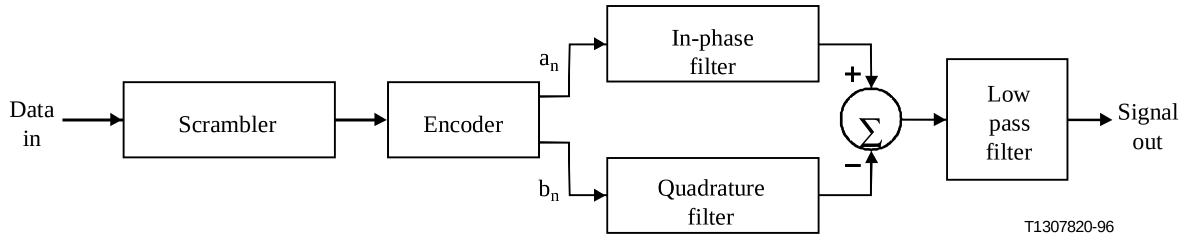


Figure 1/I.432.4 – Functional block diagram of digital 16-QAM transmitter

6.1.6.1 Symbol encoding

The encoding used is a 16-QAM code with a symbol rate of 12.96 Mbaud.

For 16-QAM, the encoder maps data four bits at a time into a symbol as shown in Figure 2. Bits are mapped from the PMD scrambler into the four-bit symbol. The first bit out of the PMD scrambler into a given symbol is b_1.

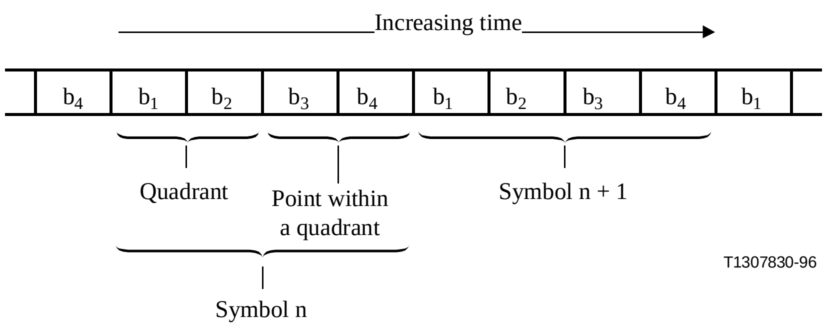


Figure 2/I.432.4 – Bit-to-symbol mapping for 16-QAM

For 16-QAM, the signal constellation is as shown in Figure 3.

Each incoming group of 4 bits is Gray encoded into a 16-QAM symbol. The relative levels of the amplitude of the symbols in each dimension are proportional to the four different levels, ±1 and ±3. Bits b_1b_2 (circled in Figure 3) designate the quadrant. Bits b_3b_4 designate the point being used within the quadrant.

For example, an incoming bit stream 10010110 would translate into two symbols: ($a_n = +1$, $b_n = -3$) and ($a_{n+1} = -3$, $b_{n+1} = +1$).

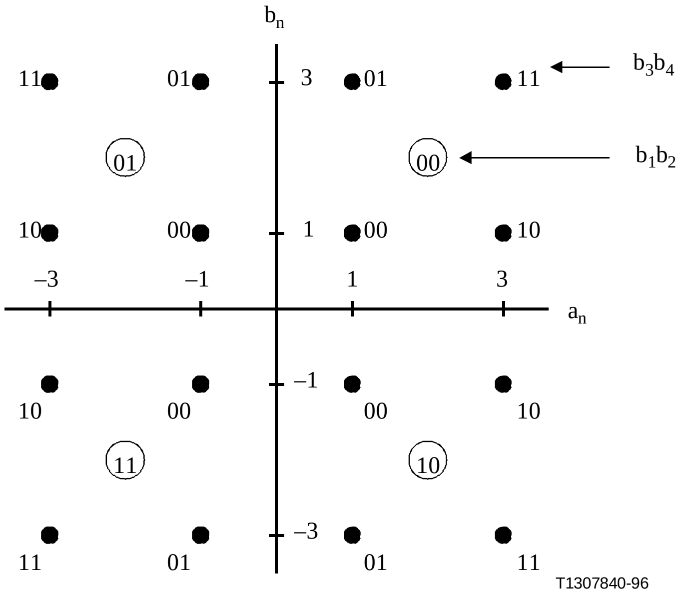


Figure 3/I.432.4 – 16-QAM signal constellation

6.1.6.2 Impulse response for the transmit filters

The impulse response of the in-phase and quadrature filters shown in the block diagram of Figure 1 is described as follows.

Let

$$g(t) = \begin{cases} \dfrac{4\cos\dfrac{2\pi t}{T}}{\pi\left[1-\left(\dfrac{4t}{T}\right)^2\right]} & \text{for } t \neq \pm\dfrac{T}{4} \\ 1 & \text{for } t = \pm\dfrac{T}{4} \end{cases}$$

be a square-root raised-cosine pulse with 100% excess bandwidth. The in-phase filter impulse response is defined as:

$$f(t) = g(t)\cdot\cos\left(\frac{2\pi t}{T}\right)$$

and the quadrature filter impulse response,

$$\tilde{f}(t) = g(t) \cdot \sin\left(\frac{2\pi t}{T}\right)$$

where T is the symbol period.

The actual impulse responses of the transmitter will be truncated approximations of the above equations over a fixed interval such as $-T \le t \le T$.

6.1.6.3 Signal spectrum

The signal at the interface has a power spectrum equivalent to the square root of a raised-cosine shaping with 100% excess bandwidth.

The normalized power spectrum of the signal of the k-QAM transmitter fits within the template of the spectral envelope shown in Figure 4.

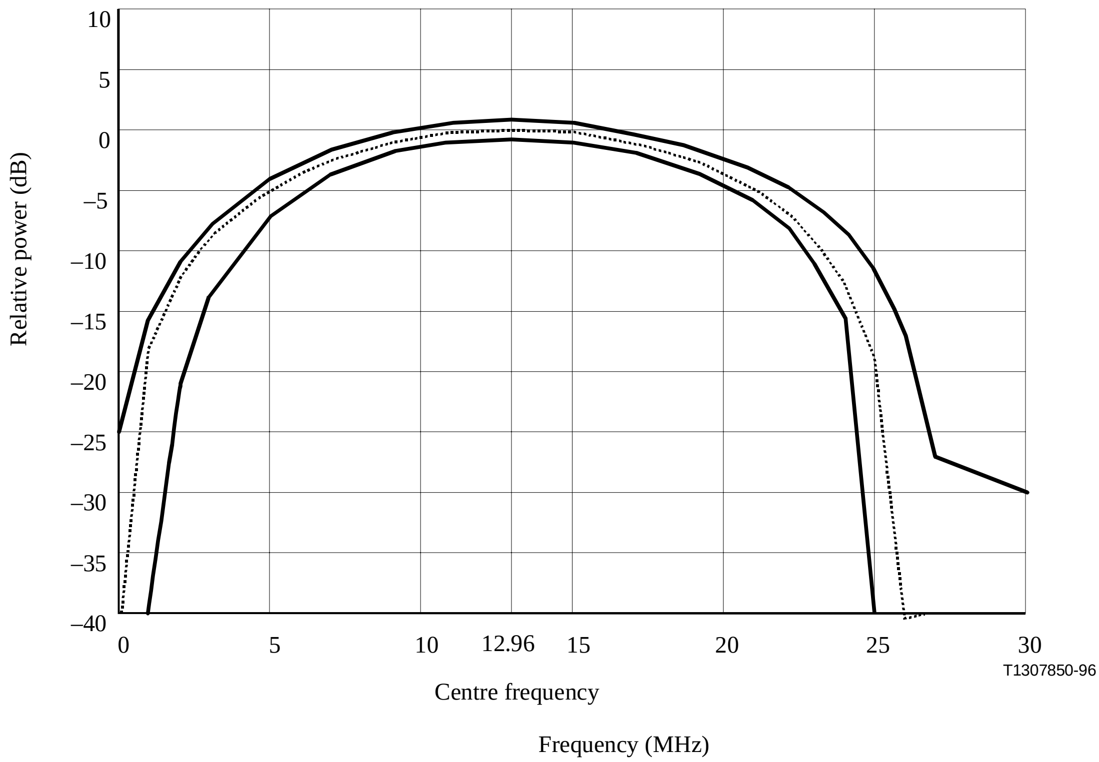


Figure 4/I.432.4 – Template for the power spectrum of the signal at the output of the transmitter

Values are normalized to the value at the center frequency. Table 1 gives quantitative values for breakpoints of the curves in Figure 4. The frequency resolution of a spectrum analyzer when measuring the spectrum of Figure 5 should be 30 kHz or better.

Table 1/I.432.4 – Breakpoints for the power spectrum curves in Figure 5

Frequency (MHz)	0	1	2	3	5	7	9	11	13	15
Upper limit (dB)	–25	–15.9	–11.1	–8.1	–4.1	–1.7	–0.2	0.6	0.8	0.5
Lower limit (dB)	NA	NA	–21.4	–13.8	–7.2	–3.9	–1.9	–1.1	–0.9	–1.2
Frequency (MHz)	17	19	21	22	23	24	25	26	27	30
Upper limit (dB)	–0.3	–1.5	–3.3	–4.6	–6.2	–8.4	–11.5	–16.7	–27	–30
Lower limit (dB)	–2.0	–3.5	–5.9	–7.8	–10.9	–15.8	NA	NA	NA	NA
NOTE – NA indicates that no lower boundary is specified for that frequency.										

6.1.6.4 Voltage output

The amplitudes of the a_n and b_n components in the k-QAM constellations should maintain the relative values 1 and 3, with a tolerance of 0.06.

The peak-to-peak differential voltage measured across the transmit pins at the interface should be 4.0 ± 0.2V when terminated with the specified test load.

The test load consists of a single 100 ohm ± 0.2% resistor. For frequencies less than 100 MHz, the series inductance of the resistor should be less than 20nH and the parallel capacitance should be less than 2pF.

6.1.6.5 Return loss

The Return Loss at the transmitter interface (RL_t) specifies an upper limit on the level of differential signal incident upon the interface that can be reflected by specifying the ratio of incident-to-reflected signal at the interface.

RL_t is defined in terms of the differential reflected voltage as:

$$RL_t = 20\log\frac{|V_i|}{|V_r|} = 20\log\frac{|Z_r + Z_{ref}|}{|Z_r - Z_{ref}|}$$

where:

V_i is the differential voltage incident at the interface;

V_r is the differential voltage reflected from the interface;

Z_r is the impedance of the transmitter; and

Z_{ref} is the reference impedance (85-110 ohms).

RL_t, specified at the interface, should be greater than 15 dB for the frequency range 1-30 MHz. The return loss is measured for a resistive test load range of 85-115 ohms. The return loss is measured while the transmitter is powered.

6.1.6.6 Jitter

Jitter of the transmitter, τ, is measured by transmitting an all binary ones pattern on the line and measuring the variation of the zero crossings of the resulting waveform as shown in Figure 5. For all measurements, the network equipment transmitter clock is used as the reference clock. The value τ at the output of the network equipment should not exceed 2 ns peak-to-peak. The value τ at the output of the customer devices should not exceed 4 ns peak-to-peak, when the input from the network has a jitter of 2 ns peak-to-peak.

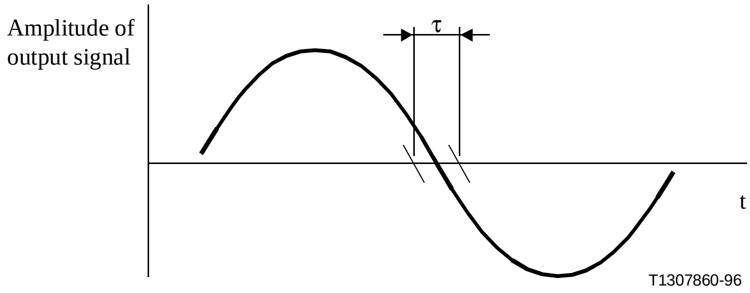


Figure 5/I.432.4 – Illustration of jitter

6.1.7 PMD Scrambler/Descrambler

For performance reasons, two different scrambler polynomials are used to ensure that the signal in one direction is uncorrelated to the signal in the other direction.

The generating polynomial for network equipment scramblers and user device descramblers is:

$$GPN(x) = x^{23} + x^{18} + 1$$

The generating polynomial for user device scramblers and network equipment descramblers is:

$$GPU(x) = x^{23} + x^{5} + 1$$

6.1.8 Receiver characteristics

6.1.8.1 Receiver functionality

The receiver detects the incoming 16-QAM signal and produces an equivalent bit stream for presentation to the TC sublayer.

6.1.8.2 Start-up

The receiver should require no more than 500 ms to reach a state that achieves the specified BER from the time it is presented with a valid signal transmitted through a cable plant as specified above. A valid signal is one meeting the specifications in this Recommendation.

6.1.8.3 Receiver Return Loss at the receiver interface (RL_r)

The return loss at the receiver interface specifies an upper limit on the level of differential signal incident upon the interface that can be reflected by specifying the ratio of incident-to-reflected signal at the interface.

RL_r is defined in terms of the differential reflected voltage as:

$$RL_r = 20\log\frac{|V_i|}{|V_r|} = 20\log\frac{|Z_r + Z_{ref}|}{|Z_r - Z_{ref}|}$$

where:

V_i is the differential voltage incident upon the receiver;

V_r is the differential voltage reflected from the receiver;

Z_r is the impedance of the receiver; and

Z_{ref} is the reference impedance (85-110 ohms).

RL_r, specified at the interface, should be greater than 16 dB for the frequency range 1-30 MHz. The return loss is measured for a resistive test load range of 85-115 ohms. The return loss is measured while the receiver is powered.

6.1.9 Connectors for Category 3 UTP cabling

6.1.9.1 UTP-Media Interface Connector (MIC) modular jack

Each end of a link is terminated with media interface connectors specified in clause 4 and Figure 1 of ISO/IEC 8877 [3]. This connector is an 8-pin modular jack (plug) and should meet or exceed the requirements for ISO/IEC 11801 [2] Category 3 100 ohm UTP connecting hardware.

6.1.9.2 UTP-MIC receptacle

The receptacle for a link should be a connector specified in clause 4 and Figure 2 of ISO/IEC 8877 [3]. The receptacle hardware used at this PMD interface should be an 8-contact connector which meets or exceeds the electrical requirements of Category 3 100 ohm UTP. These include specifications on NEXT loss.

The assignment of contacts for these connectors is as shown in Table 2, where the ± notation refers to a cable-pair for the user.

Table 2/I.432.4 – Contact assignments for UTP-MIC connectors

Contact	User device signal	Network equipment signal
1	Transmit +	Receive +
2	Transmit –	Receive –
3	(Note)	(Note)
4	(Note)	(Note)
5	(Note)	(Note)
6	(Note)	(Note)
7	Receive +	Transmit +
8	Receive –	Transmit –
NOTE – The two unused pairs of the 4-pair cable should be mechanically terminated. These unused pairs may transport non-interfering signals providing the BER of the pair in use meets the specified BER.		

7 Functions provided by the Transmission Convergence (TC) sublayer

The 51 840 kbit/s bit rate is considered a subrate of the Synchronous Digital Hierarchy (SDH). However, the frame structure is analogous to the SDH format as described in Recommendation G.707 [5], and uses the same definitions as are described in Recommendations I.432.2 [4] and G.707 [5]. A transmission convergence sublayer for cell-based systems is also specified.

7.1 Transfer capability

The transfer capability for ATM cells is 48 384 kbit/s.

7.2 Transport-specific TC functions

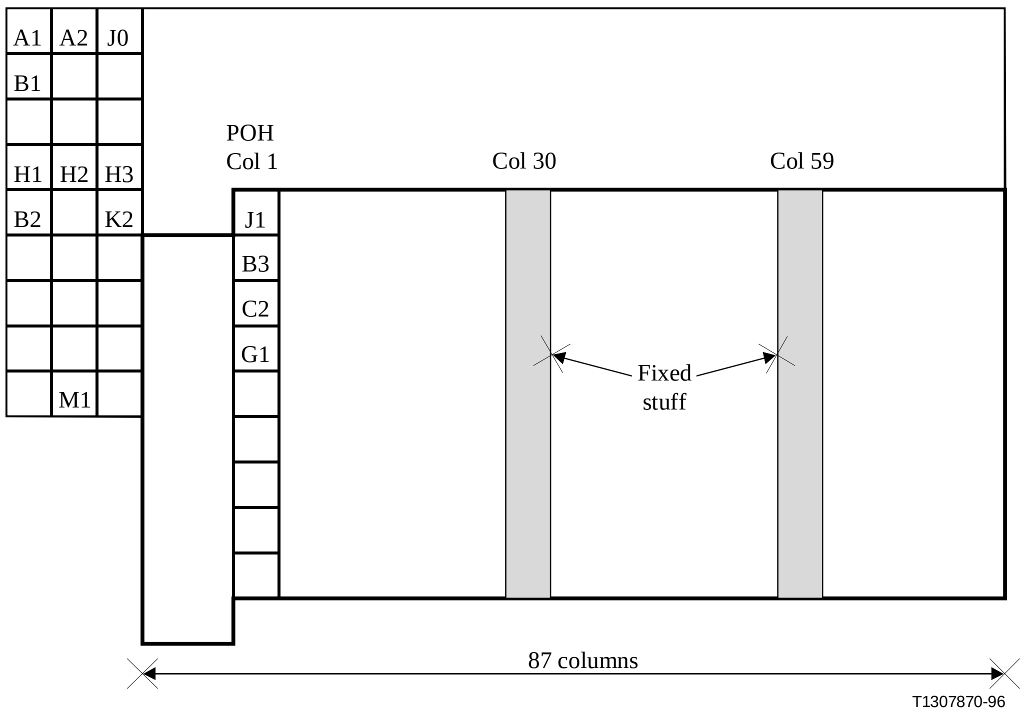
7.2.1 SDH-based

7.2.1.1 SDH-based frame format structure

Figure 6 shows a diagram of the frame structure for 51 840 kbit/s and indicates the octets that are active at the UNI.

The ATM cell stream is first mapped into an information payload (container), path overhead is added and a pointer is calculated, and the resultant is then mapped into the final structure analogously to the process used in Recommendation I.432.2 [4] and as described in Recommendation G.707 [5]. Pointer processing and the application of a frame synchronous scrambler are as described in Recommendation G.707 [5]. As in Recommendation I.432.2 [4], ATM cell boundaries are aligned with the frame octet boundaries and, since the container capacity is not an integer multiple of the cell length, a cell may cross the container boundary.

Bit ordering is 1-8, numbered left to right. The order of transmission is from left to right.



NOTE – The values contained in the columns of "fixed stuff" are not restricted except that the two octets in each row are identical.

Figure 6/I.432.4 – Frame structure for 51 840 kbit/s

7.2.1.2 Overhead functions

The octets active at the UNI are given in Table 3 and have the same functionality and coding as those given in Recommendation G.707 [5]. Octets not designated in Table 3 are reserved.

NOTE – For backward compatibility with equipment complying with the 1993 version of Recommendation I.432, new equipment may use "100" or "111" codes in bits 5 to 7 of G1 to indicate a remote Loss of Cell Delineation (LCD). New equipment may do this only when interworking with old equipment.

Table 3/I.432.4 – Active octets for 51 840 kbit/s

Octet (Note 3)	Function (Note 5)	Coding (Note 1)
Section overhead		
A1, A2	Frame alignment	As in Recommendation G.708
J0	(For further study)	
B1 (Note 2)	Regenerator section error monitoring	BIP-8 (Note 2)
H1 (bits 1-4)	- /AU AIS	1001/1111
H1 (bits 5, 6)	Reserved/AU AIS	00/11
H1 (bits 7, 8) and H2	AU pointer/AU AIS	Pointer value/11 1111 1111
H3	Pointer action	
B2	Multiplex section error monitoring	BIP-8
K2 (bits 6-8)	Multiplex section AIS and RDI	111/110
M1	Multiplex section REI (bits 5-8)	B2 error count
Path overhead		
J1	Access point ID/verification	
B3	Path error monitoring	BIP-8
C2	Path signal label	0001 0011
G1 (bits 1-4)	Path error reporting (REI)	B3 error count
G1 (bit 5)	Path RDI (Note 4)	"1"
G1 (bits 6 and 7)	LCD	"010" (Note 6)

NOTE 1 – Only octet coding relevant to OAM function implementation is listed.

NOTE 2 – The use of B1 for regenerator section error monitoring across the UNI is application dependent and is therefore optional.

NOTE 3 – The bit numbering of this table is different from the conventions used in Recommendation I.361 [6] but is in accordance with Recommendation G.707 [5].

NOTE 4 – Path RDI should also be used to indicate Loss of Cell Delineation (LCD).

NOTE 5 – The applicability of Multiplexer Section AIS (MS-AIS) at the UNI is for further study.

NOTE 6 – The use of G1 bits 6 and 7 is currently defined in Recommendation G.707 [5] as: "Bits 6 and 7 are reserved for an optional use described in VII.1. If this option is not used, bits 6 and 7 shall be set to 00 or 11. A receiver is required to be able to ignore the contents of these bits.".

7.2.2 Cell-based

7.2.2.1 Transfer capability

In order to guarantee compatibility with SDH, the transfer capability of the cell-based TC for ATM cells is limited to 48 364 kbit/s. The possibility for the TC to have a higher transfer capability is for further study. The characteristics of the TC use the same characteristics as described in Recommendation I.432.2 [4] for the cell-based application.

7.2.2.2 Format structure

The interface structure consists of a continuous stream of cells. Each cell contains 53 octets.

The maximum spacing between successive Physical Layer cells is 14 ATM layer cells, i.e. after 14 contiguous ATM layer cells have been transmitted, a Physical Layer cell is inserted in order to adapt the transfer capability to the interface rate as indicated in Figure 7. Idle cells are inserted when no ATM layer cells are available.

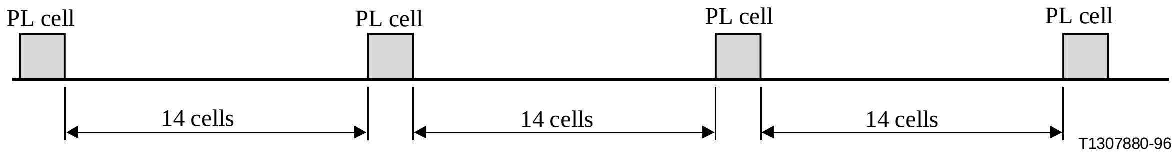


Figure 7/I.432.4 – Adaptation to the transfer capability

The Physical Layer (PL) cells which are inserted can be either idle cells or Physical Layer OAM (PL-OAM) cells, depending on the Operations, Administration and Maintenance (OAM) requirements.

7.3 ATM specific TC functions

For information on ATM cell formatting, header error control, cell delineation, scrambling and idle cells, refer to Recommendation I.432.1 [1].

7.4 OAM procedures

7.4.1 SDH-based OAM

Refer to Recommendation I.432.2 [4].

7.4.2 Cell-based OAM

Only the F3 OAM flow is implemented as it is not expected to have any regeneration level at the S_B interface.

One F3 OAM cell is inserted after 14 contiguous ATM layer cells have been transmitted.

OAM implementation should be as defined in Recommendation I.432.2 [4] with the following modifications (numbered 1 and 2):

1) There is only 1 monitored block (instead of 8 for the 155 520 kbit/s and 622 080 kbit/s interfaces). Therefore the size of the monitored block is 15 cells.

2) The fields EDC-B2..8 are not used and shall be coded 6A hexa. The corresponding F3 OAM cell payload is indicated in Table 4:

Table 4/I.432.4 – Allocation of OAM functions in information field

1	R	25	R
2	R	26	R
3	PSN	27	R
4	R	28	R
5	R	29	R
6	R	30	RDI (Note)
7	R	31	R
8	EDC-B1	32	R
9	R	33	R
10	R	34	R
11	R	35	R
12	R	36	R
13	R	37	R
14	R	38	R
15	R	39	R
16	R	40	R
17	R	41	R
18	R	42	R
19	R	43	R
20	R	44	R
21	R	45	R
22	R	46	REB
23	R	47	CEC(2)
24	R	48	CEC(8)
NOTE – RDI is coded as indicated in Recommendation I.432.2 [4].			

Implementation of F3 flow is indicated in Figure 8.

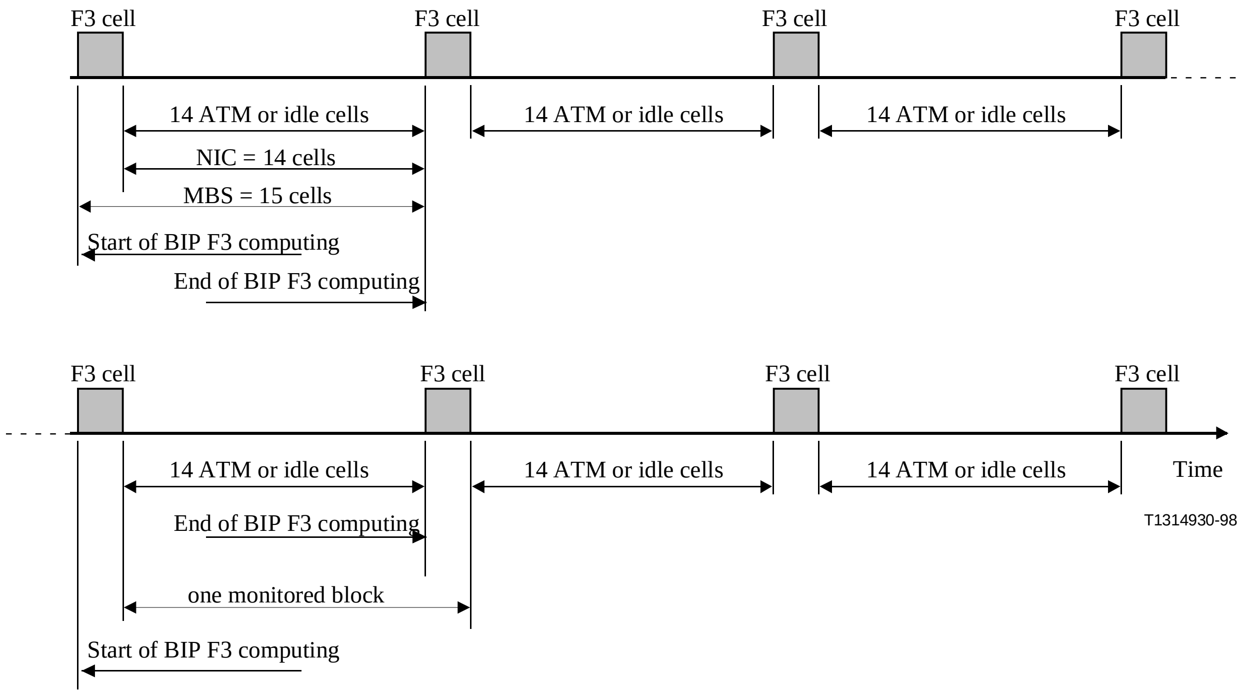


Figure 8/I.432.4 – F3 OAM flow implementation for S_B

8 Power feeding

For further study.

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