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THE INTERNATIONAL
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GENERAL ASPECTS OF DIGITAL TRANSMISSION SYSTEMS; TERMINAL EQUIPMENTS

CHARACTERISTICS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) MULTIPLEXING EQUIPMENT FUNCTIONAL BLOCKS

Recommendation G.783

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FOREWORD

permanent organ of the International Telecommunication Union (ITU). CCITT is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The Plenary Assembly of CCITT which meets every four years, establishes the topics for study and approves Recommendations prepared by its Study Groups. The approval of Recommendations by the members of CCITT between Plenary Assemblies is covered by the procedure laid down in CCITT Resolution No. 2 (Melbourne, 1988).

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CCITT NOTE

indicate both a telecommunication Administration and a recognized private operating agency.

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CHARACTERISTICS OF SYNCHRONOUS DIGITAL HIERARCHY (SDH) MULTIPLEXING EQUIPMENT FUNCTIONAL BLOCKS

The CCITT,

considering

(a) that Recommendations G.707, G.708 and G.709 form a coherent set of specifications for the synchronous digital hierarchy (SDH) and the Network Node Interface (NNI);

(b) that Recommendation G.781 gives the structure of Recommendations on multiplexing equipment for the SDH;

(c) that Recommendation G.782 gives the types and general characteristics of SDH multiplexing equipment;

(d) that Recommendation G.784 addresses management aspects of the SDH;

(e) that Recommendation G.957 specifies characteristics of optical interfaces for use within the SDH;

(f) that Recommendation G.958 specifies digital line systems based on the SDH for use on optical fibre cables;

(g) that Recommendation G.703 describes electrical interfaces for use within the SDH,

recommends

that SDH multiplexing equipments having the general characteristics described in Recommendation G.782 should support interfaces and functions as described in this Recommendation.

1 General

This Recommendation defines the interfaces and functions to be supported by the multiplexer types defined in Recommendation G.782. The description is generic and no particular physical partitioning of functions is implied. The input/output information flows associated with the functional blocks serve for defining the functions of the blocks and are considered to be conceptual, not physical.

1.1 *Abbreviations*

AIS	Alarm indication signal
ALS	Automatic laser shutdown
APS	Automatic protection switching

AU	Administrative unit
AUG	Administrative unit group
BER	Bit error ratio
BIP	Bit interleaved parity
CM	Connection matrix
CMISE	Common Management Information Service Element
DCC	Data communications channel

EOW	Engineering order-wire
ES	Errored second
FAL	Frame alignment loss
FEBE	Far end block error
FERF	Far end receive failure
HPA	Higher order path adaptation
HPC	Higher order path connection
HPT	Higher order path termination
LOF	Loss of frame
LOM	Loss of multiframe
LOP	Loss of pointer
LOS	Loss of signal
LPA	Lower order path adaptation
LPC	Lower order path connection
LPT	Lower order path termination
MCF	Message comunications function
MRTIE	Maximum relative time interval error
MS	Multiplex section
MSOH	Multiplex section overhead
MSP	Multiplex section protection
MST	Multiplex section termination
MTG	Multiplexer timing generator
MTIE	Maximum time interval error
MTPI	Multiplexer timing physical interface
MTS	Multiplexer timing source
NDF	New data flag
NE	Network element
NEF	Network element function
NNI	Network node interface
NU	National use
OFS	Out-of-frame second

OHA	Overhead access
OOF	Out of frame
PDH	Plesiochronous digital hierarchy

PI	Physical interface
PJE	Pointer justification event
POH	Path overhead
RS	Regenerator section
RSOH	Regenerator section overhead
RST	Regenerator section termination
SA	Section adaptation
SD	Signal degrade
SDH	Synchronous digital hierarchy
SEMF	Synchronous equipment management function
SES	Severely errored second
SF	Signal fail
SPI	SDH physical interface
STM	Synchronous transport module
TMN	Telecommunications management network
TU	Tributary unit
VC	Virtual container

1.2 *Definitions*

Note — The following definitions are relevant in the context of SDH-related Recommendations.

1.2.1 *Automatic laser shutdown (ALS)*

See Recommendation G.958.

1.2.2 **automatic protection switching (APS)**

Autonomous switching of a signal between and including two MST functions, from a failed working channel to a protection channel and subsequent restoration using control signals carried by the K-bytes in the MSOH.

1.2.3 *Administrative unit (AU)*

See Recommendation G.708.

1.2.4 *Administrative unit group (AUG)*

See Recommendation G.708.

1.2.5 *Bit interleaved party (BIP)*

See Recommendation G.708.

1.2.6 **connection matrix (CM)**

A connection matrix is a matrix of appropriate dimensions which describes the connection pattern for assigning VC-ns on one side of an LPC or HPC function to VC-n capacities on the other side and vice versa.

1.2.7 *Common management information service element (CMISE)*

See ISO 9595.

1.2.8 *Data communications channel (DCC)*

See Recommendation G.784.

1.2.9 **desynchronizer**

The desynchronizer function smooths out the timing gaps resulting from decoded pointer adjustments and VC payload de-mapping in the time domain.

1.2.10 *Frame alignment loss (FAL)*

See Recommendation G.706.

1.2.11 *Far end block error (FEBE)*

See Recommendation G.709.

1.2.12 *Far end receive failure (FERF)*

See Recommendation G.709.

1.2.13 **higher order path adaptation (HPA)**

The HPA function adapts a lower order VC (VC-1/2/3) to a higher order VC (VC-3/4) by processing the TU pointer which indicates the phase of the VC-1/2/3 POH relative to the VC-3/4 POH and assembling/disassembling the complete VC-3/4.

1.2.14 **higher order path connection (HPC)**

The HPC function provides for flexible assignment of higher order VCs (VC-3/4) within an STM-N signal.

1.2.15 **higher order path termination (HPT)**

The HPT function terminates a higher order path by generating and adding the appropriate VC POH to the relevant container at the path source and removing the VC POH and reading it at the path sink.

1.2.16 **loss of frame (LOF)**

An LOF state of an STM-N signal is considered to have occurred when an OOF state persists for a defined period of time.

1.2.17 **loss of pointer (LOP)**

The LOP state is one resulting from a defined number of consecutive occurrences of certain conditions which are deemed to have caused the value of the pointer to be unknown.

1.2.18 loss of signal (LOS)

The LOS state is considered to have occurred when the amplitude of the relevant signal has dropped below prescribed limits for a prescribed period.

1.2.19 lower order path adaptation (LPA)

The LPA function adapts a PDH signal to an SDH network by mapping/de-mapping the signal into/out of a synchronous container. If the signal is asynchronous, the mapping process will include bit level justification.

1.2.20 lower order path connection (LPC)

The LPC function provides for flexible assignment of lower order VCs in a higher order VC.

1.2.21 **lower order path termination (LPT)**

The LPT function terminates a lower order path by generating and adding the appropriate VC POH to the relevant container at the path source and removing the VC POH and reading it at the path sink.

1.2.22 **multiplex section alarm indication signal (MS-AIS)**

MS-AIS is an STM-N signal that contains a valid RSOH and an all ONEs pattern for the remainder of the signal.

1.2.23 *Multiplex section far end receive failure (MS-FERF)*

See Recommendation G.709.

1.2.24 **multiplex section overhead (MSOH)**

The MSOH comprises rows 5 to 9 of the SOH of the STM-N signal.

1.2.25 **multiplex section protection (MSP)**

The MSP function provides capability for switching a signal between and including two MST functions, from a “working” to a “protection” section.

1.2.26 **multiplex section termination (MST)**

The MST function generates the MSOH in the process of forming an SDH frame signal and terminates the MSOH in the reverse direction.

1.2.27 **multiplexer timing generator (MTG)**

The MTG function filters the timing reference signal from those selected in the MTS to ensure that the timing requirements at the T0 reference point are met.

1.2.28 **multiplexer timing physical interface (MTPI)**

The MTPI function provides the interface between an external synchronization signal and the multiplexer timing source.

1.2.29 **multiplexer timing source (MTS)**

The MTS function provides timing reference to the relevant component parts of a multiplexing equipment and represents the SDH network element clock.

1.2.30 *Network element function (NEF)*

See Recommendation G.784.

1.2.31 *Network node interface (NNI)*

See Recommendation G.708.

1.2.32 **out-of-frame second (OFS)**

An OFS is a second in which one or more out of frame events have occurred.

1.2.33 **overhead access (OHA)**

The OHA function provides access to transmission overhead functions.

1.2.34 **out of frame (OOF)**

The OOF state of an STM-N signal is one in which the position of the frame alignment bytes in the incoming bit stream is unknown.

1.2.35 **pointer justification event (PJE)**

A PJE is an inversion of the I- or D-bits of the pointer, together with an increment or decrement of the pointer value to signify a frequency justification opportunity.

1.2.36 *Path overhead (POH)*

See Recommendation G.708.

1.2.37 **regenerator section (RS)**

A regenerator section is the part of a line system between two regenerator section terminations.

1.2.38 **regenerator section overhead (RSOH)**

The RSOH comprises rows 1 to 3 of the SOH of the STM-N signal.

1.2.39 **regenerator section termination (RST)**

The RST function generates the RSOH in the process of forming an SDH frame signal and terminates the RSOH in the reverse direction.

1.2.40 **section adaptation (SA)**

The SA function processes the AU-3/4 pointer to indicate the phase of the VC-3/4 POH relative to the STM-N SOH and assembles/disassembles the complete STM-N frame.

1.2.41 **signal degrade (SD)**

An SD condition is one in which a signal has been degraded beyond prescribed limits.

1.2.42 **synchronous equipment management function (SEMF)**

The SEMF converts performance data and implementation specific hardware alarms into object-oriented messages for transmission over the DCC(s) and/or a Q-interface. It also converts object-oriented messages related to other management functions for passing across the Sn reference points.

1.2.43 **SDH physical interface (SPI)**

The SPI function converts an internal logic level STM-N signal into an STM-N line interface signal.

1.2.44 *Synchronous transport module (STM)*

See Recommendation G.708.

1.2.45 *Telecommunications management network (TMN)*

See Recommendation M.30.

1.2.46 *Tributary unit (TU)*

See Recommendation G.708.

1.2.47 *Virtual container (VC)*

See Recommendation G.708.

2 Transport terminal functions

The transport terminal functions comprise SDH physical interface (SPI), regenerator section termination (RST), multiplex section termination (MST), multiplex section protection (MSP) and section adaptation (SA) functions as illustrated in Figure 2-l/G.783. The functional description of each of these functions is based on this figure.

FIGURE 2-1/G.783

2.1 *SDH Physical Interface function (SPI)*

The SPI function provides the interface between the physical transmission medium at reference point A and the RST function at reference point B. The interface signal at A shall be one of those specified in Recommendation G.707. The physical characteristics of the interface signals are specified in Recommendation G.957 for optical media and Recommendation G.703 for electrical media. The information flows associated with the SPI function are described with reference to Figure 2-2/G.783.

FIGURE 2-2/G.783

2.1.1 *Signal flow from B to A*

DATA at A is fully formatted STM-N data as specified in Recommendations G.707, G.708 and G.709. DATA is presented together with associated TIMING at B by the RST function. The SPI function conditions the DATA for transmission over a particular medium and presents it at A.

Parameters relating to the physical status of the interface such as transmit fail or transmit degraded (e.g. optical output level, laser bias current, other media-specific indicators) shall be reported at S1. For optical systems, these parameters are specified in Recommendation G.958.

For other media, these parameters are for further study.

2.1.2 *Signal flow from A to B*

The STM-N signal at A is a similarly formatted and conditioned signal which is degraded within specific limits by transmission over the physical medium. The SPI function regenerates this signal to form data and associated timing at B. The recovered timing is also made available at reference point T1 to the multiplexer timing source for the purpose of synchronizing the multiplexer reference clock if selected.

If the STM-N signal at A fails, then the receive LOS condition is generated and passed to reference point S1 and to the RST function at B. The criteria for LOS are defined in Recommendation G.958.

2.2 *Regenerator Section Termination function (RST)*

The RST function acts as a source and sink for the regenerator section overhead (RSOH). A regenerator section is a maintenance entity between and including two RST functions. The information flows associated with the RST function are described with reference to Figure 2-3/G.783.

Note 1 — In regenerators, the A1, A2 and C1 bytes may be relayed (i.e. passed transparently through the regenerator) instead of being terminated and generated as described below. Refer to Recommendation G.958.

Note 2 — This Recommendation is intended for the general case of an inter-station interface. A reduced functionality requirement for an intra-station interface is for further study.
FIGURE 2-3/G.783

2.2.1 *Signal flow from C to B*

DATA at C is an STM-N signal as specified in Recommendations G.707, G.708 and G.709, timed from the T0 reference point and having a valid multiplex section overhead (MSOH). However, the RSOH bytes (i.e. bytes A1, A2, B1, C1, E1, F1, D1 to D3 and some bytes reserved for national use (NU) or for future international standardization) are indeterminate in this signal. Figure 2-4/G.783 shows the assignment of bytes to RSOH and MSOH in the SOH of an STM-N frame. RSOH bytes are set in accordance with Recommendation G.708 as part of the RST function to give a fully formatted STM-N data and associated timing at B. After all RSOH bytes have been set, the RST function shall scramble the STM-N signal before it is presented to B. Scrambling is performed according to Recommendation G.709, which excludes the first row of the STM-N RSOH (9 ´ N bytes, including the A1, A2, C1 and some bytes reserved for national use or future international standardization) from scrambling.

FIGURE 2-4/G.783

Frame alignment bytes A1 and A2 (3N of each) are generated and inserted in the first row of the RSOH.

The STM identifier bytes are placed in their respective C1 byte positions in the first row of the RSOH. Each is assigned a unique number to identify the binary value of the multi-column, interleave depth co-ordinate, “C” (Recommendation G.708 refers). The C1 byte shall be set to a binary number corresponding to its order of appearance in the byte-interleaved STM-N frame. The first to appear in the frame shall be designated number 1 (00000001). The second shall be designated number 2 (00000010), and so on. If the signal at B is an STM-1 (i.e. N = 1) then the use of the C1 byte is optional.

The error monitoring byte B1 is allocated in the STM-N for a regenerator section bit error monitoring function. This function shall be a bit interleaved parity 8 (BIP-8) code using even parity as defined in Recommendation G.708. The BIP-8 is computed over all bits of the previous STM-N frame at B after scrambling. The result is placed in byte B1 position of the RSOH before scrambling.

The order-wire byte E1 derived from the OHA function at reference point U1 is placed in byte E1 position of the RSOH. This byte shall be terminated at each RST function. Optionally, it provides a 64 kbit/s unrestricted channel and is reserved for voice communication between network elements.

The user channel byte F1 derived from the OHA function at reference point U1 is placed in byte F1 position of the RSOH. It is reserved for the network provider (for example, for network operations). This byte shall be terminated at each RST function; however, access to the F1 byte is optional at regenerators. User channel specifications are for further study. Special usage, such as the identification of a failed section in a simple backup mode while the operations support system is not deployed or not working, is for further study. An example of such usage is given in Appendix I.

The three Data communications channel bytes derived from the Message Communications function at reference point N are placed in bytes D1-D3 positions of the RSOH. These bytes are allocated for data communication and shall be used as one 192 kbit/s message-oriented channel for alarms, maintenance, control, monitor, administration, and other communication needs between RST functions. This channel is available for internally generated, externally generated, and manufacturer specific messages. The protocol stack used shall be as specified in Recommendation G.784.

Certain RSOH bytes are presently reserved for national use or for future international standardization, as defined in Recommendation G.708. One or more of these bytes may be derived from the OHA function at reference point U1. The unused bytes in the first row of the STM-N signal, which are not scrambled for transmission, shall be set to 10101010 when not used for a particular purpose. No pattern is specified for the other unused bytes when not used for a particular purpose.

If a logical all-ONEs DATA signal is received from an MST function (or an RST function in the case of a regenerator) at reference point C, a multiplex section alarm indication signal (MS-AIS) data signal shall be applied at reference point B.

2.2.2 *Signal flow from B to C*

Fully formatted and regenerated STM-N data and associated timing is received at B from the SPI function. The RST function recovers frame alignment and identifies the frame start positions in the data at C. The STM-N signal is first descrambled (except for the first row of the RSOH) and then the RSOH bytes are recovered before presenting the framed STM-N data and timing at C.

Frame alignment is found by searching for the A1 and A2 bytes contained in the STM-N signal. The framing pattern searched for may be a subset of the A1 and A2 bytes contained in the STM-N signal. The frame signal is continuously checked with the presumed frame start position for alignment. If in the in-frame state, the maximum out-of-frame (OOF) detection time shall be 625 µs for a random unframed signal. The algorithm used to check the alignment shall be such that, under normal operation, a 10-3 (Poisson type) error ratio will not cause a false OOF more than once per six minutes. If in the OOF state, the maximum frame alignment time shall be 250 µs for an error-free signal with no emulated framing patterns. The algorithm used to recover from OOF shall be such that the probability for false frame recovery with a random unframed signal is no more than 10-5 per 250 µs time interval.

If the OOF state persists for [TBD] milliseconds, a loss of frame (LOF) state shall be declared. To provide for the case of intermittent OOFs, the integrating timer shall not be reset to zero until an in-frame condition persists continuously for [TBD] milliseconds. Once in a LOF state, this state shall be left when the in-frame state persists continuously for [TBD] milliseconds.

Note — Time intervals [TBD] are for further study. Values in the range 0 to 3 ms have been proposed.

OOF events shall be reported at reference point S2 for performance monitoring filtering in the SEMF. A LOF condition shall be reported at reference point S2 for alarm filtering in the SEMF.

The STM identifier C1 bytes are present in the RSOH within the STM-N signal; however, processing of the C1 bytes is not required.

The error monitoring byte B1 is recovered from the RSOH after descrambling and compared with the computed BIP-8 over all bits of the previous STM-N frame at B before descrambling. Any errors are reported at reference point S2 as the number of errors within the B1 byte per frame. The B1 byte shall be monitored and recomputed at every RST function.

The order-wire byte E1 is recovered from the RSOH and passed to the OHA function at reference point U1.

The user channel byte F1 is recovered from the RSOH and passed to the OHA function at reference point U1.

The Data communications channel bytes D1-D3 are recovered from the RSOH and passed to the message communications function at reference point N.

One or more of the bytes for national use or future international standardization may be recovered from the STM-N and may be passed to the OHA function at reference point U1. The RST function shall be capable of ignoring these bytes.

If loss of signal (LOS) or loss of frame (LOF) is detected, then a logical all ONEs signal shall be applied at the data signal output at reference point C towards the MST function within a certain time interval which is for further study. Upon termination of the above failure conditions, the logical all ONEs signal shall be removed within a certain time interval which is for further study.

2.3 *Multiplex section termination function (MST)*

The MST function acts as a source and sink for the multiplex section overhead (MSOH). A multiplex section is a maintenance entity between and including two MST functions. The information flows associated with the MST function are described with reference to Figure 2-5/G.783.

Note — This Recommendation is intended for the general case of an inter-station interface. A reduced functionality requirement for an intra-station interface is

FIGURE 2-5/G.783

2.3.1 *Signal flow from D to C*

Data at reference point D is an STM-N signal as specified in Recommendations G.707 and G.708, timed from the T0 reference point, having a payload constructed as in Recommendation G.709, but with indeterminate MSOH bytes (i.e. bytes B2, K1, K2, D4 to D12, Z1, Z2, E2, and bytes reserved for national use or future international standardization) and indeterminate RSOH bytes. Figure 2-4/G.783 shows the assignment of bytes to MSOH in the SOH of an STM-N frame. The MSOH bytes are set in accordance with Recommendation G.708 as part of the MST function. The resulting STM-N data and associated timing are presented at C.

The error monitoring byte B2 is allocated in the STM-N for a multiplex section bit error monitoring function. This function shall be a bit interleaved parity (BIP-24N) code using even parity as defined in Recommendation G.708. The BIP-24N is computed over all bits (except those in the RSOH bytes) of the previous STM-N frame and placed in the 3 ´ N respective B2 byte positions of the current STM-N frame.

The automatic protection switching bytes derived from the multiplex section protection (MSP) function at reference point D are placed in the K1 and K2 byte positions. Bits 6 to 8 of the K2 byte are reserved for future use for drop and insert and nested protection switching. Note that codes 111 and 110 will not be assigned to bits 6, 7, and 8 of K2 for protection switching since they are used for MS-AIS detection and MS-FERF indication.

The nine data communications channel bytes issued by the message communications function are placed consecutively in the D4 to D12 byte positions. This should be considered as a single message based channel for alarms, maintenance, control, monitoring, administration, and other communication needs. It is available for internally generated, externally generated, and manufacturer specific messages. The protocol stack used shall be in accordance with the specifications given in Recommendation G.784. Regenerators are not required to access this DCC. The nine DCC bytes may alternatively be issued by the overhead access function via the U2 reference point to provide a transparent data channel by using an appropriate OHA interface.

The N ´ 6 spare bytes issued by the OHA function at reference point U2 are placed in the (3 ´ N) Z1 and (3 ´ N) Z2 byte positions. These bytes are reserved for future use and currently have no defined value.

The order-wire byte is issued by the OHA function at reference point U2 and is placed in the E2 byte position. It provides an optional 64 kbit/s unrestricted channel and is reserved for voice communications between terminal locations.

Certain MSOH bytes are presently reserved for national use or for future international standardization, as defined in Recommendation G.708. One or more of these bytes may be derived from the OHA function at reference point U2. No patterns are specified for these bytes when they are not used.

If a logical all ONEs data signal is received at reference point D, an AU path alarm indication signal (AU PATH AIS) shall be applied at the data signal output at reference point C.

If the signal fail (SF) defect at reference point D (see § 2.3.2) is detected, then MS-FERF shall be applied within 250 µs at the data signal output at reference point C. MS-FERF is defined as an STM-N signal with the code 110 in bit positions 6, 7 and 8 of byte K2.

2.3.2 *Signal Flow from C to D*

The framed STM-N data signal whose RSOH bytes have already been recovered in the RST function is received at reference point C from the RST function together with the associated timing. The MST function recovers the MSOH bytes. Then the STM-N data and associated timing are presented at reference point D.

The 3N error monitoring B2 bytes are recovered from the MSOH. A BIP-24N code is computed for the STM-N frame. The computed BIP-24N value for the current frame is compared with the recovered B2 bytes from the following frame and errors are reported at reference point S3 as number of errors within the B2 bytes per frame for performance monitoring filtering in the synchronous equipment management function.

The BIP-24N errors are also processed within the MST function to detect excessive BER and signal degrade (SD) defects.

An Excessive BER defect should be detected if the equivalent BER exceeds a threshold of 10-3. An SD defect should be detected if the equivalent BER exceeds a preset threshold in the range of 10-5 to 10-9. Maximum detection time requirements for the BER calculation are listed in Table 2-1/G.783. The SD defect should be applied at reference point D. Excessive BER and SD defects should be reported at reference point S3 for alarm filtering in the synchronous equipment management function.

Note — The figures above and in Table 2-1/G.783 are based on a Poisson distribution of errors. Studies have shown that error distributions in practice tend to be bursty. Derivation of BER values from BIP measurements depends on the error distribution; the relevant studies are in the province of Study Group XVIII.

µTABLE 2-1/G/783

Maximum detection time requirements

BER	Detection time
³ 10-3	~~10 0~~10 ms
³10-4	~~10~~ 100 ms
³10-5	~~10 001 sm~~
³10-6	~~10 0~~10 s~~m~~
³10-7	~~10 100 sm~~
³10-8	~~1~~1 000 s~~m~~
³10-9	10 000 s~~m~~

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Automatic protection switching bytes K1 and K2 are recovered from the MSOH at C and are passed to the MSP function at reference point D.

The multiplex section data communications channel bytes D4 to D12 are recovered from the MSOH and are passed to the message communications function at reference point P. Alternatively, they may be passed to the overhead access function via reference point U2.

The N ´ 6 Spare bytes Z1 and Z2 may be recovered from the STM-N signal and may be passed to the OHA function at reference point U2. These bytes are reserved for future use and currently have no defined value.

The order-wire byte E2 is recovered from the MSOH and is passed to the OHA function at reference point U2.

One or more of the bytes reserved for national use or for future international standardization may be recovered from the STM-N signal and may be passed to the OHA function at reference point U2. The MST function shall be capable of ignoring these bytes.

An MS-AIS defect shall be detected by the MST function when the pattern 111 is observed in bits 6, 7 and 8 of byte K2 in at least three consecutive frames. Removal of the MS-AIS defect shall take place when any pattern other than the code 111 in bits 6, 7 and 8 of byte K2 is received in at least three consecutive frames.

An incoming MS-FERF defect shall be detected by the MST function when the pattern 110 is observed in bits 6, 7 and 8 of byte K2 in at least three consecutive frames. Removal of MS-FERF defect shall take place when any pattern other than 110 in bits 6, 7 and 8 of byte K2 is received in at least three consecutive frames.

The MS-AIS and MS-FERF defects shall be reported at reference point S3 for alarm filtering in the synchronous equipment management function.

If MS-AIS or Excessive BER is detected, then a logical all ONEs DATA signal and a signal fail condition shall be applied at reference point D. It should be possible to disable the insertion of FERF at reference point C and AIS at reference point D on detection of excessive BER defect by a configuration command from the SEMF.

2.4 *Multiplex section protection function (MSP)*

The MSP function provides protection for the STM-N signal against channel-associated failures within a multiplex section, i.e. the RST, SPI functions and the physical medium from one MST function where section overhead is inserted to the other MST function where that overhead is terminated.

The MSP functions at both ends operate the same way, by monitoring STM-N signals for failures, evaluating the system status taking into consideration the priorities of failure conditions and of external and remote switch requests, and switching the appropriate channel to the protection section. The two MSP functions communicate with each other via a bit-oriented protocol defined for the MSP bytes (K1 and K2 bytes in the MSOH of the protection section). This protocol is described in § A.1 of Annex A, for the various protection switching architectures and modes defined in Recommendation G.782.

The signal flow associated with the MSP function is described with reference to Figure 2-6/G.783. The MSP function receives control parameters and external switch requests at the S14 reference point from the synchronous equipment management function and outputs status indicators at S14 to the synchronous equipment management function, as a result of switch commands described in § A.2 of Annex A.

FIGURE 2-6/G.783

2.4.1 *Signal flow from E to D*

Data at reference point E is an STM-N signal, timed from the T0 reference point, with indeterminate MSOH and RSOH bytes.

For 1 + 1 architecture, the signal received at E from the SA function is bridged permanently at D to both working and protection MST functions.

For 1 : n architecture, the signal received at E from each working SA is passed at D to its corresponding MST. The signal from an extra traffic SA (if provisioned) is connected to the protection MST. When a bridge is needed to protect a working channel, the signal at E from that working SA is bridged at D to the protection MST and the extra traffic channel is terminated.

The K1 and K2 bytes generated according to the rules in § 1 of Annex A are presented at D to the protection MST.

2.4.2 *Signal flow from D to E*

Framed STM-N signals (data) whose RSOH and MSOH bytes have already been recovered are presented at the reference point D along with incoming timing references. The failure conditions SF and SD are also received at the reference point D from all MST functions.

Also, the recovered K1 and K2 bytes from the protection MST function are presented at the reference point D.

Under normal conditions, MSP passes the data and timing from the working MST functions to their corresponding working SA functions at the reference point E. The data and timing from the protection section is passed to the extra traffic SA, if provisioned in a 1 : n MSP architecture, or else it is terminated.

If a switch is to be performed, then the data and timing received from the protection MST at reference point D is switched to the appropriate working channel SA function at E, and the signal received from the working MST at D is terminated.

2.4.3 *Switch initiation criteria*

Automatic protection switching is based on the failure conditions of the working and protection sections. These conditions, signal fail (SF) and signal degrade (SD), are provided by the MST functions at reference point D. Detection of these conditions is described in § 2.3.

The protection switch can also be initiated by switch commands received via the synchronous equipment management function.

2.4.4 *Switching time*

Protection switching shall be completed within 50 ms of detection of an SF or SD condition that initiates a switch.

2.4.5 *Switch restoral*

In the revertive mode of operation, the working channel shall be restored, i.e. the signal on the protection section shall be switched back to the working section, when the working section has recovered from failure. Restoral allows other failed working channels or an extra traffic channel to use the protection section.

To prevent frequent operation of the protection switch due to an intermittent failure (e.g. BER fluctuating around the SD threshold), a failed section must become fault-free (i.e. BER less than a restoral threshold). After the failed section meets this criterion, a fixed period of time shall elapse before it is used again by a working channel. This period, called wait-to-restore (WTR) period should be of the order of 5-12 minutes and should be capable of being set. An SF or SD condition shall override the WTR.

2.5 *Section adaptation function (SA)*

This function provides adaptation of higher order paths into administrative units (AUs), assembly and disassembly of AU groups, byte interleaved multiplexing and demultiplexing, and pointer generation, interpretation and processing. The signal flow associated with the SA function is described with reference to Figure 2-7/G.783.

FIGURE 2-7/G.783

2.5.1 *Signal flow from F to E*

The higher order paths at reference point F are mapped into AUs which are incorporated into AU groups. N such AUGs are byte interleaved to form an STM-N payload at the reference point E. The byte interleaving process shall be as specified in Recommendation G.709. The frame offset information is used by the PG function to generate pointers according to pointer generation rules in Recommendation G.709. STM-N data at E is synchronized to timing from the T0 reference point. If an all ONEs data signal is applied at reference point F (i.e. invalid frame offset due to loss of AU pointer), an AU path AIS shall be applied at reference point E.

2.5.2 *Signal flow from E to F*

STM-N payloads received at reference point E are disinterleaved and the VC-3/4s recovered using the AU pointers. The latter process must allow for the case of continuously variable frame offset which occurs when the received STM-N signal has been derived from a source which is plesiochronous with the local clock reference.

The PP function provides accommodation for wander and plesiochronous offset in the received signal with respect to the multiplexer timing reference. This function may be null in some applications where the timing reference is derived from the incoming STM-N signal, i.e. loop timing.

The PP function can be modelled as a data buffer which is being written with data, timed from the received VC clock, and read by a VC clock derived from reference point T0. When the write clock rate exceeds the read clock rate the buffer gradually fills and vice-versa. Upper and lower buffer occupancy thresholds determine when pointer adjustment should take place. The buffer is required to reduce the frequency of pointer adjustments in a network. When the data in the buffer rises above the upper threshold for a particular VC, the associated frame offset is decremented by one byte for a VC-3 or three bytes for a VC-4, and the corresponding number of bytes are read from the buffer. When the data in the buffer falls below the lower threshold for a particular VC, the associated frame offset is incremented by one byte for a VC-3 or three bytes for a VC-4 and the corresponding number of read opportunities are cancelled. The pointer hysteresis threshold spacing allocation is specified in § 7.1.4.1.

The mechanism of pointer processing is illustrated as a flow chart in Figure 2-8/G.783.

The algorithm for pointer detection is defined in Annex B/G.783. Two failure conditions can be detected by the pointer interpreter:

— loss of pointer (LOP),

— AU Path AIS.

If either or both of these failure conditions are detected then a logical all ONEs signal shall be applied at reference point F. These defects shall be reported at reference point S4 for alarm filtering at the synchronous equipment management function. Pointer justification events (PJE) are also reported at reference point S4 for performance monitoring filtering. PJEs need only be reported for one selected AU-3/4 out of an STM-N signal.

It should be noted that a mismatch between provisioned and received AU type will result in a LOP failure condition.

3 Higher order path functions

Higher order paths have been defined according to two types of virtual container (VC-3 and VC-4). These VCs can be created in two ways:

i) by direct mappings in AUs (direct mappings are defined for 3rd and 4th level signals and the locked mode level 1 mappings are also direct);

ii) by mapping of lower level signals into TUs which are then mapped into AUs.

These possibilities are illustrated in Figure 2-1/G.783.

3.1 *Higher order Path Connection function (HPC-n)*

HPC-*n* is the function which assigns assembled higher order VCs of level *n* (*n* = 3 or 4) to available VC-*n* capacity on a multiplex section. The inclusion of the HPC-*n* function constitutes a significant functional difference among multiplexer types illustrated in Figures 3-1/G.782 to 3-7/G.782.

Figure 3-1/G.783 illustrates reference points associated with the HPC-*n*. VC-*n*s coming from reference point G are assigned to available VC-*n* capacity at reference point F. Conversely, the VC-*n*s coming from reference point F are assigned to available VC-*n* capacity at reference point G. The signal format at reference points G and F are thus similar, differing only in the logical sequence of VC-*n*s.

FIGURE 2-8/G.783

FIGURE 3-1/G.783

The assignment of VC-*n*s at reference point G to VC-*n* capacities at reference point F and vice versa is defined as the connection pattern which can be described by a two column connection matrix CM (*Vi*, *Vj*), where *Vi* identifies the i-th VC channel at reference point F and *Vj* identifies the j-th VC channel at reference point G. For some connection patterns *Vj* is further identified by parameters *k* and *l* indicating the k-th port in l tributary ports. The multiplexer types are described below in terms of the CM.

At reference point S5 the following primitives are possible:

- Set matrix, which causes a particular port assignment to be made according to the connection matrix (CM) (from SEMF to HPC-*n*).
- Request CM report (from SEMF to HPC-*n*).
- Report CM (to SEMF from HPC-*n*).

A clock signal is provided to HPC-*n* at reference point T0 from the MTS.

Depending on the multiplexer type, there may be a degree of flexibility in the connection pattern which can be exercised when HPC-*n* is configured. Thus, various multiplexers will have various constraints in the parameters *i*, *j*, *k*, *l* of the connection matrix described above. Multiplexer types I, II, and IV assume HPC-*n* is null. Multiplexer types IIa and III assume a configurable connection pattern. The functions of the HPC-*n* are described below in terms of signal flow and multiplexer types.

3.1.1 *Signal flow from G to F*

HPC-*n* assigns assembled higher order VC-*n*s coming from reference point G to available VC-*n* capacity at reference point F. This assignment is based on the connection pattern (fixed or configurable) established.

3.1.2 *Signal flow from F to G*

This is similar to the one described in § 3.1.1 above.

3.1.3 *HPC-n for multiplexer types IIIa and IIIb*

This multiplexer performs an add and drop function as illustrated in Figures 3-5/G.782, 3-6/G.782 and 3-2/G.783.

FIGURE 3-2/G.783

Signals at FW and FE reference points support a VC-*n* capacity equivalent to the STM-N aggregate signal of the multiplexer. The add/drop ports GW1-GWn and GE1-GEm generally support lower VC-*n* capacity.

In the general case of a type IIIa/b add/drop multiplexer a cross-connect function will be performed where any of the *Vi* channels at FW and FE can be dropped to any of the *Vj* channels at GW1-GWn or GE1-GEm.

A specific example of a type IIIa/b multiplexer is one where, in the connection matrix CM (*Vi*, *Vj*), *Vi* identifies one of the VC-*n* channels at FW and FE and *Vj* identifies one of the VC-*n* channels at GW1-GWn and GE1-GEm. This implies that *Vi* at FW is dropped to *Vj* at GW1-GWn and *Vi* at FE is dropped to *Vj* at GE1-GEm. All the *Vi* channels at FW which are not dropped are passed through to the corresponding *Vi* channels at FE. The number of rows in CM (*Vi*, *Vj*) is the same as the number of VC-*n* channels dropped.

3.1.4 *HPC-n for multiplexer types Ia and IIa*

These multiplexers perform a consolidation function as illustrated in Figures 3-2/G.782, 3-4/G.782 and 3-3/G.783.
FIGURE 3-3/G.783

The signal at reference point F supports a VC-*n* capacity equivalent to the STM-M aggregate signal of the multiplexer. The multiplexer ports G1 to Gl each support a VC-*n* equivalent to STM-N where M > N. The total capacity at G1 to Gl shall not exceed the capacity at F.

In the connection matrix CM (*Vi*, *Vjk*) for this multiplexer, *Vi* identifies one of the VC-*n* channels at F and *Vjk* identifies the j-th VC-*n* channel at *Gk* (*k* = 1, - - - l). This requires that a particular VC-*n* channel *Vjk* at G is connected to a particular channel *Vi* at F.

3.1.5 *HPC-n for multiplexer types I, II, and IV*

These multiplexers perform a terminal multiplexer function as illustrated in Figures 3-1/G.782, 3-3/G.782, 3-7/G.782 and 3-4/G.783.

The signal at reference point F supports a VC-*n* capacity equivalent to the STM-M or STM-N at the aggregate port of the multiplexer. The total capacity at G is the same as that at F.

The HPC-*n* is a null function where *Vi* = *Vj* for all values of *i* and *j*; i.e. a fixed connection pattern exists between the assembled VCs at G and F.
FIGURE 3-4/G/783

3.2 *Higher order path termination function (HPT-n)*

This function acts as a source and sink for the higher order path overhead (VC-*n* POH, *n* = 3,4). A higher order path is a maintenance entity defined between two higher order path terminations. The information flows associated with the HPT-*n* function are described with reference to Figures 2-1/G.783 and 3-5/G.783.
FIGURE 3-5/G/783

The timing signal is provided from the MTS at the T0 reference point.

3.2.1 *Signal flow from G to H*

Data at G is a VC-*n* (*n* = 3,4), having a payload as described in Recommendations G.708 and G.709, with complete VC-3/4 POH (bytes J1, B3, C2, G1, F2, H4, Z3, Z4, Z5). These POH bytes are recovered as part of the HPT-*n* function and the VC-*n* is forwarded to reference point H.

Bytes J1, G1 and C2 are recovered from the VC-*n* POH at G and the corresponding information on path trace, path status and signal label are passed via reference point S6 to the synchronous equipment management function.

The G1 byte is illustrated in Recommendation G.709. FEBE information is decoded from bits 1 to 4 of the G1 byte and reported as path termination error report at S6. The path FERF information in bit 5 of the G1 byte is recovered and reported as remote alarm indication at S6.

In the case of payloads requiring multiframe alignment, a multiframe indicator is derived from the H4 byte. The received H4 value is compared to the next expected value in the multiframe sequence. The H4 value is assumed to be in phase when it is coincident with the expected value. If several H4 values are received consecutively not as expected but correctly in sequence with a different part of the multiframe sequence, then subsequent H4 values shall be expected to follow this new alignment. If several H4 values are received consecutively not correctly in sequence with any part of the multiframe sequence then a loss of multiframe (LOM) event shall be reported at S6. When several H4 values have been received consecutively correctly in sequence with part of the multiframe sequence, then the event shall be ceased and subsequent H4 values shall be expected to follow the new alignment.

Note — The meaning of “several” is that the number should be low enough to avoid excessive delay in re-framing but high enough to avoid re-framing due to errors; a value in the range 2 to 10 is suggested.

The error monitoring byte B3 is recovered from the VC-*n* frame. BIP-8 is computed for the VC-*n* frame. The computed BIP-8 value for the current frame is compared with the recovered B3 byte from the following frame and errors are reported at reference point S6 as number of errors within the B3 byte per frame for performance monitoring filtering in the synchronous equipment management function.

One byte per frame is allocated for user communication purposes. It is derived from the F2 byte and passed via reference point U3 to the overhead access function.

The three bytes Z3, Z4 and Z5 are reserved for future use. Currently they have no defined value at G.

3.2.2 *Signal flow from H to G*

Data at H is a VC-*n* (*n* = 3,4), having a payload as described in Recommendations G.708 and G.709, but with indeterminate VC-3/4 POH (bytes J1, B3, C2, G1, F2, H4, Z3, Z4, Z5). These POH bytes are set as part of the HPT-*n* function and the complete VC-*n* is forwarded to G.

Path trace, path status and signal label information, derived from reference point S6 are placed in J1, G1 and C2 byte positions respectively.

If the path termination error report indicates an errored block, then the FEBE (bits 1 to 4 of the G1 byte) are encoded according to Figure 4-2/G.709. If AU path AIS at G is reported, then a path FERF indication should be sent in bit 5 of the G1 byte.

Bit interleaved parity (BIP-8) is computed over all bits of the previous VC-*n* and placed in B3 byte position.

A multiframe indicator is generated as described in Recommendation G.709 and placed in the H4 byte position.

One byte per frame is allocated for user communication purposes. It is derived from reference point U3 and placed in the F2 byte position.

The three bytes Z3, Z4 and Z5 are reserved for future use. Currently they have no defined value at G.

3.3 *Higher order path adaptation function (HPA-m/n)*

HPA-*m*/*n* (*m* =1, 2 or 3; *n* = 3 or 4) defines the TU pointer processing. It may be divided into three functions:

- pointer generation;
- pointer interpretation;
- frequency justification.

The format for TU pointers, their roles for processing, and mappings of VCs are described in Recommendation G.709.

Figure 3-6/G.783 illustrates the HPA-*m*/*n* function.
FIGURE 3-6/G.783

3.3.1 *Signal flow from J to H*

The HPA-*m*/*n* function assembles VCs of lower order *m* (*m* = 11, 12, 2, 3) as TU-*m* into VCs of higher order *n* (*n* = 3 or 4).

The frame offset in bytes between a lower order VC and higher order VC is indicated by a TU pointer which is assigned to that particular lower order VC. The method of pointer generation is described in Recommendation G.709.

3.3.2 *Signal flow from H to J*

The HPA-*m*/4 function disassembles VC-4 into VCs of lower order *m* (*m* = 11, 12, 2, 3). HPA-*m*/3 disassembles VC-3 into VCs of lower order *m* (*m* = 11, 12, 2). The TU pointer of each lower order VC is decoded to provide information about the frame offset in bytes between the higher order VC and the individual lower order VCs. The method of pointer interpretation is described in Recommendation G.709. This process must allow for continuous pointer adjustments when the clock frequency of the node where the TU was assembled is different from the local clock reference. The frequency difference between these clocks affects the required size of the data buffer whose function is described below.

The PP function can be modelled as a data buffer which is being written with data, timed from the received VC clock, and read by a VC clock derived from reference point T0. When the write clock rate exceeds the read clock rate the buffer gradually fills and vice versa. Upper and lower buffer occupancy thresholds determine when pointer adjustment should take place. The buffer is required to reduce the frequency of pointer adjustments in a network. When the data in the buffer rises above the upper threshold for a particular VC, the associated frame offset is decremented by one byte and an extra byte is read from the buffer. When the data in the buffer falls below the lower threshold for a particular VC, the associated frame offset is incremented by one byte and one read opportunity is cancelled. The threshold spacing is for further study.

The algorithm for pointer detection is defined in Annex B. Two failure conditions can be detected by the pointer interpreter:

— loss of pointer (LOP),

— TU path AIS.

If either or both of these failure conditions are detected then a logical all ONEs signal shall be applied at reference point J. These defects shall be reported at reference point S7 for alarm filtering at the synchronous equipment management function. Pointer justification events (PJE) shall be reported at reference point S7 for performance monitoring filtering. PJEs need only be reported for one selected TU-1/2/3 out of an STM-N signal and only if PJEs are not reported at the AU level.

It should be noted that a mismatch between provisioned and received TU type will result in a Loss of Pointer (LOP) defect. LOP is reported to the Synchronous Equipment Management function through the S7 reference point. Pointer hysteresis threshold spacing allocation is specified in § 7.1.4.2.

4 Lower order path functions

Recommendations G.708 and G.709 define five basic path capacities corresponding to Recommendation G.702 digital hierarchy levels and denoted by indices 11, 12, 2, 3 and 4. In addition, the concatenation function which is defined for level 2 makes possible the creation of 21 new path capacities. User signals are adapted to form containers which are then allocated to higher order paths. The functions involved in path creation and assignment are described in this section.

Note — A VC-3 path can be a lower order or a higher order path, depending on its application. When VC-1s or VC-2s are multiplexed into a VC-3, the VC-3 constitutes a higher order path; when a VC-3 is multiplexed into a VC-4, it constitutes a lower order path.

4.1 *Lower order path connection function (LPC-m)*

LPC-*m* is the function which assigns VCs of level *m* (*m* = 1, 2 or 3) to available VC-*m* capacity in higher order paths. There is no LPC-*m* function in multiplexer types II, IIa and IV and the LPC-*m* function in type I multiplexer is null. The LPC-*m* function in multiplexer type III is defined to allow add/drop operations between tributaries and one or both aggregate ports in support of bus and ring network topologies.

Figure 4-1/G.783 illustrates reference points associated with the LPC-*m*. VC-*m*s coming from reference point K are assigned to available VC-*m* capacity at reference point J and vice versa. The signal format at reference points K and J are thus similar, differing only in the logical sequence of VC-*m*s.

FIGURE 4-1/G.783

The assignment of VC-*m*s at reference point K to VC-*m* capacities at reference point J and vice-versa is defined as the connection pattern which can be described by a two column connection matrix CM (*Vi*, *Vj*), where *Vi* identifies the i-th VC channel at reference point J and *Vj* identifies the j-th VC channel at reference point K. The multiplexer types are described below in terms of the CM.

At reference point S8 the following primitives are possible:

— Set matrix, which causes a particular port assignment to be made according to the connection matrix (CM) (from SEMF to LPC-*m*)

— Request CM report (from SEMF to LPC-*m*)

— Report CM (to SEMF from LPC-*m*).

A clock signal is provided to LPC-*m* at reference point T0 from the MTS.

Depending on the multiplexer type, there may be a degree of flexibility in the connection pattern which can be exercised when LPC-*m* is configured. Thus, various multiplexers will have various constraints in the parameters *i*, *j* of the connection matrix described above.

4.1.1 *Signal flow from K to J*

LPC-*m* assigns assembled VC-*m*s coming from reference point K to available VC-*m* capacity at reference point J. This assignment is based on the connection pattern (fixed or configurable) established.

4.1.2 *Signal flow from J to K*

This is similar to the one described in § 4.1.1.

4.1.3 *Connection matrix for multiplexer type III*

The connection matrix is illustrated in Figure 4-2/G.783. The signals at reference points J West and J East each support a VC-*m* capacity equivalent to the higher order paths which have to be accessed. The signal at reference point K supports a similar or lower capacity. The connection function allows VC-*n*s to be dropped from and inserted into J East and J West to and from reference point K without rearranging the through traffic. The connection pattern can be described by the matrix (*Vj*, *Vij*) where *Vj* identifies the j-th VC-*n* channel at K and the *Vij* represents the j-th channel at reference point J West if $i = 1$, the j-th channel at reference point J East if $i = 2$ and the j-th channel at J East and/or J West if $i = 3$; i.e. in the direction from K to J East/J West, transmission is on both channels while in the direction from J East/J West to K, the J East or J West channel is selected.

Note — The mode of operation selected when $i = 3$ enables type III multiplexers to operate in a ring configuration with path layer protection provided by the alternative route and

without intervention from higher layer functions.
FIGURE 4-2/G.783

4.2 *Lower order path termination function (LPT-m)*

The LPT-*m* function creates a VC-*m* (*m* = 1, 2, or 3) by generating and adding POH to a container C-*m*. In the other direction of transmission it terminates and processes the POH to determine the status of the defined path attributes. The POH formats are defined in Recommendations G.708 and G.709. The information flows associated with the LPT function are described in Figure 4-3/G.783.
FIGURE 4-3/G.783

Referring to Figure 2-1/G.783, Data at L takes the form of a container C-*m* (*m* = 1,2,3) which is synchronized to the timing reference T0.

Synchronously adapted information in the form of synchronous containers (data) and the associated container frame offset information (frame offset) are received at reference point L. POH is added to form data which together with the frame offset is passed to reference point K.

4.2.1 *Path OH at levels 1 and 2*

The VC-1/VC-2 POH is carried in the V5 byte as defined in Recommendation G.709.

4.2.1.1 *Signal flow from K to L*

If TU Path AIS is received at K then path AIS condition shall be reported at S9 (TU path AIS detection is described in § 3.3) and the all ONEs data signal shall be presented at data (L). Additionally, a path FERF indication shall be sent in bit 8 of V5 in the data in the reverse direction.

Bits 5, 6 and 7 of V5 at K shall be detected and reported as signal label at S9.

The error monitoring bits 1 and 2 of V5 at K shall be recovered. BIP-2 is computed for the VC-*n* frame. The computed BIP-2 value for the current frame is compared with the recovered bits 1 and 2 from the following frame and the number of errors (0, 1 or 2) in the block shall be reported as path termination error report at S9. (Excessive error ratio detection is for further study.)

FEBE in bit 3 shall be recovered and reported at S9.

The path FERF information in bit 8 shall be recovered and reported as remote alarm indication at S9.

Bit 4 is unused. The receiver must be capable of ignoring the value of this bit.

4.2.1.2 *Signal flow from L to K*

The signal label presented at S9 shall be inserted in bits 5, 6 and 7 in the V5 byte.

BIP-2 shall be calculated on data at L on the previous frame or multiframe and the result transmitted in bits 1 and 2 of the V5 byte.

If the path termination error report indicates an errored block then FEBE bit (3) shall be set to 1 in the next frame.

4.2.2 *Path overhead at level 3*

The VC-*m* path overhead (for $m = 3$) is the same as the path overhead for VC-*n* ($n = 3$) and is described in § 3.2.

4.3 *Lower order path adaptation functions (LPA-m/n)*

LPA operates at the access port to a synchronous network or subnetwork and adapts user data for transport in the synchronous domain. For asynchronous user data, lower order path adaptation involves bit justification. The LPA-*n* function directly maps G.703 signals into a higher order container (*n* = 3 or 4). The LPA-*m* function maps G.703 signals into lower order containers which may subsequently be mapped into higher order containers (*m* = 11, 12, 2, 3). The information flows associated with the LPA function are shown in Figure 4-4/G.783.

(*Note* — Primary rate signals can be mapped directly into higher order paths using the locked mode mappings:)

FIGURE 4-4/G.783

LPA functions are defined for each of the levels in the existing plesiochronous hierarchies. Each LPA function defines the manner in which a user signal can be mapped into one of a range of synchronous containers C of appropriate size. The container sizes have been chosen for ease of mapping various combinations of sizes into high order containers; see Table 4-2/G.783. Detailed specifications for mapping user data into containers are given in Recommendation G.709.

The LPA type is reported on request to the SEMF through the S10 reference point.

µTABLE 4-2/G.783

LPA-*m* LPA-*n*	Container size
LPA-11 bit sync.	C-11
~~LPA-11~~ byte sync.	C-11
~~LPA-11~~ async.	C-11
~~LPA-11~~ locked	C-11
LPA-12 bit sync.	C-12
~~LPA-12~~ byte sync.	C-12
~~LPA-12~~ async.	C-12
~~LPA-12~~ locked	C-12
LPA-2 async.	

4.3.1 *Direction M to L or H*

DATA at M is the user information stream delivered by the PI function. Timing of the data is also delivered as timing at M by the PI function. Data is adapted according to one of the LPA functions referred to above. This involves synchronization and mapping of the information stream into a container as described in Recommendation G.709.

The container is passed to the reference point L (or H in the case of direct mapping) as data together with frame offset which represents the offset of the container frame with respect to reference point T0. In byte synchronous mappings, the frame offset is obtained from the associated framer. In other mappings, a convenient fixed offset can be generated internally.

Mapping of overhead and maintenance information from byte synchronously mapped G.703 signals is for further study.

Frame alignment loss (FAL) is reported to the synchronous equipment management function through the S10 reference point (byte sync mapping only). The strategy for FAL detection/indication is described in Recommendation G.706.

4.3.2 *Direction L or H to M*

The information stream data at L (or H in the case of direct mapping) is presented as a container together with frame offset. The user information stream is recovered from the container together with the associated clock suitable for tributary line timing and passed to the reference point M as data (M) and timing (M). This involves de-mapping and desynchronizing as described in Recommendation G.709.

Note — Other signals may be required from L to generate overhead and maintenance information for byte-synchronously mapped G.703 signals. This is for further study.

When path AIS is reported through S10, the LPA function shall generate AIS in accordance with the relevant G.700-Series Recommendations.

4.4 *Physical interface (PI) function*

This function provides the interface between the multiplexer and the physical medium carrying a tributary signal which may have any of the physical characteristics of those described in Recommendation G.703 and in some cases the signal structure in Recommendation G.704. The information flows for the PI function are described with reference to Figure 4-5/G.783.

FIGURE 4-5/G.783

4.4.1 *Signal flow from M to tributary interface*

The functions performed by the PI are encoding and adaptation to the physical medium.

The PI function takes data and timing at M to form the transmit tributary signal. The PI passes the data and timing information to the tributary interface transparently.

4.4.2 *Signal flow from tributary interface to M*

The PI function extracts timing from the received tributary signal and regenerates the data. After decoding, it passes the data and timing information to reference point M. The timing may also be provided at reference point T2 for possible use as a reference in the MTS.

In the event of loss of signal (LOS) at the tributary input, AIS in the form of all ONEs is transmitted on data at M accompanied by a suitable reference timing signal. LOS is reported at reference point S11.

5 Synchronous equipment management function

The synchronous equipment management function (SEMF) provides the means through which the synchronous network element function (NEF) is managed by an internal or external manager. If a network element (NE) contains an internal manager, this manager will be part of the SEMF.

The SEMF interacts with the other functional blocks by exchanging information across the Sn reference points. The SEMF contains a number of filters that provide a data reduction mechanism on the information received across the Sn reference points. The filter outputs are available to the agent via managed objects which represent this information. The managed objects also present other management information to and from the agent.

Managed objects provide event processing and storage and represent the information in a uniform manner. The agent converts this information to CMISE (Common Management Information Service Element) messages and responds to CMISE messages from the manager performing the appropriate operations on the managed objects.

This information to and from the agent is passed across the V reference point to the message communications function (MCF).

The event processing and storage provided by the managed objects is described in Recommendation G.784 including the filtering and thresholding of performance and failure information.

In the subsequent sections on the SEMF only the information flowing across the Sn reference points and the three filters shown in Figure 5-1/G.783 is described.
FIGURE 5-1/G/783

5.1 *Information flow across the Sn reference points*

The information flows described in this section are functional. The existence of these information flows in the equipment will depend on the options selected at the external interfaces to the equipment, in particular, the options selected by the TMN.

The information that arises from anomalies and defects detected in the functional blocks is summarized in Tables 5-1/G.783 to 5-11/G.783. For ease of reference these tables also show the consequent actions that are described in the sections on the individual functional blocks.

Table 5-12/G.783 summarizes the configuration and provisioning information that is passed across the S reference points. The information listed under “Set” in this table refers to configuration and provisioning data that is passed from the SEMF to the other functional blocks.

The information listed under “Get” refers to status reports made in response to a request from the SEMF for such information.

As an example we may consider the higher order path trace. The higher order path termination may be provisioned for the HO path trace that it should expect by a Set_Rx_HO_path_trace_ID command received from the manager. If the HO path trace that is received does not match the expected HO path trace this will give rise to a report of a mismatch of the HO path trace across the S6 reference point. Having received this mismatch indication, the relevant managed object may then decide to request a report of the HO path trace ID that has been received by a Get_Rx_HO_ path_trace_ID.

5.2 *Filter functions*

Note — Fixed one second filter processing of the information is considered satisfactory for the purpose of network surveillance and fault identification and sectionalization. This does not preclude the additional use of other filter processing techniques for detailed performance or fault characterization where it is demonstrated that these provide significant additional information on the nature of errored events. If an alternative filter technique is used, it should be in addition to the fixed one second filter.

The filtering functions provide a data reduction mechanism on the anomalies and defects presented at the S reference points. Three types of filters can be distinguished:

5.2.1 *One second filters*

The one second filters perform a simple integration of reported anomalies by counting during a one second interval. At the end of each one second interval the contents of the counters may be obtained by the relevant managed objects. The following counter outputs will be provided:

- regenerator section (B1) errors,
- regenerator section out of frame (OOF) events,
- multiplex section (B2) errors,
- HO path (B3) errors,
- path errors (B3/V5),
- HO path far end block errors (G1),
- path far end block errors (G1/V5),
- AU justification events (for further study),
- TU justification events (for further study).

5.2.2 *Defect filter*

The defect filter will provide a persistency check on the defects that are reported across the S reference points. Since all of the defects will appear at the input of this filter it may provide correlation to reduce the amount of information offered as failure indications to the agent. The following failure indications will be provided:

- loss of signal,
- loss of frame,
- loss of AU pointer,
- loss of TU pointer,
- multiplex section AIS,
- HO path AIS,
- path AIS,
- far-end receive failure,
- HO path FERF,
- path FERF, etc. (as listed in Tables 5-1/G.783 to 5-11/G.783 in the “anomalies and defects” column).

In addition to the transmission failures listed above, equipment failures are also reported at the output of the defect filter for further processing by the agent.

5.2.3 *ES, SES filter*

The ES, SES filter processes the information available from the one second and the defect filter to derive errored seconds and severely errored seconds that are reported to the agent.

ES and SES information will be made available for all the parameters listed in § 5.2.1 above, except justification events. In addition, information will be provided on out of frame (OOF) seconds; an OOF second is defined as a second in which one or more out of frame events have occurred.

µTABLE 5-1/G.783

SDH physical interface

Signal flow

Anomalies and defects

Report across

SEMF filtering

Consequent actions

S1
Alarm
Performance
AIS inserted

From A to B

Receive loss of signal

Yes

Yes

Yes (Note)

Transmit fail

Yes

Yes

From B to A

6 Timing functions

6.1 *Multiplexer timing source function*

This function provides timing reference to the following functional blocks: LPA, LPT, LPC, HPA, HPT, HPC, SA, MSP, MST, and RST. The multiplexer timing source (MTS) function represents the SDH network element clock. The MTS function includes an internal oscillator function and multiplexer timing generator (MTG) function. The information flows associated with the MTS function are described with reference to Figure 6-1/G.783.

The synchronization source may be selected from any of the reference points T1, T2, T3 or the internal oscillator. When the MTS is synchronized to a signal carrying a network frequency reference standard the short-term stability requirements at the T reference points are specified in Figure 6-2/G.783.

FIGURE 6-1/G.783

FIGURE 6-2/G/783

The MTG function filters the selected timing reference to ensure that the timing requirements at the T reference points are met. Additionally the MTG filtering function must filter the step change in frequency caused by a change in reference source so that the rate of change of frequency at the T reference points does not exceed x Hz/s; the value of x is for further study. This applies to the following three cases:

— change from one reference source to another;

— change from reference source to the internal oscillator;

— change from the internal oscillator to a reference source.

In practice, the last change will be the worst case.

The long- and short-term stability of the internal oscillator function is for further study.

Note 1 — The maximum rate of change of frequency must be tracked by the desynchronizer at the SDH/PDH boundary. This will put an upper bound on the rate for practical desynchronizer designs.

Note 2 — Desynchronizers must be designed to allow for maximum frequency offset of the internal oscillator. This may set an upper bound on its stability for some desynchronizer designs.

The overall quality requirements of the MTS are in the province of Study Group XVIII.

6.2 *Multiplexer timing physical interface (MTPI) function*

This function provides the interface between the external synchronization signal and the multiplexer timing source and shall have, at the synchronization interface port, the physical characteristics of one of the G.703 synchronization interfaces. (See Figure 6-3/G.783.)

FIGURE 6-3/G.783

6.2.1 *Signal flow from MTS to synchronization interface*

This signal flow only exists if the MTS can provide external synchronization.

The functions performed by the MTPI are encoding and adaptation to the physical medium.

The MTPI function takes timing from the MTS to form the transmit synchronization signal. The MTPI passes the timing information to the synchronization interface transparently.

6.2.2 *Signal flow from synchronization interface to MTS*

The MTPI function extracts timing from the received synchronization signal. After decoding, it passes timing information to the MTS.

7 Specification of jitter and wander

SDH jitter and wander is specified at both STM-N and G.703 interfaces. The SDH multiplex equipment's jitter and wander characteristics at such interfaces may be categorized in terms of whether:

- its jitter and wander performance is governed exclusively by the input timing extraction circuitry;
- tributary bit justification is performed in addition to input timing extraction;
- phase smoothing of pointer justifications is performed as well as tributary bit justification and input timing extraction.

In addition, the wander encoded in both the AU and TU pointer adjustments is specified. (This determines the statistics of occurrence of pointer adjustments.)

7.1 *STM-N interfaces*

7.1.1 *Input jitter and wander accommodation*

Jitter present on the STM-N signal must be accommodated by the SPI. The detailed parameters and limits are given in Recommendation G.958.

The STM-N signal may be used to synchronize the multiplexer timing source (MTS), which must be able to accommodate the maximum absolute jitter and wander present on the STM-N signal. This will be primarily affected by wander, and can be specified in terms of maximum time interval error (MTIE), together with its first and second derivatives with respect to time. The detailed parameters and limits are for further study.

7.1.2 *Output jitter and wander generation*

The output jitter and wander must meet the short-term stability requirements given in Figure 6-2/G.783.

When the multiplexer timing source is used, the output jitter and wander depends on the inherent properties of the multiplexer timing generator as well as the properties of the synchronization input.

When the equipment is loop-timed, the output jitter and wander depends on the incoming jitter and wander as filtered by the jitter and wander transfer characteristics described in § 7.1.3.

Further requirements for wander can be specified in terms of MTIE, together with its first and second derivatives with respect to time. The specification of output jitter depends on the demarcation between jitter and wander. The output jitter should be less than or equal to 0.01 UI rms as measured in a 12 kHz high pass filter. A second output jitter requirement as measured in a lower frequency high pass filter is for further study. The measurement technique needs to be specified.

7.1.3 *Jitter and wander transfer*

The jitter and wander transfer is dependent on whether the equipment is synchronized and the manner in which it is synchronized.

When the equipment is not synchronized, the jitter and wander transfer characteristics have no meaning as the output jitter and wander is determined solely by the internal oscillator.

When the equipment is synchronized, the jitter and wander transfer characteristics are determined by the filtering characteristics of the multiplexer timing generator (MTG). These filtering characteristics may vary depending on whether the equipment is loop timed or uses a multiplexer timing source. Figure 7-1/G.783 provides a block diagram of timing functions for multiplex equipment using loop timing.

The jitter transfer characteristics (specifically, the ratio of the output jitter to the applied input jitter as a function of frequency) can be tested using sinusoidal input jitter. It should be noted that this may not adequately test some non-linear timing generator implementations. The introduction of some new tests based on broad-band jitter may help to characterize such implementations.

Detailed specifications are for further study.

FIGURE 7-1/G.783

7.1.4 *Transfer of wander encoded in AU and TU pointer adjustments*

The transfer of wander encoded in the AU and TU pointer adjustments is controlled by the AU and TU pointer processors, respectively. Wander is affected by the difference between the incoming phase and the fill within the pointer processor buffer. The larger the buffer spacing, the less likely that incoming pointer adjustments will result in outgoing pointer adjustments.

7.1.4.1 *AU pointer processor buffer threshold spacing*

The MTIE of the higher order VC with respect to the clock generating the STM-N frame is quantized and encoded in the AU pointer. When a higher-order VC is transferred from an STM-N to another STM-N derived from a different clock, the AU pointer must be processed. The pointer is first decoded to derive the frame phase and a clock to write to the AU pointer processor buffer. The read clock from the buffer is derived from the multiplexer timing source. The buffer fill is monitored and when upper or lower thresholds are crossed, the frame phase is adjusted.

The allocation in the pointer processor buffer for pointer hysteresis threshold spacing should be at least 12 bytes for AU-4 and at least 4 bytes for AU-3 (corresponding to maximum relative time interval error (MRTIE) of 640 ns between reference point T0 and the incoming STM-N line signal).

7.1.4.2 *TU pointer processor buffer threshold spacing*

The MTIE of the lower-order VC with respect to the clock generating the higher-order VC is quantized and encoded in the TU pointer. When a lower-order VC is transferred from one higher-order VC into another higher-order VC derived from a different clock, the TU pointer must be processed. The pointer is first decoded to derive the frame phase and a clock to write to the TU pointer processor buffer. The read clock from the buffer is derived from the multiplexer timing source. The buffer fill is monitored and when upper or lower thresholds are crossed, the frame phase is adjusted.

The allocation in the pointer processor buffer for pointer hysteresis threshold spacing should be at least 4 bytes for TU-3s and at least 2 bytes for TU-1s and TU-2s.

7.2 *G.703 interfaces*

7.2.1 *Input jitter and wander tolerance*

Input jitter and wander tolerance for 2048 kbit/s hierarchy based signals are specified in Recommendation G.823. Input jitter and wander tolerance of 1544 kbit/s hierarchy based signals are specified in Recommendations G.824, G.743, and G.752.

Note — It may be necessary to specify transmit and receive separately for multi-vendor systems.

7.2.2 *Jitter and wander transfer*

As a minimum requirement, the jitter transfer specifications in the corresponding plesiochronous multiplex equipment Recommendations must be met.

Note 1 — Multiplexer jitter and wander transfer may be difficult to specify for multi-vendor systems. Demultiplexer jitter and wander transfer may be more amenable to specification.

Note 2 — The above-mentioned specifications are not sufficient to assure that SDH multiplexers provide adequate overall jitter and wander attenuation. Specifically, attenuation of the jitter and wander arising from decoded pointer adjustments places more stringent requirements on the SDH demultiplexer transfer characteristic.

7.2.3 *Jitter and wander generation*

7.2.3.1 *Jitter and wander from tributary mapping*

Specifications for jitter arising from mapping G.703 tributaries into containers, described in Recommendation G.709, should be specified in terms of peak-to-peak amplitude over a given frequency band over a given measurement interval. Detailed specifications are for further study.

Note 1 — Tributary mapping jitter is measured in the absence of pointer adjustments.

The output wander should be specified in terms of MTIE together with its first and second derivatives with respect to time. The need for and details of this specification are for further study.

7.2.3.2 *Jitter and wander from pointer adjustments*

The jitter and wander arising from decoded pointer adjustments must be sufficiently attenuated to ensure that existing plesiochronous network performance is not degraded. Detailed specifications are for further study.

7.2.3.3 *Combined jitter and wander from tributary mapping and pointer adjustments*

The combined jitter arising from tributary mapping and pointer adjustments should be specified in terms of peak-to-peak amplitude over a given frequency band, under application of representative specified pointer adjustment test sequences, for a given measurement interval. This interval is dependent on the test sequence duration and number of repetitions. A key feature that must be considered in the specification of the effects of pointer adjustments on G.703 interfaces is the demarcation between jitter and wander. Thus a critical feature is the high-pass filter characteristics. The limits for each G.703 tributary interface and the corresponding filter characteristics are given in Table 7-1/G.783. Detailed specifications of the pointer adjustment test sequences are for further study.

Two tests for wander may be necessary; one with a single pole HPF and another with a double pole HPF in order to differentiate between the first and second derivatives of MTIE. Detailed specifications are for further study.

8 Overhead access function

In SDH multiplex equipment, it may be required to provide access in an integrated manner to transmission overhead functions. This subject is for further study in CCITT. The present Recommendation defines the U reference points across which information may be exchanged with the other functional blocks.

A particular overhead access function which will be required is the engineering orderwire function (EOW) which is used to provide voice contact between regenerator and line terminal locations for maintenance personnel. This subject is for further study.

µTABLE 7-1/G.783

Combined jitter generation specification

Filter characteristics

Maximum pk — pk jitter

G.703
inter-

Bit rate

f1

f3

f4

mapping

combined

face

range

high pass

high pass

low pass

f1-f4

f3-f4

f1-f4

ANNEX A

(to Recommendation G.783)

Multiplex section protection (MSP) protocol, commands and operation

A.1 *MSP Protocol*

The MSP functions, at the ends of a multiplex section, make requests for and give acknowledgements of switch action by using the MSP bytes (K1 and K2 bytes in the MSOH of the protection section). The bit assignments for these bytes and the bit-oriented protocol are defined as follows.

A.1.1 *K1 byte*

The K1 byte indicates a request of a channel for switch action.

Bits 1-4 indicate the type of request, as listed in Table A-1/G.783. A request can be:

1) a condition (SF and SD) associated with a section. A condition has high or low priority. The priority is set for each corresponding channel;
2) a state (wait-to-restore, do not revert, no request, reverse request) of the MSP function; or
3) an external request (lockout of protection, forced or manual switch, and exercise).

Bits 5-8 indicate the number of the channel for which the request is issued, as shown in Table A-2/G.783.

A.1.2 *K1 byte generation rules*

Local SF and SD conditions, WTR or do not revert state and the external request are evaluated by a priority logic, based on the descending order of request priorities in Table A-1/G.783. If local conditions (SF or SD) of the same level are detected on different sections at the same time, the condition with the lowest channel number takes priority. Of these evaluated requests, the one of the highest priority replaces the current local request, only if it is of higher priority.

A.1.2.1 *In bidirectional operation*

The priorities of the local request and the remote request on the received K1 byte are compared according to the descending order of priorities in Table A-1/G.783. Note that a received reverse request is not considered in the comparison.

The sent K1 shall indicate:

a) a Reverse Request if
    i)

ii)
Reverse Request, or if
iii)
Reverse Request and the remote request indicates a lower channel number;

b) the local request in all other cases.

µTABLE A-1/G.783

Types of request

Bits 1234	Condition, state or external request	Order
1111	Lockout of protection (Note 1)	Highest
1110	Forced switch	|
1101	Signal fail — high priority	|
1100	Signal fail — low priority	|
1011	Signal degrade — high priority	|
1010	Signal degrade — low priority	|
1001	Unused (Note 2)	|
1000	Manual switch	|

A.1.2.2 *In unidirectional operation*

The sent K1 byte shall always indicate the local request. Therefore, reverse request is never indicated.

A.1.3 *Revertive/non-revertive modes*

In revertive mode of operation, when the protection is no longer requested, i.e. the failed section is no longer in SD or SF condition (and assuming no other requesting channels), a local Wait-to-restore state shall be activated. Since this state becomes the highest in priority, it is indicated on the sent K1 byte, and maintains the switch on that channel. This state shall normally time out and become a no request — null channel (or no request — channel 15, if applicable). The wait-to-restore timer deactivates earlier if the sent K1 byte no longer indicates "wait-to-restore", i.e. when any request of higher priority pre-empts this state.

In non-revertive mode of operation, applicable only to 1 + 1 architecture, when the failed working section is no longer in SD or SF condition, the selection of that channel from protection is maintained by activating a do not revert state or a wait-to-restore state rather than a no request state.

Both wait-to-restore and do not revert requests in the sent K1 byte are normally acknowledged by a reverse request in the received K1 byte. However, no request is acknowledged by another no request received.

A.1.4 *K2 byte*

Bits 1-5 indicate the status of the bridge in the MSP switch (see Figures A-1/G.783 and A-2/G.783). Bits 6 to 8 are reserved for future use to implement drop and insert (nested) switching. Note that codes 111 and 110 will not be assigned for such use, since they are used for MS-AIS detection and MS-FERF indication.
FIGURE A-1/G.783

FIGURE A-2/G.783

Bits 1-4 indicate a channel number, as shown in Table A-3/G.783. Bit 5 indicates the type of the MSP architecture: set 1 indicates 1 : n architecture and set 0 indicates 1 + 1 architecture.

µTABLE A-3/G.783

Channel number	Indication
0	Null channel
1 to 14	Working channel (1-14) For 1 + 1, only working channel 1 is applicable.
15	Extra traffic channel Exists only when provisioned in a 1 : n architecture

§

A.1.5 *K2 byte generation rules*

The sent K2 byte shall indicate in bits 1 to 4, for all architectures and operation modes:

a) null channel (0) if the received K1 byte indicates either null channel or the number of a locked-out working channel;

b) the number of the channel which is bridged, in all other cases.

The sent K2 byte shall indicate in bit 5:

a) 0 if 1 + 1 architecture;

b) 1 if 1 : n architecture.

Bit 5 of the sent and received K2 bytes may be compared; if a mismatch persists for Y ms, a mismatch is indicated at reference point S14. A provisional value for Y is 50 ms.

A.1.6 *Control of the bridge*

In 1 : n architecture, the channel number indicated on the received K1 byte controls the bridge. If, at the bridge end, the protection section is in SF condition, the bridge is:

a) frozen (current bridge maintained), if the operation is unidirectional;

b) released, if the operation is bidirectional.

In 1 + 1 architecture, the working channel 1 is permanently bridged to protection.

A.1.7 *Control of the selector*

In 1 + 1 architecture in unidirectional operation, the selector is controlled by the highest priority local request. If the protection section is in SF condition, the selector is released.

In 1 + 1 architecture in bidirectional operation, and in 1 : n architecture, the selector is controlled by comparing the channel numbers indicated on received K2 and sent K1 bytes. If there is a match, then the indicated channel is selected from the protection section. If there is a mismatch, the selector is released. Note that a match on 0000 also releases the selector. If the mismatch persists for Y ms, a mismatch is indicated at reference point S14. If the protection section is in SF condition, the selector is released and the mismatch indication is disabled.

A.1.8 *Transmission and acceptance of MSP bytes*

Byte K1 and bits 1 to 5 of byte K2 shall be transmitted on the protection section. Although they may also be transmitted identically on working sections, receivers should not assume so, and should have the capability to ignore this information on the working sections.

MSP bytes shall be accepted as valid only when identical bytes are received in three consecutive frames.

A detected failure of the received K1 or K2 is considered as equivalent to an SF condition on the protection section.

A.2 *MSP commands*

The MSP function receives MSP control parameters and switch requests from the synchronous equipment management function at the S14 reference point. A switch command issues an appropriate external request at the MSP function. Only one switch request can be issued at S14. A control command sets or modifies MSP parameters or requests the MSP status.

A.2.1 *Switch commands*

Switch commands are listed below in the descending order of priority and the functionality of each is described.

1) Clear: Clears all switch commands listed below.
2) Lockout of protection: Denies all working channels (and the extra traffic channel, if applicable) access to the protection section by issuing a lockout of protection request.

3) Forced switch #: Switches working channel # to the protection section, unless an equal or higher priority switch command is in effect or SF condition exists on the protection section, by issuing a forced switch request for that channel.
Note — For 1 + 1 non-revertive systems, forced switch — no working channel transfers the working channel from protection to the working section, unless an equal or higher priority request is in effect. Since forced switch has higher priority than SF or SD on the working section, this command will be carried out regardless of the condition of the working section.

4)
failure condition exists on other sections (including the protection section) or an equal or higher priority switch command is in effect, by issuing a manual switch request for that channel.
Note — For 1 + 1 non-revertive systems, manual switch — no working channel transfers the working channel back from protection to the working section, unless an equal or higher priority request is in effect. Since manual switch has lower priority than SF or SD on a working section, this command will be carried out only if the working section is not in SF or SD condition.

5)
MSP bytes, unless the protection channel is in use. The switch is not actually completed, i.e. the selector is released by an exercise request on either the sent or the received and acknowledged K1 byte. The exercise functionality may not exist in all MSP functions.

Note that a functionality and a suitable command for freezing the current status of the MSP function is for further study.

A.3 *Switch operation*

A.3.1 *1 : n bidirectional switching*

Table A-4/G.783 illustrates protection switching action between two multiplexer sites, denoted by A and C, of a 1 : n bidirectional protection switching system, shown in Figure 2-6/G.782.

When the protection section is not in use, null channel is indicated on both sent K1 and K2 bytes. Any working channel may be bridged to the protection section at the head end. The tail end must not assume or require any specific channel. In the example in Table A-4/G.783, working channel (WCh) 3 is bridged at site C, and WCh 4 is bridged at site A.

When a fail condition is detected or a switch command is received at the tail end of a multiplex section, the protection logic compares the priority of this new condition with the request priority of the channel (if any) on the protection. The comparison includes the priority of any bridge order; i.e. of a request on received K1 byte. If the new request is of higher priority, then the K1 byte is loaded with the request and the number of the channel requesting use of the protection section. In the example, SD is detected at C on working section 2, and this condition is sent on byte K1 as a bridge order at A.

At the head end, when this new K1 byte has been verified (after being received identically for three successive frames) and evaluated (by the priority logic), byte K1 is set with a reverse request as a confirmation of the channel to use the protection and order a bridge at the tail end for that channel. This initiates a bidirectional switch. Note that a reverse request is returned for exerciser and all other requests of higher priority. This clearly identifies which end originated the switch request. If the head end had also originated an identical request (not yet confirmed by a reverse request) for the same channel, then both ends would continue transmitting the identical K1 byte and perform the requested switch action.

Also, at the head end, the indicated channel is bridged to protection. When the channel is bridged, byte K2 is set to indicate the number of the channel on protection.

µ

TABLE A-4/G.783

1 : n bidirectional protection switching example

MSP bytes

Failure condition or controller state

C ® A

A ® C

Action

Byte K1

Byte K2

Byte K1

Byte K2

At C

At A

No failures (protection section is not in use)

00000000

00001000

00000000

00001000

At the tail end, when the channel number on received byte K2 matches the number of the channel requesting the switch, that channel is selected from protection. This completes the switch to protection for one direction. The tail end also performs the bridge as ordered by byte K1 and indicates the bridged channel on byte K2.

The head end completes the bidirectional switch by selecting the channel from protection when it receives a matching K2 byte.

If the switch is not completed because the requested/bridged channels did not match within 50 ms, the selectors would remain released and the “failure of the protocol” would be indicated. This may occur when one end is provisioned as unidirectional and the other as bidirectional. A mismatch may also occur when a locked-out channel at one end is not locked out at the other. Note that a mismatch may also occur when a 1+1 architecture connects to a 1:1 architecture (which is not in a provisioned for 1+1 state), due to a mismatch of bit 5 on K2 bytes. This may be used to provision the 1:1 architecture to operate as 1+1.

The example further illustrates a priority switch, when an SF condition on working section 1 pre-empts the WCh 2 switch. Note that selectors are temporarily released before selecting WCh 1, due to temporary channel number mismatch on sent K1 and received K2 bytes. Further in the example, switching back WCh 2 after failed section 1 is repaired is illustrated.

When the switch is no longer required, e.g. the failed working section has recovered from failure and Wait-to-restore has expired, the tail end indicates “No Request” for Null Channel on byte K1 (00000000). This releases the selector due to channel number mismatch.

The head end then releases the bridge and replies with the same indication on byte K1 and Null channel indication on byte K2. The selector at the head end is also released due to mismatch.

Receiving Null channel on K1 byte causes the tail end to release the bridge. Since the K2 bytes now indicate Null Channel which matches the Null Channel on the K1 bytes, the selectors remain released without any mismatch indicated, and restoration is completed.

A.3.2 *1:n unidirectional switching*

All actions are as described in § A.3.1 except that the unidirectional switch is completed when the tail end selects from protection the channel for which it issued a request. This difference in operation is obtained by not considering remote requests in the priority logic and therefore not issuing reverse requests.

A.3.3 *1 + 1 unidirectional switching*

For 1 + 1 unidirectional switching, the channel selection is based on the local conditions and requests. Therefore each end operates independently of the other end, and bytes K1 and K2 are not needed to coordinate switch action. However, byte K1 is still used to inform the other end of the local action, and bit 5 of byte K2 is set to zero.

A.3.4 *1 + 1 bidirectional switching*

The operation of 1 + 1 bidirectional switching can be optimized for a network in which 1 : n protection switching is widely used and which is therefore based on compatibility with a 1 : n arrangement; alternatively it can be optimized for a network in which predominantly 1 + 1 bidirectional switching is used. This leads to two possible switching operations described below.

A.3.4.1 *1 + 1 bidirectional switching compatible with 1 : n bidirectional switching*

Bytes K1 and K2 are exchanged as described in § A.3.1 to complete a switch. Since the bridge is permanent, i.e. working channel number 1 is always bridged, WCh 1 is indicated on byte K2, unless received K1 indicates null channel (0). Switching is completed when both ends select the channel, and may take less time because K2 indication does not depend on a bridging action.

For revertive switching, the restoration takes place as described in § A.3.1. For non-revertive switching, Table A-5/G.783 illustrates the operation of a 1 + 1 bidirectional protection switching system, shown in Figure 2-5/G.782.

For non-revertive operation, assuming the working channel is on protection, when the working section is repaired, or a switch command is released, the tail end maintains the selection and indicates do not revert for WCh 1. The head end also maintains the selection and continues indicating reverse request. The do not revert is removed when pre-empted by a failure condition or an external request.

A.3.4.2 *1 + 1 bidirectional switching optimized for a network using predominantly 1 + 1 bidirectional switching*

Bytes K1 and K2 are exchanged to complete a switch. Since the bridge is permanent, the traffic is always bridged to the working and protection channel. Byte K2 indicates the number of the channel which is carrying the traffic, i.e. the working channel. Therefore the channel number on byte K2 will be changed after switching is completed. Note that for this mode of operation, the use of channel numbers may differ from the description in § A.1. Switching is completed when both the receive end switches select the channel and receive no request.

For non-revertive switching, Table A-6/G.783 illustrates the operation of a 1 + 1 bidirectional protection switching system, using channel numbers 1 and 2.

µTABLE A-5/G.783

Example of 1 + 1 bidirectional switching compatible with 1 : n bidirectional switching

APS bytes

Failure condition or controller state

C ® A

A ® C

Action

Byte K1

Byte K2

Byte K1

Byte K2

At C

At A

No failures (assume protection section is not in use)

00000000

00000000

00000000

00000000

ANNEX B

(to Recommendation G.783)

Algorithm for pointer detection

B.1 *Pointer interpretation*

The pointer processing algorithm can be modelled by a finite state machine. Within the pointer interpretation algorithm three states are defined (as shown in Figure B-1/G.783):

—

—

—

The transitions between the states will be consecutive events (indications), e.g. three consecutive AIS indications to go from NORM_state to the AIS_state. The kind and number of consecutive indications activating a transition is chosen such that the behaviour is stable and low BER sensitive.

The only transition on a single event is the one from the AIS_state to the NORMAL_state after receiving an NDF enabled with a valid pointer value.

It should be noted that, since the algorithm only contains transitions based on consecutive indications, this implies that non-consecutively received invalid indications do not activate the transitions to the LOP_state.

The following events (indications) are defined:

- Norm_point:
- NDF_enable:
- AIS_ind:
  11111111 11111111;
- Incr_ind:
  Normal NDF + ss + majority of I bits inverted + no majority of D bits inverted + previous NDF_enable, incr_ind or decr_ind more than 3 times ago;
- Decr_ind:
  majority of I bits inverted + previous NDF_enable, incr_ind or decr_ind more than 3 times ago;
- Inv_point:
  Any other + norm_point with offset value not equal to active offset.

Note — Active offset is defined as the accepted current phase of the VC in the NORM_state and is undefined in the other states.

The transitions indicated in the state diagram are defined as follows:

- Inc_ind/dec_ind:
- 3 ´ norm_point:
- NDF_enable:
- 3 ´ AIS_ind: Three consecutive AIS indications;
- N ´ inv_point: N consecutive inv_point (8£N£10);
- N ´ NDF_enable:

Note — The transitions from NORM to NORM do not represent changes of state but imply offset
changes.

B.2 *Concatenated payloads*

In case a TU-2 is concatenated to a previous TU-2 the algorithm to verify the presence of the Concatenation Indicator can be described conveniently in the same way as for a normal pointer. This is shown by the state diagram of Figure B-2/G.783. Again, three states have been described:

—

—

—

The following events (indications) are defined:

- Conc_ind:

— AIS_ind:
11111111 11111111;

— Inv_point:

> *Note* — dd bits are unspecified in G.709 and are therefore don't care for the algorithm.

The transitions indicated in the state diagram are defined as follows:

— 3 ´ AIS_ind: Three consecutive AIS indications;

— N ´ inv_point: N consecutive inv_point (8£N£10);

— 3 ´ conc_ind:

A failure in one or more of the TUs of a concatenated payload should be reported across the S reference point as a single failure. Two types of failures can be reported:

— Loss of pointer,

— Path AIS.

A Loss of pointer failure is defined as a transition of the pointer interpreter from the NORM_state to the LOP_state or the AIS_state, or a transition from the CONC_state to the LOPC_state or AISC_state in any concatenated TU. In case both the pointer interpreter is in the AIS_state and the concatenation indicators of all concatenated TUs are in the AISC_state, a path AIS failure will be reported. These failures will be reported across the S reference point for alarm filtering at the SEMF.

FIGURE B-1/G.783

FIGURE B-2/G.783

APPENDIX I

(to Recommendation G.783)

Example of F1 byte usage

Note — The following is not part of the Recommendation and is provided for information only.

The F1 byte can be used to identify a failed section in a chain of regenerator sections. When a regenerator detects a failure in its section, it inserts the regenerator number and the status of its failure into the F1 byte. Figure I-1/G.783 illustrates the procedure.

FIGURE I-1/G.783