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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,  
DIGITAL SYSTEMS AND NETWORKS

Transmission media characteristics – Characteristics of  
optical components and sub-systems

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**Functional characteristics of interoffice and  
long-haul line systems using optical amplifiers,  
including optical multiplexing**

ITU-T Recommendation G.681

(Previously CCITT Recommendation)

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## **ITU-T RECOMMENDATION G.681**

### **FUNCTIONAL CHARACTERISTICS OF INTEROFFICE AND LONG-HAUL LINE SYSTEMS USING OPTICAL AMPLIFIERS, INCLUDING OPTICAL MULTIPLEXING**

#### **Summary**

This Recommendation covers the functional characteristics of interoffice and long-haul line systems using optical amplifiers, including optical multiplexing. It represents a bridge between reference/physical configurations of SDH interoffice systems described in Recommendations G.782, G.783, G.958 and between functional transport network architectures described in Recommendations G.803 and G.805. Extended or new "functional blocks, functions and sub-functions" of SDH equipment (e.g. line termination, optical/electrical/optical regenerator and optical non-regenerative repeater) are mapped on "compound functions, atomic functions and processes" of transport networks. Optical channel layer, optical multiplex section layer and optical amplifier section layer are identified for optical transport systems. In addition optical safety considerations, including Automatic Power Shutdown (APSD) and Optical Surge Prevention (OSP), and the Optical Supervisory Channel (OSC) are topics of this Recommendation.

In future Recommendations on "optical media-based transport network architectures", there will be standardized "optical path layer with optical add and drop multiplexers and optical cross-connects" and "optical circuit layer with optical switches" which are not in the scope of this Recommendation.

#### **Source**

ITU-T Recommendation G.681 was prepared by ITU-T Study Group 15 (1993-1996) and was approved by WTSC (Geneva, 9-18 October 1996).

## FOREWORD

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## **Recommendation G.681**

# **FUNCTIONAL CHARACTERISTICS OF INTEROFFICE AND LONG-HAUL LINE SYSTEMS USING OPTICAL AMPLIFIERS, INCLUDING OPTICAL MULTIPLEXING**

*(Geneva 1996)*

## **1 Scope**

This Recommendation applies to the functional characteristics of interoffice and long-haul line systems using Optical Amplifiers (OAs), including optical multiplexing. Existing Recommendations such as G.958, and the G.780-Series have not considered these new technologies. As such this Recommendation is the first attempt to characterize the functions that OAs and optical multiplexing require to describe these capabilities. Its present structure and contents describe the systems where optical interfaces for single-channel systems with optical amplifiers and optical interfaces for multichannel systems with optical amplifiers are implemented.

This Recommendation represents a bridge between reference/physical configurations of SDH interoffice systems in Recommendations G.782, G.783, G.958 and between functional network architectures described in Recommendations G.803 and G.805. Thus, it is structured in a way that is intended to complement the directions that the network architecture and the network management activities are following. The guiding principles of these areas have been used in developing this description. The description is based on a client/server approach. In order to provide this, the functional blocks described in this Recommendation were derived from rules developed from layered transport architecture techniques. The functions related to management were developed from an understanding of information flows. It is not in the scope of this Recommendation to identify how the management messages are formatted or the protocols by which they are conveyed.

The line systems described within this Recommendation are intended to provide transverse compatibility, i.e. the possibility of mixing various manufacturers' equipments within a particular system. The use of optical transmission capabilities including optical multiplexing and amplification requires management solutions.

This Recommendation describes how a supervisory signal is combined with user information.

NOTE – This Recommendation has been prepared from the experience with Erbium-doped silica-based fibre amplifiers (EDFA), operating in the 1550 nm wavelength region. Future optical amplifiers (e.g. semiconductor optical amplifiers or optical amplifiers based on different active fibres, possibly in the 1310 nm wavelength region) are not intended to be excluded from this Recommendation and may lead to additional functions, as well as to modifications of the existing ones.

## **2 References**

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

- ITU-Recommendation G.652 (1993), *Characteristics of a single-mode optical fibre cable.*
- ITU-Recommendation G.653 (1993), *Characteristics of a dispersion-shifted single-mode optical fibre cable.*
- ITU-Recommendation G.655 (1996), *Characteristics of a non-zero dispersion single-mode optical fibre cable.*
- ITU-Recommendation G.661 (1996), *Definition and test methods for the relevant generic parameters of optical fibre amplifiers.*
- ITU-Recommendation G.662 (1995), *Generic characteristics of optical fibre amplifier devices and sub-systems.*
- ITU-Recommendation G.663 (1996), *Application related aspects of optical fibre amplifier devices and sub-systems.*
- ITU-Recommendation G.671 (1996), *Transmission characteristics of passive optical components.*
- ITU-Recommendation G.707 (1996), *Network node interface for the Synchronous Digital Hierarchy (SDH).*
- ITU-Recommendation G.781 (1994), *Structure of Recommendations on equipment for the Synchronous Digital Hierarchy (SDH).*
- ITU-Recommendation G.782 (1994), *Types and general characteristics of Synchronous Digital Hierarchy (SDH) equipment.*
- ITU-Recommendation G.783 (1994), *Characteristics of Synchronous Digital Hierarchy (SDH) equipment functional blocks.*
- ITU-Recommendation G.784 (1994), *Synchronous Digital Hierarchy (SDH) management.*
- ITU-Recommendation G.803 (1993), *Architectures of transport networks based on the Synchronous Digital Hierarchy (SDH).*
- ITU-Recommendation G.805 (1995), *Generic functional architecture of transport networks.*
- ITU-Recommendation G.825 (1993), *The control of jitter and wander within digital networks which are based on the Synchronous Digital Hierarchy (SDH).*
- ITU-Recommendation G.957 (1995), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy.*
- ITU-Recommendation G.958 (1994), *Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables.*
- IEC 825-1:1993, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide.*
- IEC 825-2:1993, *Safety of laser products – Part 2: Safety of optical fibre communication systems.*

### **3 Terms and definitions**

This Recommendation defines the following terms.



### 3.1 Definitions

**3.1.1 optical amplifier:** The optical amplifier is an element that alters the amplitude of the incident signals but does not perform timing recovery or decision thresholding. Many optical signals can be accommodated simultaneously. It can communicate to the system management facility using a data messaging channel, which may be of optical and electrical means. The optical supervisory signal is for monitoring in-line optical amplifiers. The electrical supervisory signal approach is used in systems without in-line amplifiers.

**3.1.2 wavelength:** Whilst wavelength is used throughout this Recommendation, it is recognized that future multichannel systems will be defined in frequency spacing. Wavelength and frequency are interchangeable for the purposes of this Recommendation.

**3.1.3 optical channel:** The optical channel in an optical interoffice link or regenerator section starts at the access point, AP, of an OCA/OCT in a line termination (or regenerator) and ends at the access point, AP, of an OCA/OCT in a line termination (or regenerator).

**3.1.4 compound function:** The compound function contains a number of atomic functions in a single layer.

**3.1.5 atomic function:** The atomic function is a function, which, if divided into simpler functions would no longer be uniquely defined for transmission hierarchies. It is therefore indivisible from a network point of view. Atomic functions are composed of a number of processes. The atomic functions associated with each layer are the trail termination function and adaptation function.

**3.1.6 process:** A process is a generic term for an action or collection of actions. A process receives input messages in defined format, processes the inputs in a defined way, and generates output messages in defined format.

### 3.2 Terms defined in other Recommendations

- optical/electrical/optical regenerator (REG): see Recommendation G.958;
- Optical Amplifier (OA): see Recommendations G.661, G.662 and G.663;
- optical multiplexer/demultiplexer: see Recommendation G.671;
- regenerator section overhead (RSOH): see Recommendation G.782;
- regenerator section termination (RST): see Recommendation G.782;
- S/R reference points: see Recommendations G.955 and G.957;
- A, ..., L reference points: see Recommendations G.955 and G.957;
- SDH physical interface (SPI): see Recommendations G.782, G.783 and G.958;
- section overhead (SOH): see Recommendation G.707;
- Synchronous Digital Hierarchy (SDH): see Recommendation G.707;
- Synchronous Equipment Management Function (SEMF): see Recommendation G.782;
- Synchronous Transport Module (STM): see Recommendation G.707.

## 4 Abbreviations

This Recommendation uses the following abbreviations.

ALS	Automatic Laser Shutdown
AP	Access Point
APSD	Automatic Power Shutdown

BA	Booster Amplification or Booster Amplifier
CI	Channel Identification
CIc	Channel Identification due to optical channel layer
CI <sub>m</sub>	Channel Identification due to optical multiplex section layer
DA	Dispersion Accommodation
DAa	amplifier-aided Dispersion Accommodation
DAc	channel Dispersion Accommodation
DSF	Dispersion Shifted Fibre (Recommendation G.953)
DST	Dispersion Supported Transmission
EMF	Equipment Management Function
FWM	Four-Wave Mixing
I/F	InterFace
IOL	InterOffice Line
JW	Jitter and Wander
LA	Line Amplification or Line Amplifier
LCRF	Local Connections Related Functions (e.g. local exchange)
LOS	Loss of Signal
LT <sub>mcs</sub>	Line Termination for multichannel system
LT <sub>scs</sub>	Line Termination for single-channel system
MCF	Message Communication Function
MCS	MultiChannel System
MOD	Modulation
MPI-R	Main Path Interface – R reference point
MPI-S	Main Path Interface – S reference point
MST	Multiplex Section Termination
nrREP	non-regenerative repeater
OA	Optical Amplification or Optical Amplifier
OAR	Optically Amplified Receiver
OAS <sub>1</sub>	Optical Amplifier Section for single-channel system
OAS <sub>m</sub>	Optical Amplifier Section for multichannel system
OASA	Optical Amplifier Section Adaptation
OASOH	Optical Amplifier Section Overhead
OAST	Optical Amplifier Section Termination
OAT	Optically Amplified Transmitter
OC	Optical Channel
OCA	Optical Channel Adaptation

OCOH	Optical Channel Overhead
OCT	Optical Channel Termination
OFA	Optical Fibre Amplifier
OFDM	Optical Frequency Division Multiplexing
OHA	Overhead Access
OM	Optical Multiplexing or Optical Multiplexer (OFDM or WDM)
OMS <sub>1</sub>	Optical Multiplex Section for single-channel
OMS <sub>m</sub>	Optical Multiplex Section for multichannel
OMSA	Optical Multiplex Section Adaptation
OMSOH	Optical Multiplex Section Overhead
OMST	Optical Multiplex Section Termination
OSCA	Optical Supervisory Channel Adaptation
OSP	Optical Surge Protection
PA	Pre-Amplification or Pre-Amplifier
PDC	Passive Dispersion Compensation or Compensator
REG	(optical/electrical/optical) regenerator
REP	(optical non-regenerative) repeater
RS	Regenerator Section
RSA	Regenerator Section Adaptation
RSOH	Regenerator Section Overhead
RST	Regenerator Section Termination
RTG	Regenerator Timing Generator
S1, S2, ...	management reference points
SCS	Single-Channel System
SDH	Synchronous Digital Hierarchy
SEMF	Synchronous Equipment Management Function
SETPI	Synchronous Equipment Timing Physical Interface
SETS	Synchronous Equipment Timing Source
SLM	Single-Longitudinal Mode (laser)
SMF	Single-Mode Fibre (Recommendation G.952)
SOA	Semi-conductor Optical Amplifier
SOH	Section Overhead
SPI	SDH Physical Interface
SPM	Self-Phase Modulation
STM	Synchronous Transfer Module
T	Timing function

TCRF	Transit Connections Related Functions (e.g. transit exchange)
WA	Wavelength Assignment
WC	Wavelength (frequency) Conversion
WDM	Wavelength Division Multiplexing
Wref	Wavelength referencing

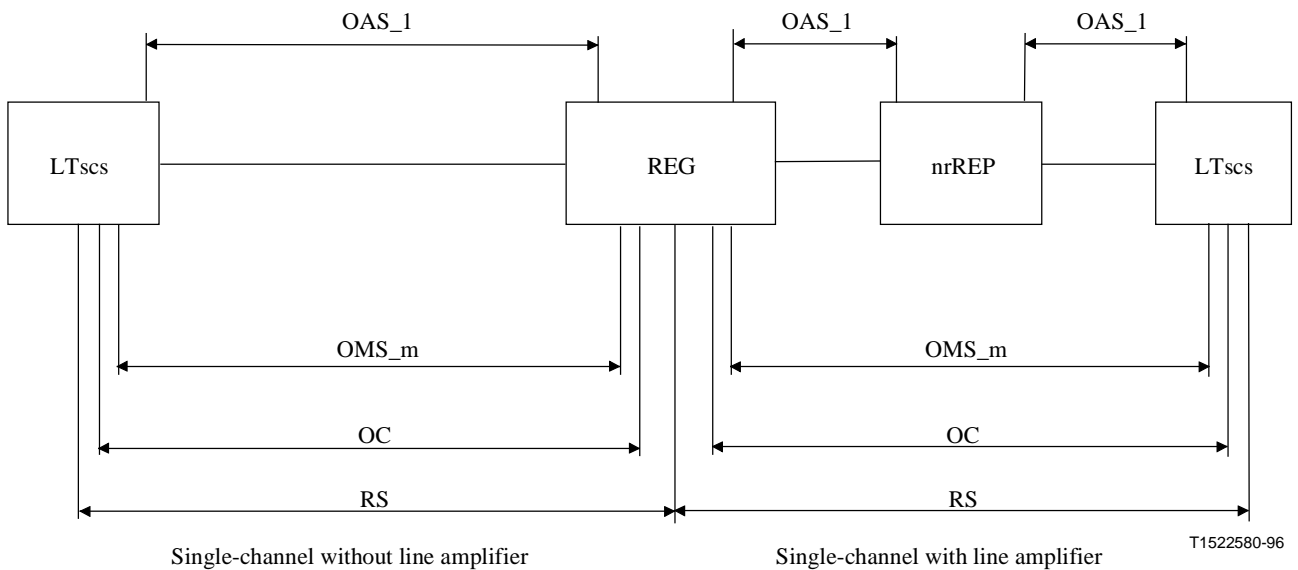
## 5 Applications

### 5.1 System types

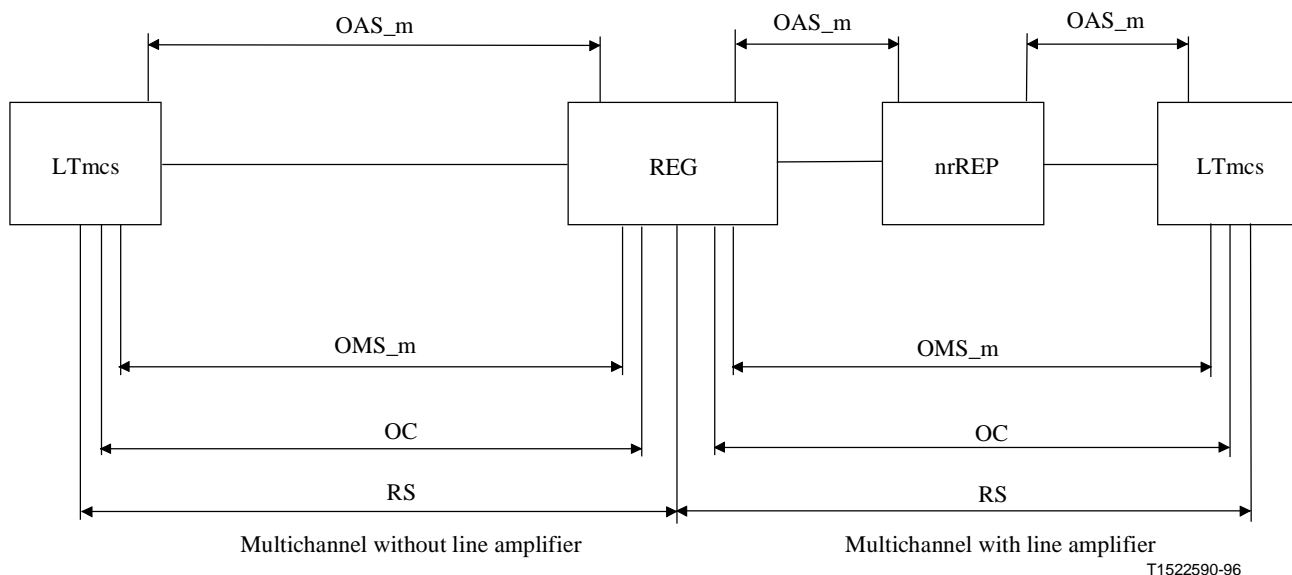
The systems described in this Recommendation are for application in SDH interoffice and long-haul line systems. The general description for these systems is shown in Figure 5-1.

The systems may involve the use of regenerators or/and non-regenerative repeaters (see later description). Unlike Recommendation G.958, the following description refers only to the system parts between regenerator section terminations (reference points B, Recommendation G.783) in Line Termination (LT) and regenerator (REG). It therefore covers the functional description of extended LT, extended REG and the optical non-regenerative repeater.

Since optical multiplexing is used in multichannel systems, this Recommendation also provides the functional representation and reference points associated with this capability.



**Figure 5-1a/G.681 – Representation of component parts to systems described by G.681 functions for single-channel systems**



**Figure 5-1b/G.681 – Representation of component parts to systems described by G.681 functions for multichannel systems**

## 5.2 System components

As described in Figure 5-1, the system may include combinations of line termination equipments, optical amplifiers, optical multiplexers, transponders, regenerators and optical fibre links. Optical channel, optical multiplex and amplifier sections are identified as further sub-units of regenerator sections.

## 6 Types of transmission medium

The use of fibres according to Recommendations G.652, G.653 and G.655 is considered.

## 7 Definitions of functions and compound functions (Functional blocks)

### 7.1 Functions defined in other Recommendations

**7.1.1** Regenerator Section Termination (RST) function: see Recommendations G.783 and G.958.

**7.1.2** SDH Physical Interface (SPI) function: see Recommendations G.782, G.783 and G.958.

**7.1.3** Message Communication Function (MCF): see Recommendations G.782 and G.783.

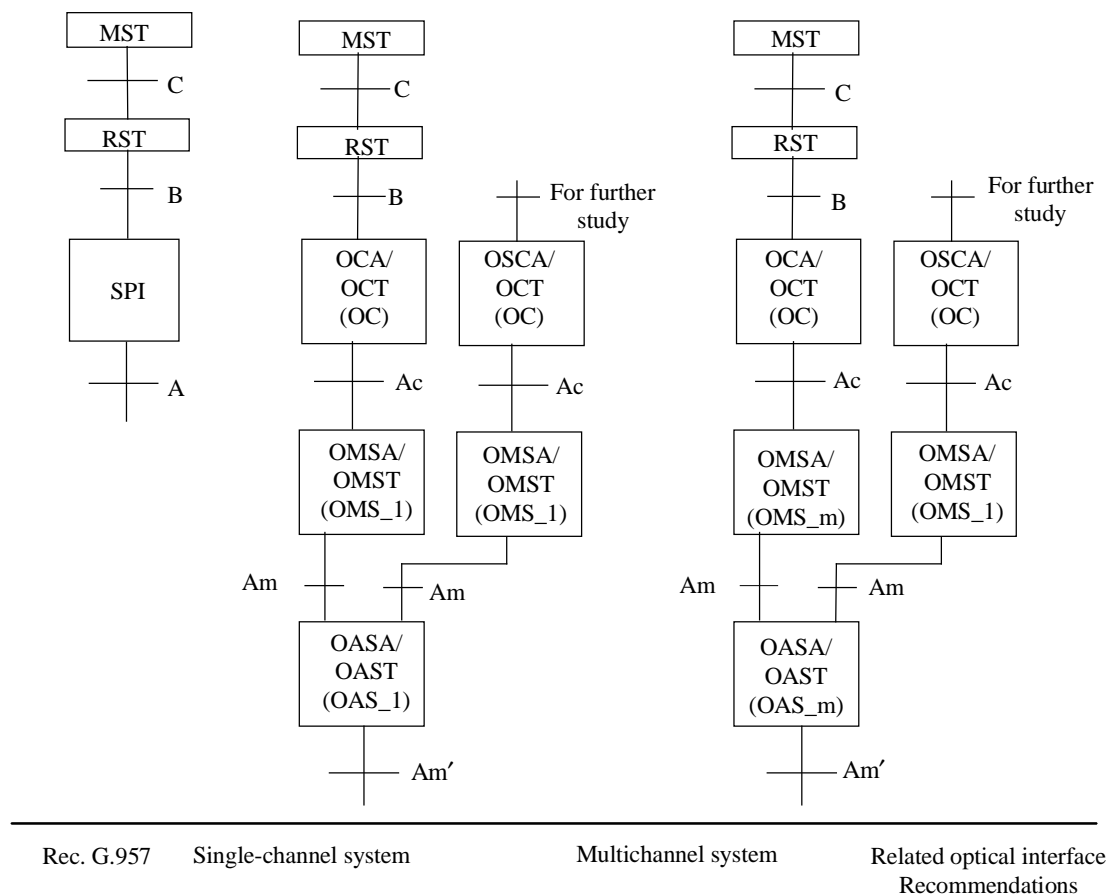
**7.1.4** Overhead Access (OHA) function: see Recommendations G.782 and G.783.

**7.1.5** Synchronous Equipment Timing Physical Interface (SETPI) function: see Recommendation G.783.

**7.1.6** Synchronous Equipment Timing Source (SETS) function: see Recommendation G.783.

### 7.2 New functions and compound functions (Functional blocks)

The functional representation of the existing Recommendation G.957 and of the external single-channel and multichannel systems application is shown in Figure 7-1. The used compound and atomic functions are further explained in the following text.



Functions or compound functions (functional blocks)

T1522600-96

- MST            Multiplex Section Termination
- OCA/OCT     Optical channel adaptation/termination
- OMSA/OMST   Optical multiplex section adaptation/termination
- OASA/OAST   Optical amplifier section adaptation/termination
- OSCA/OCT    Optical supervisory channel adaptation/optical channel termination. The description of this compound function is for further study.
- RST           Regenerator Section Termination

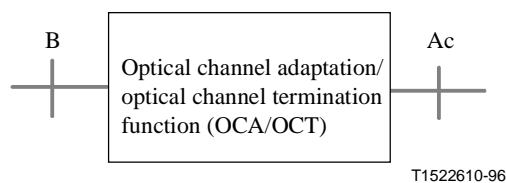
Reference points

$Am'$ ,  $Am$ ,  $Ac$ ,  $B$ ,  $C$  Reference points of reference configuration

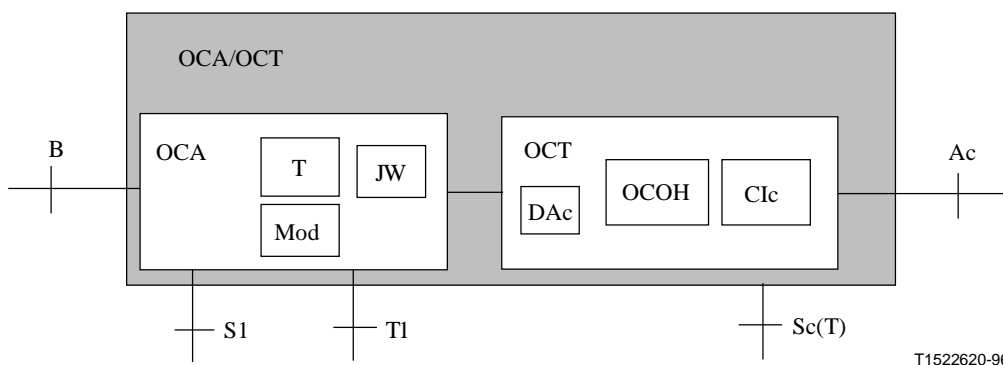
**Figure 7-1/G.681 – Functional representation of G.957 and future single channel multichannel line terminations. For the supervisory and user information wavelength division multiplexing/demultiplexing is part of the OASA/OAST. The OMSA/T (OMS\_1) compound function associated with the optical supervisory provides wavelength assignment**

### 7.2.1 Optical Channel Adaptation and Termination (OCA/OCT) compound function

This compound function (see Figure 7-2a) adapts client layers signals (e.g. SDH) to/from an optical signal of given bandwidth with a maximum amplitude and a defined signal-to-noise ratio. An optical channel overhead, is also added/extracted. This is for further study.



**Figure 7-2a/G.681 – The optical channel adaptation and termination (OCA/OCT) compound function**



**Figure 7-2b/G.681 – The processes for the OCA/OCT**

The reference points for other functions are for further study. Figure 7-2b indicates the functions/processes contained within this compound function in more detail.

### **Definition of processes within OCA/OCT compound function**

#### **T Timing (T) process**

The optical channel adaptation source has at its input STM-N data with associated timing. The optical channel adaptation sink recovers the signal to form STM-N data and associated timing at reference point B. In the case of SDH, the recovered timing is also made available at reference point T1 to the synchronous equipment timing source for the purpose of synchronizing the synchronous equipment reference clock if selected.

#### **JW Jitter and Wander (JW) process**

The source jitter and wander of the STM-N signal must meet the short-term stability requirements as described in Recommendation G.783 and the network interface jitter requirements as described in Recommendation G.825. Jitter present on the STM-N signal must be accommodated by the sink function. Detailed limits are given in Recommendations G.958 and G.825.

#### **Mod Modulation/demodulation (Mod) process**

This process enables the STM-N signal to be impressed/removed from the carrier by means of logical to optical and optical to logical conversion. The output of the modulation source is an optical signal of given bandwidth, maximum amplitude and defined signal-to-noise ratio. The modulation sink function recovers the STM-N signal from the optical signal. Parameters relating to the status of the optical signal shall be reported at S1.

**DAc Channel Dispersion Accommodation (DAc) process**

This process allows for the accommodation of system dispersion limitations and operates at the optical channel level.

**CIc Optical Channel Identification (CIc) process**

This process enables an unambiguous access point identifier to be added to the adapted client signal.

**OCOH Optical Channel Overhead (OCOH) process**

This process acts as a source and sink for the optical channel overhead (OCOH). OCOH is for further study.

**Sc(T) Reference point**

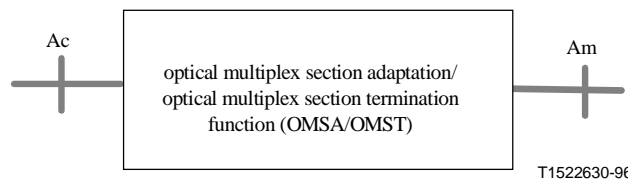
This reference point is for reporting parameters relating to the status of the OCT function and is for further study.

**7.2.2 Optical Supervisory Channel Adaptation/Optical Channel Termination (OSCA/OCT) compound function**

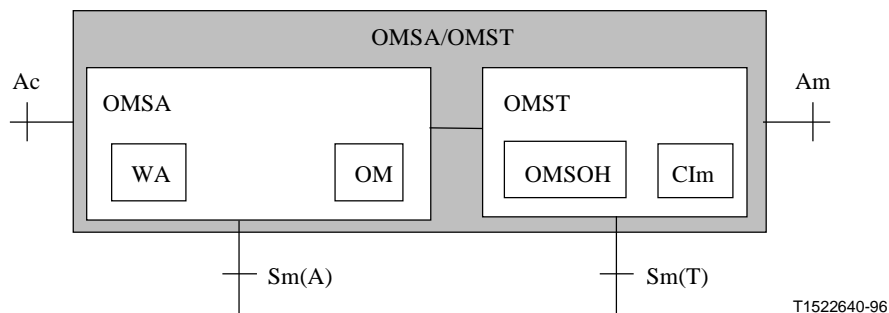
The OSCA/OCT compound function is for further study.

**7.2.3 Optical Multiplex Section Adaptation and Termination (OMSA/OMST) compound function**

This compound function (see Figure 7-3a) provides adaptation of optical channels to and from an optical multiplex by means of generation and termination of wavelength assignment, assembly and disassembly of an optical multiplex and acts as a source and sink for the optical multiplex section overhead.



**Figure 7-3a/G.681 – The optical multiplex section adaptation and termination compound function**



**Figure 7-3b/G.681 – The processes for the OMSA/OMST**



The reference points for other functions are for further study. Figure 7-3b indicates the functions/processes contained within this compound function in more detail.

### **Definition of processes within OMSA/OMST compound function**

#### **CIm Multiplex Channel Identification (CIm) process**

This process enables a local channel identifier to be added to the optical channels contained in the optical multiplex section.

#### **OM Optical Multiplexing (OM) process**

This process multiplexes/demultiplexes a number of optical channels together and separates them. For OMS\_1 this process provides a one-to-one mapping (optical wavelength or frequency conversion) and represents the WA process.

#### **WA Wavelength assignment process**

This process generates and terminates wavelength assignment to optical channels.

#### **Wref Wavelength referencing process (Wref)**

This process allows the verification of the channel wavelength within the multiplex. For further study.

#### **OMSOH Optical Multiplex Section Overhead (OMSOH) process**

This process acts as a source and sink for the Optical Multiplex Section Overhead (OMSOH). For further study.

#### **Sm(A) Reference point**

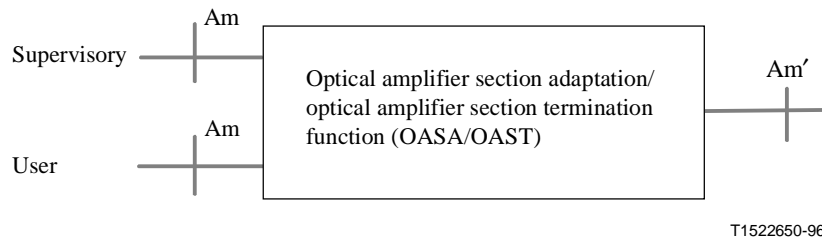
This reference point is for reporting parameters relating to the status of the OMSA function and is for further study.

#### **Sm(T) Reference point**

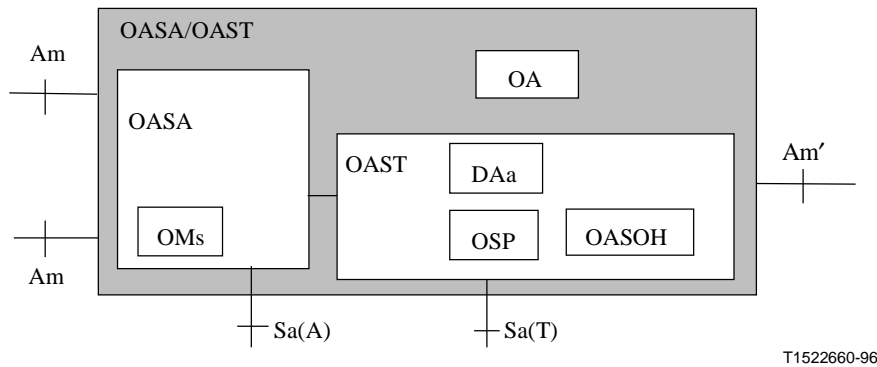
This reference point is for reporting parameters relating to the status of the OMST function and is for further study.

### **7.2.4 Optical Amplifier Section Adaptation and Termination (OASA/OAST) compound function**

The OASA/OAST (see Figure 7-4a) compound function, comprising Optical Amplification (OA) and fibre Dispersion Accommodation (DA) processes, provides the interface between the physical transmission medium at reference point Am' and the OMSA/OMST compound function at reference points Am. The interface signal at Am' shall be one of those specified in Recommendations G.690 Series and the Recommendations on multichannel systems (see Figure 7-4a).



**Figure 7-4a/G.681 – The optical amplifier section adaptation and termination (OASA/OAST) compound function**



**Figure 7-4b/G.681 – The processes for the OASA/OAST**

NOTE – The allocation of the OA process to either the OASA or the OAST is for further study.

### **Definition of functions/processes within OASA/OAST compound function**

#### **OA Optical Amplification (OA) process**

The definition and allocation of this process is for further study.

#### **DAa Amplifier-Aided Dispersion Accommodation (DAa) process**

This process allows for the accommodation of the chromatic fibre dispersion of single- or multi-wavelength signals in an optical amplifier section.

#### **OASOH Optical Amplifier Section Overhead (OASOH) process**

This process acts as the source and sink of the Optical Amplifier Section Overhead (OASOH). This is for further study.

#### **OMs Optical Multiplexing (OMs) process**

This process multiplexes/demultiplexes user and supervisory information together and separates them.

#### **OSP Optical Surge Prevention (OSP) process**

This process prevents the generation of surges within the amplifier section and is implemented on a distributed basis. Details are for further study.

### **Sa(A) Reference point**

This reference point is for reporting parameters relating to the status of the OASA function and is for further study.

### **Sa(T) Reference point**

This reference point is for reporting parameters relating to the status of the OAST function and is for further study.

## **7.2.5 Other functions/processes for internetworking**

### **7.2.5.1 Wref Wavelength reference process (Wref): see 7.2.3**

### **7.2.5.2 EMF Equipment Management Function/process (EMF)**

This function is for further study. The definition is similar to the definition of SEMF in Recommendations G.783 and G.784.

### **7.2.5.3 OHA Overhead access function/process (OHA)**

The overhead access (OHA) function is defined in Recommendation G.783 for SDH equipment. The extension of this function for optical non-SDH equipment is for further study.

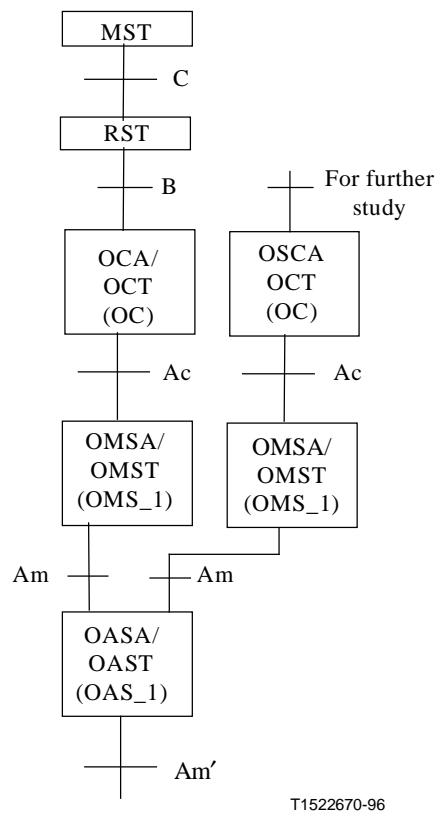
### **7.2.5.4 MCF Message Communication Function (MCF)**

This function is already defined in Recommendation G.783.

NOTE 1 – Annex A provides a graphical description for the links between the compound functions (functional blocks) described in 7.2 and a transport network architecture representation. It also provides a definition of the layers and identifies the reference points and their relation to the compound functions (functional blocks).

NOTE 2 – Annex B provides a table that relates both the compound functions and the transport (adaptation or termination) functions to the functions/processes defined in 7.2.

## 8 Reference configurations for single-channel systems



**Figure 8-1/G.681 – Functional configuration of a line termination for a single-channel system**

### 8.1 Compound functions describing single-channel systems

Figure 8-1 shows the functional configuration of a line termination in a single-channel system for an interoffice line (IOL). A single-channel system is characterized by the use of the following compound functions:

- i) RST function;
- ii) OCA/OCT and OSCA/OCT compound functions;
- iii) OMSA/OMST compound function;
- iv) OASA/OAST compound function.

The reference points  $Ac$ ,  $Am$ , and  $Am'$  describe the characteristics of the OCA/OCT (and OSCA/OCT), OMSA/OMST and OASA/OAST compound functions.

### 8.2 Functional configuration for single-channel interoffice line (IOL) systems

#### 8.2.1 Without in-line function capabilities

Figure 8-2 a) shows the functional configuration for IOL systems without non-regenerative repeater or regenerator capabilities.

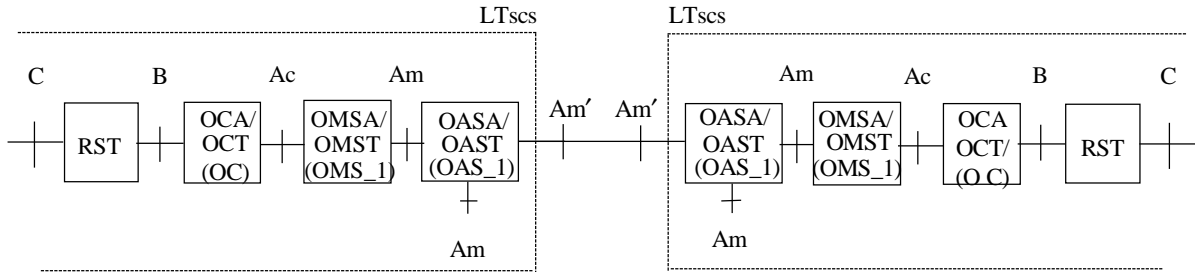
#### 8.2.2 In-line non-regenerative repeater

Figure 8-2 b) shows the functional configuration for IOL systems with in-line non-regenerative repeater capability.

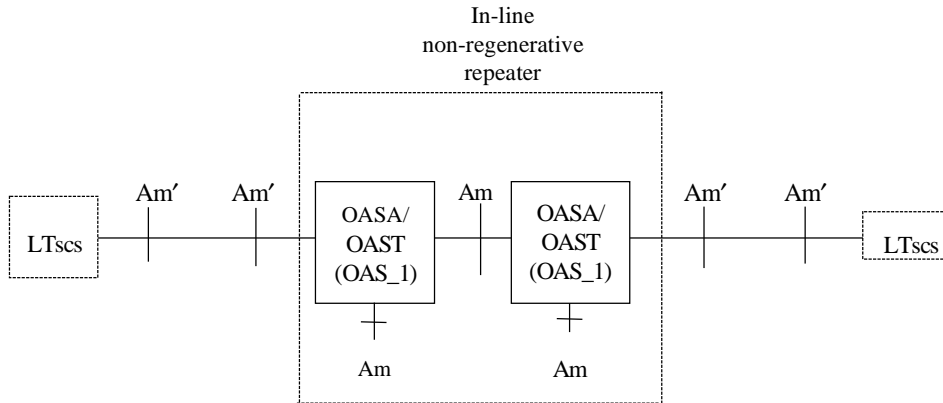
### 8.2.3 Regenerator

Figure 8-2 c) shows the functional configuration for the IOL systems with regenerator capability.

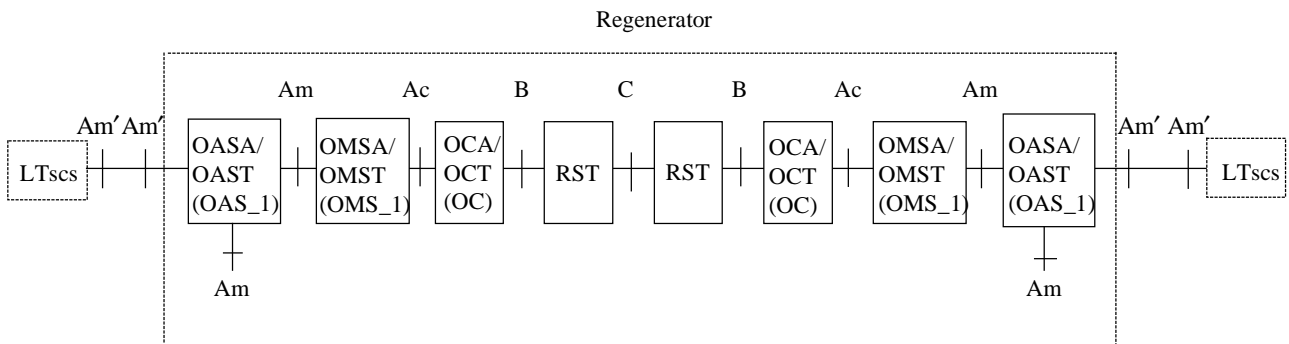
a) Without non-regenerative repeater (REP) or regenerator (REG)



b) With in-line non-regenerative repeater (nrREP)



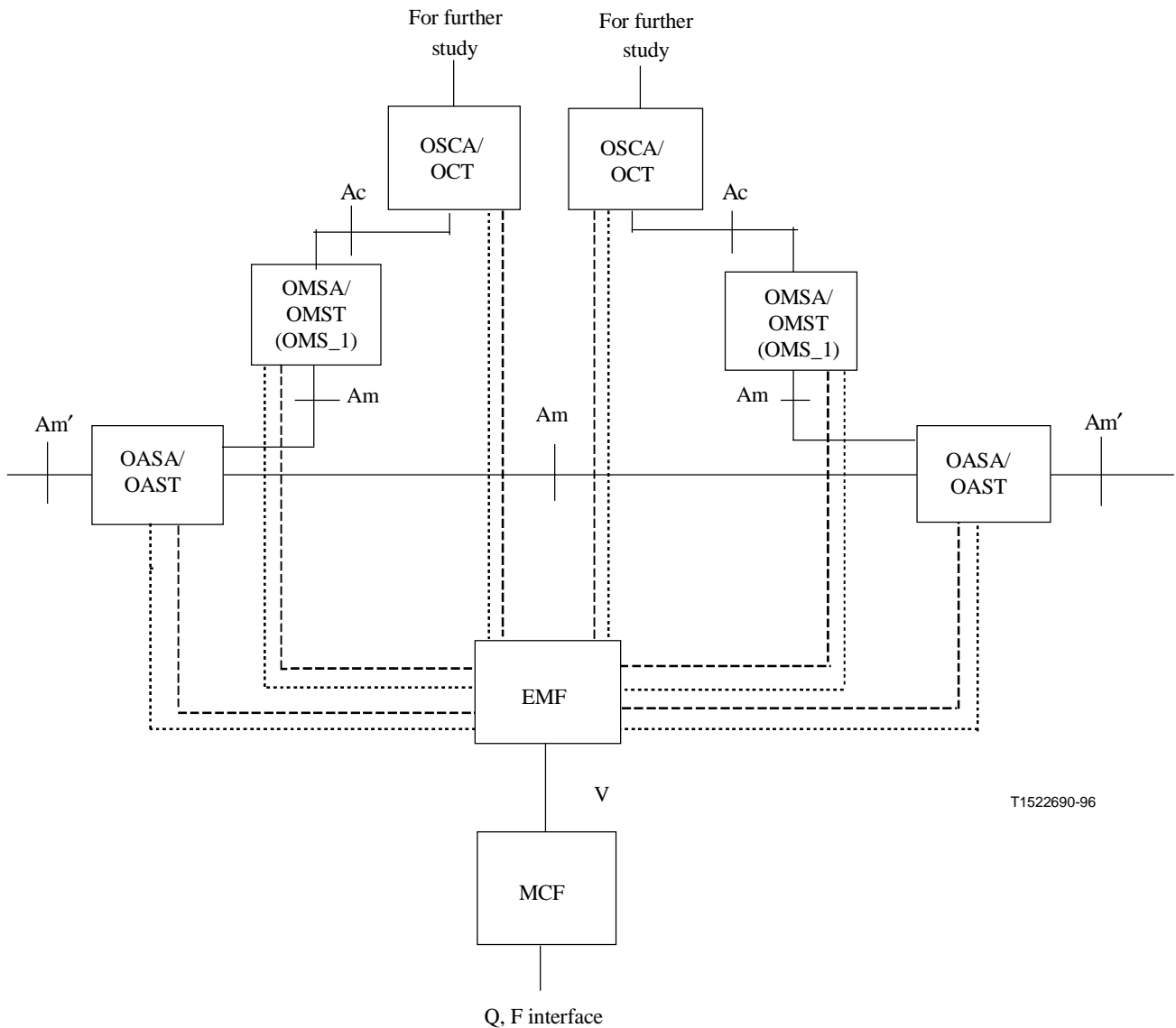
c) With regenerator



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**Figure 8-2/G.681 – Functional configuration for single channel IOL systems: a) without regenerator or in-line non-regenerative repeaters; b) with in-line non-regenerative repeaters and c) with regenerators**

The functions associated with the optical in-line non-regenerative repeater are detailed further in Figure 8-3.



**Figure 8-3/G.681 – Functional configuration of optical in-line non-regenerative repeater – For the supervisory and user information wavelength division multiplexing/demultiplexing is part of the OASA/T – The OMSA/T (OMS\_1) compound function provides wavelength assignment for the optical supervisory only**

NOTE – Appendix I shows some possible configurations for multichannel systems using these compound functions and the functions described within clause 7. In particular the transponder approach as well as stand-alone components are described.

## 9 Reference configurations for multichannel systems

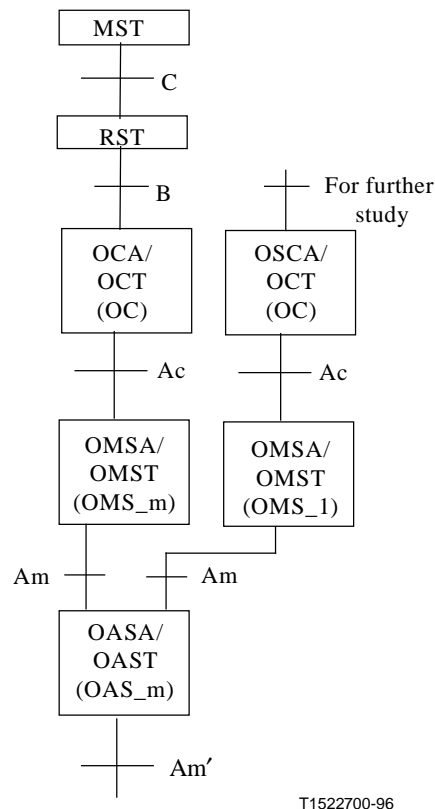
### 9.1 Functional blocks describing multichannel systems

Figure 9-1 shows the functional configuration for a line termination in a multichannel system of an interoffice line (IOL). A multichannel system is characterized by the use of the following compound functions, in addition to the RST function:

- i) OCA/OCT and OSCA/OCT compound functions;
- ii) OMSA/OMST compound function;
- iii) OASA/OAST compound function.

Following reference points are defined namely  $A_c$ ,  $A_m$  and  $A_m'$  describing the optical interface characteristics of the OCA/OCT, OSCA/OCT, OMSA/OMST and OASA/OAST compound functions as they are mapped to the "optical layers", respectively:

- i) optical channel layer;
- ii) optical multiplex section layer; and
- iii) optical amplifier section layer.

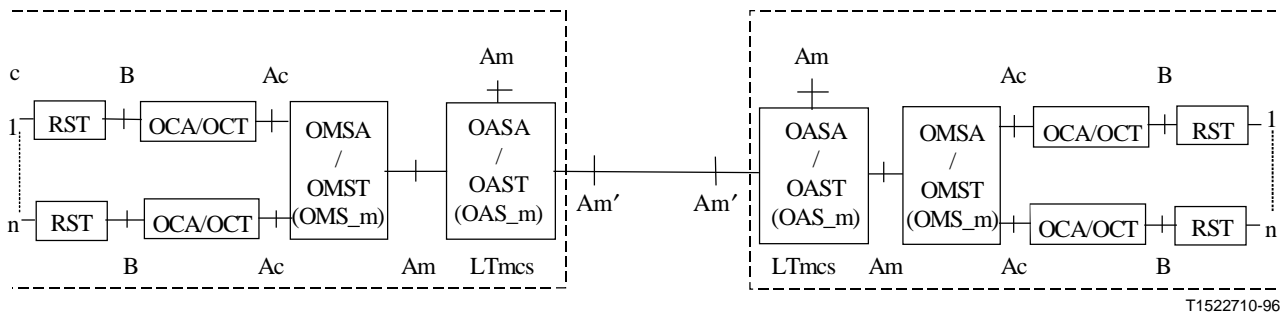


**Figure 9-1/G.681 – Functional configuration for a line termination in a multichannel system**

### 9.2 Functional configurations for a multichannel interoffice line system

#### 9.2.1 Without in-line function capabilities

Figure 9-2a shows the functional configuration for IOL without in-line non-regenerative repeater or regenerator capabilities.

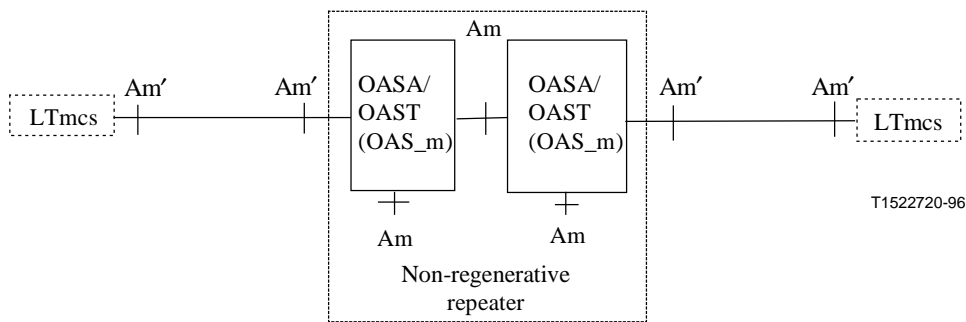


**Figure 9-2a/G.681 – Functional configuration for a multichannel IOL system without in-line capabilities**

### 9.2.2 Non-regenerative repeater

Figure 9-2b shows the functional configuration for IOL systems with non-regenerative repeater capabilities.

NOTE – The reference points to functions EMF, MCF and OHA are identical to those described for single-channel systems in Figure 8-3.

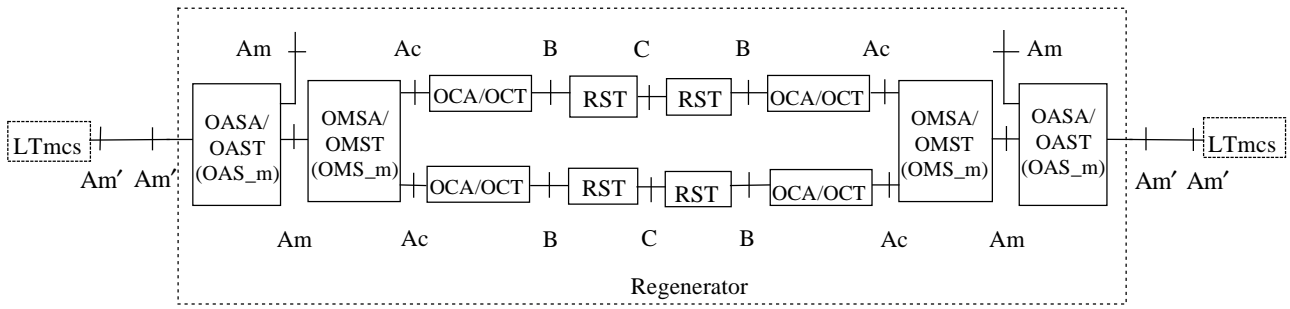


**Figure 9-2b/G.681 – Functional configuration for a multichannel IOL system with non-regenerative repeater capability**

### 9.2.3 Regenerator

Figure 9-2c shows the functional configuration for an IOL system with regenerator capability.



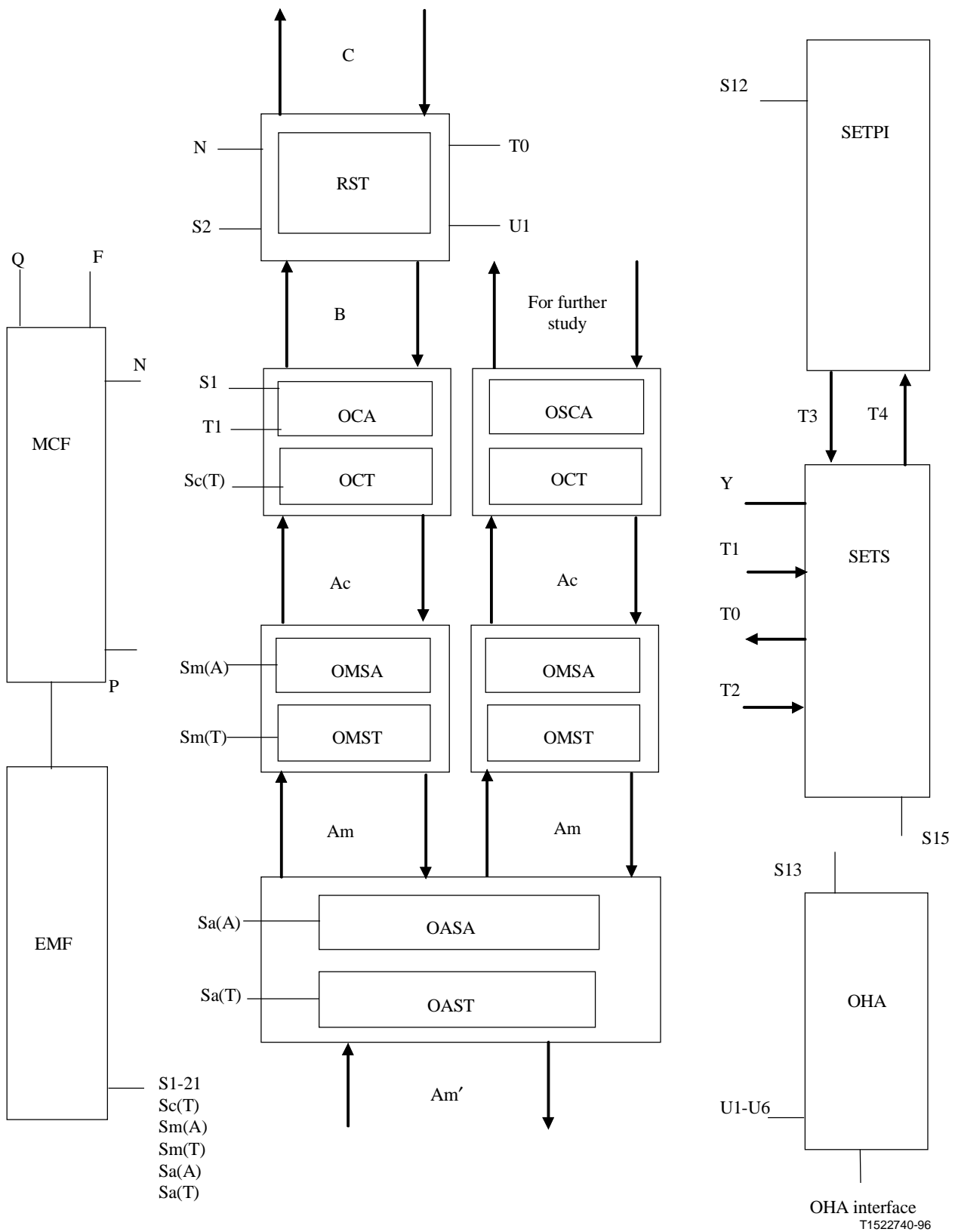


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**Figure 9-2c/G.681 – Functional configuration for a multichannel IOL system with regenerator capability**

### 9.3 Interworking of compound functions in a multichannel system

Figure 9-3 shows the functional configuration of a line termination in a multichannel system more in detail.



NOTE – S1-S21, Q, F, N, P, U1-U6, Y, T0, T1, T2 and OHA interface are defined in Recommendation G.783.

**Figure 9-3/G.681 – Interworking of compound functions within a line termination of a multichannel system**

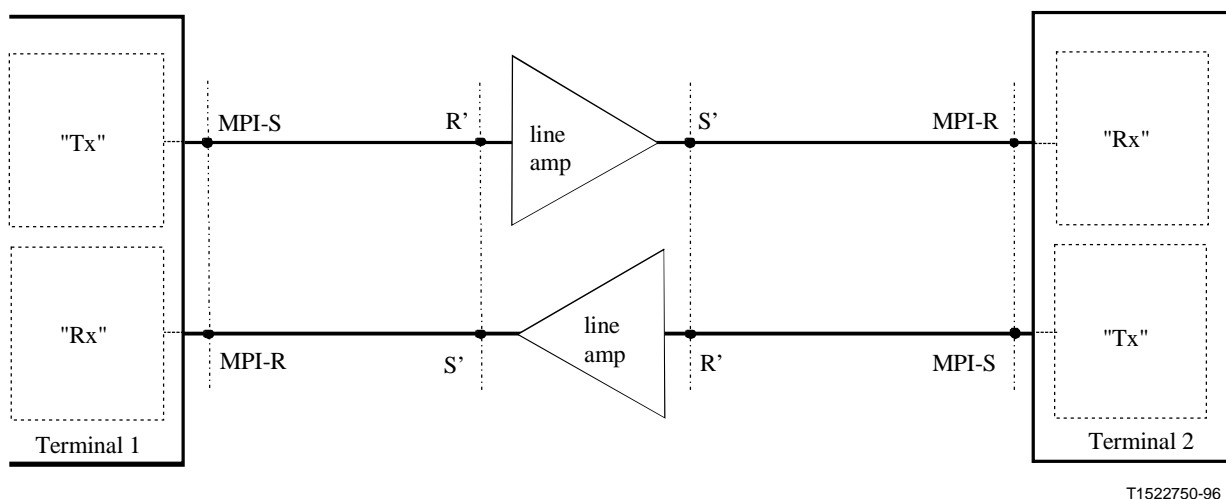
## 10 Optical safety considerations (Optical surge prevention, automatic power shutdown)

For eye safety considerations, according to IEC 825-1, IEC 825-2 or national regulations, and to avoid optical surges in optical amplifiers, it is necessary to provide for a capability for automatic (optical) power shutdown (APSD) and restart in case of loss of optical power within one or more section(s) of the main optical path. For example, this loss of power can be caused by cable break, equipment failure, connector unplugging, etc.

The purpose of this capability is to provide a transversely compatible procedure which can be used to shut down all optical amplifiers in a link after detection of loss of optical power and to reactivate those after restoring all connections within the link. In this way, it is ensured that all optical power levels along the link are within Class 1 during shutdown. Furthermore the occurrence of optical surges after restoration of all connections within the link or after reactivation of the optical amplifiers is prevented by quick shutdown of the optical amplifiers and by appropriate requirements for optical amplifier response times.

Figure 10-1 shows the reference configuration of the Automatic Power Shutdown (APSD) capability. The APSD procedure applies to, and must preserve all implementations of Optical Supervisory Channels (OSCs).

A power shutdown signal in a multichannel system shall only be set when all main channels are absent.



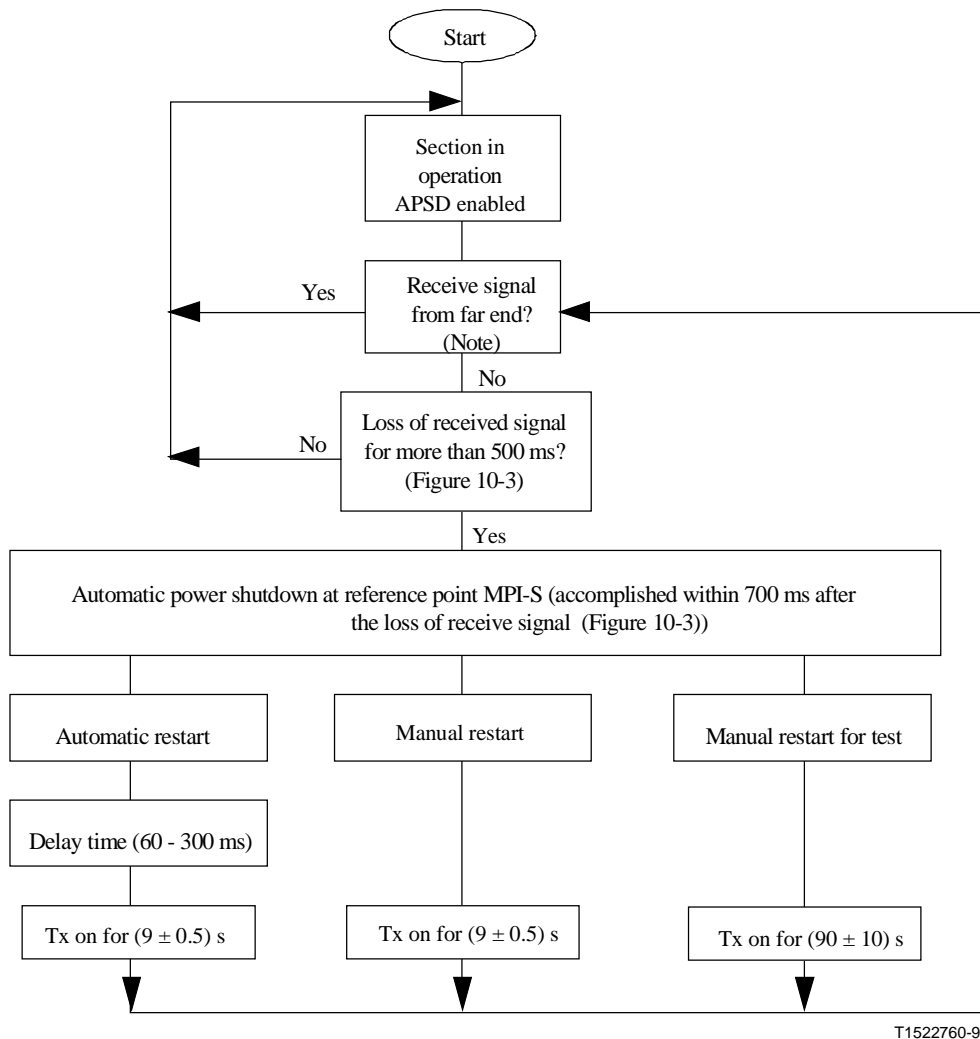
**Figure 10-1/G.681 – Reference configuration for description of APSD capability**

In Figure 10-1, "Tx" can be either a transmitter in a single-channel system (i.e. OAT or BA in combination with suitable adaptation of equipment according to Recommendations G.957 and G.958) or a multiplexer/optical amplifier in a multichannel system. Furthermore "Rx" can be either a receiver in a single-channel system (i.e. OAR or PA used in combination with a suitable adaptation of equipment according to Recommendations G.957 and G.958) or an optical amplifier/demultiplexer in a multichannel system.

Figure 10-2 shows the required functionality of the automatic shutdown and restart procedure in line terminations and regenerators. In cases where interfaces are achieved by suitable adaptation of equipment according to Recommendations G.957 and G.958, the operator has also to care for any necessary adaptation of the procedure to provide the shutdown and restart performance as required in this Recommendation, being aware of the possible safety implications. This requires change of the

restart pulse length as defined in Recommendation G.958 or other appropriate means, for example the use of manual restart processes.

NOTE – During restart it may be unavoidable that restart pulses will have power levels within Class 3A.



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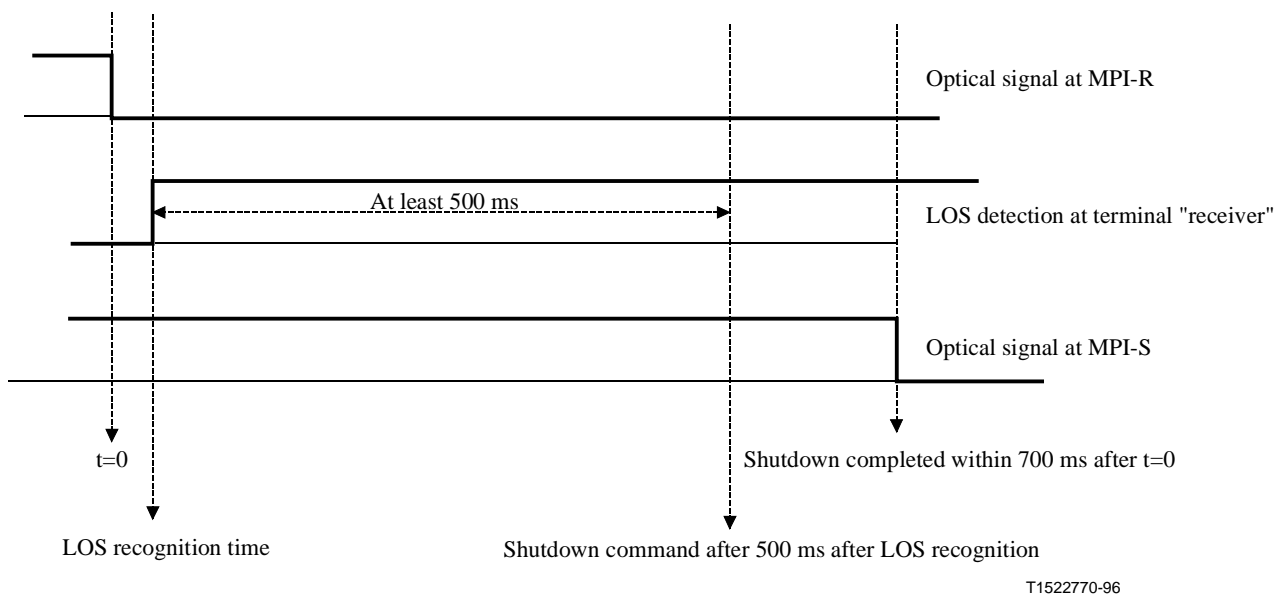
NOTE – "Receive signal from far end?" is also active when the transmitter is in the shutdown situation.

**Figure 10-2/G.681 – Automatic power shutdown and restart concept for terminal equipment including optional test procedure**

For test and monitoring purposes it is possible to override the shutdown mechanism by switching the optical signal on manually.

To restore the optical signal, either an automatic or a manual action is necessary, at Terminal 1 or Terminal 2, according to Figure 10-2.

When Loss of Signal (LOS) at reference point MPI-R is detected at the terminal equipment, then the output power of the associated "transmitter" at reference point MPI-S shall be shut down as indicated in Figure 10-2. A clarification of the requirements for the shutdown procedure is given in Figure 10-3. After a short but undefined recognition time LOS will be activated.



**Figure 10-3/G.681 – Clarification of shutdown at line terminal**

After at least 500 milliseconds of continuous presence of the LOS, the actual shutdown command will be activated, which shall result in shutdown of the optical output power at MPI-S within 700 milliseconds from the moment loss of optical signal occurs at MPI-R.

The activation response time of the "transmitter"/"receiver" combination at the terminal, measured from "receiver" input (point MPI-R) to "transmitter" output (point MPI-S) should not be greater than 1.25 s. This response time of 1.25 s refers to the time difference between the moment an optical signal enters the "receiver" at point MPI-R and the moment the "transmitter" starts emitting an optical signal at point MPI-S in case the "transmitter" has been in the shutdown condition.

The in-line amplifier should operate in a "master-slave" mode. Loss of optical power at point R', detected in the amplifier, shall result in shutdown of the output power of the line amplifier at point S' within a deactivation time of (40 – 100) ms. The activation time of each line amplifier, measured from input (point R') to output (point S') should be (10 – 300) ms. This activation time refers to the time difference between the moment optical power enters the line amplifier at point R' and the moment the line amplifier starts emitting optical power at point S' in case the line amplifier has been in the shutdown situation.

"Manual restart" or "Manual activation for test" can only be activated when the output is in the shutdown condition.

The APSD time constants for automatic shutdown are listed in Table 10-1.

Ten line amplifiers are assumed for the calculation of the minimum required pulse length for the restart procedure.

**Table 10-1/G.681 – Time constants for automatic shutdown**

<b>Time constant</b>	<b>Reference points</b>	<b>Value</b>	<b>Note</b>
Terminal response activation time	MPI-R to MPI-S	1250 ms max.	1
Terminal deactivation time	MPI-R to MPI-S	(500 – 700) ms	2
Line amplifier activation time	R' → S'	(10 – 300) ms	3
Line amplifier deactivation time	R' → S'	(40 – 100) ms	
BA activation time	R' to MPI-S	(10 – 100) ms	3
Pulse length for manual and automatic restart	N/A	(8.5 – 9.5) s	
Pulse repetition time for automatic restart is kept	N/A	(60 – 300) s	

NOTE 1 – The 1250 ms are derived from 850 ms according to Recommendation G.958 plus 300 ms for the PA and 100 ms for the BA.

NOTE 2 – The LOS - condition as described in Recommendation G.958 applies even in the presence of ASE.

The maximum value of 700 ms is derived from the maximum value of the deactivation time of 600 ms as in Recommendation G.958 plus additional 100 ms for the BA.

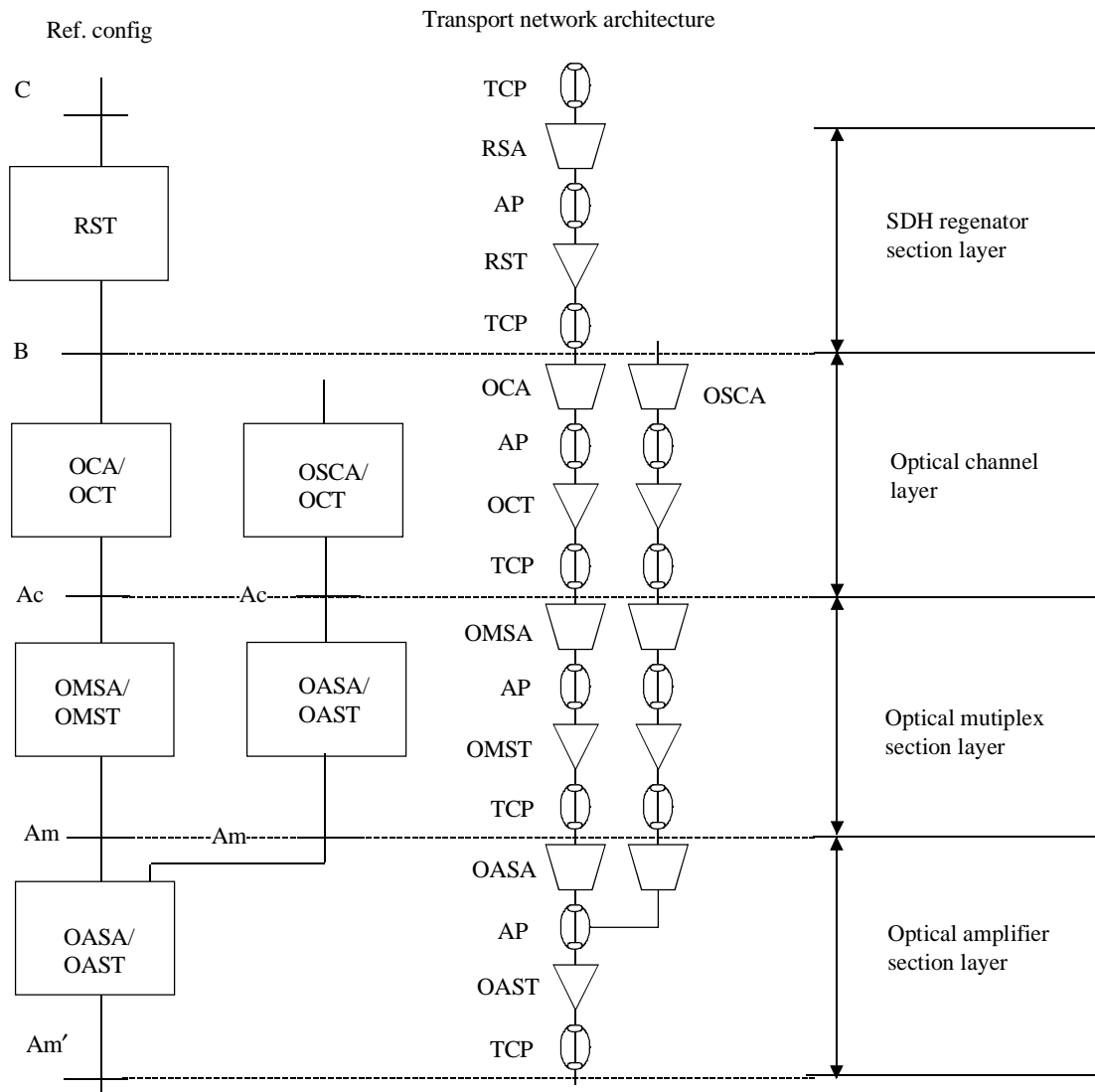
NOTE 3 – The rise time of the optical output signal between 10% and 90% of the nominal value should be greater than 10 ms.

## ANNEX A

### **Relation between compound functions and layered transport network architecture**

Figure A.1 identifies the relation between the compound functions used to describe optically amplified and multiplexed transmission network systems and a transport network architecture used to identify management information flows.

NOTE – The use of the G.805 architectural constructs to model an optical media-based transport network is the subject of further study.



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**Figure A.1/G.681 – Compound functions and transport network architecture for single-channel and multichannel systems**

## ANNEX B

### Mapping between compound functions and transport functions

Table B.1 provides the mapping between the compound functions and the adaptation and termination functions described within the transport network architecture (Annex A).

**Table B.1/G.681 – Relation between compound functions (functional blocks) and the adaptation and termination functions for single-channel and multichannel systems**

<b>Proposed compound function</b>	<b>Configuration functionality</b>	<b>Transport. Transport function</b>	<b>Network architecture Process</b>
RST	Scrambling/ descrambling RSOH	RSA	
		RST	RSOH source/sink scrambling/ descrambling
OCA/OCT	Mod, T, OCOH JW  CIc, DAc	OCA	Mod JW T
		OCT	OCOH DAc, CIc
OMSA/OMST	OM, WA, OMSOH, CIm	OMSA	OM WA
		OMST	OMSOH CIm
OASA/OAST	OA, DAa, OASOH  OSP, OMs	OASA	OMs, others for further study
		OAST	OASOH DAa OSP

## APPENDIX I

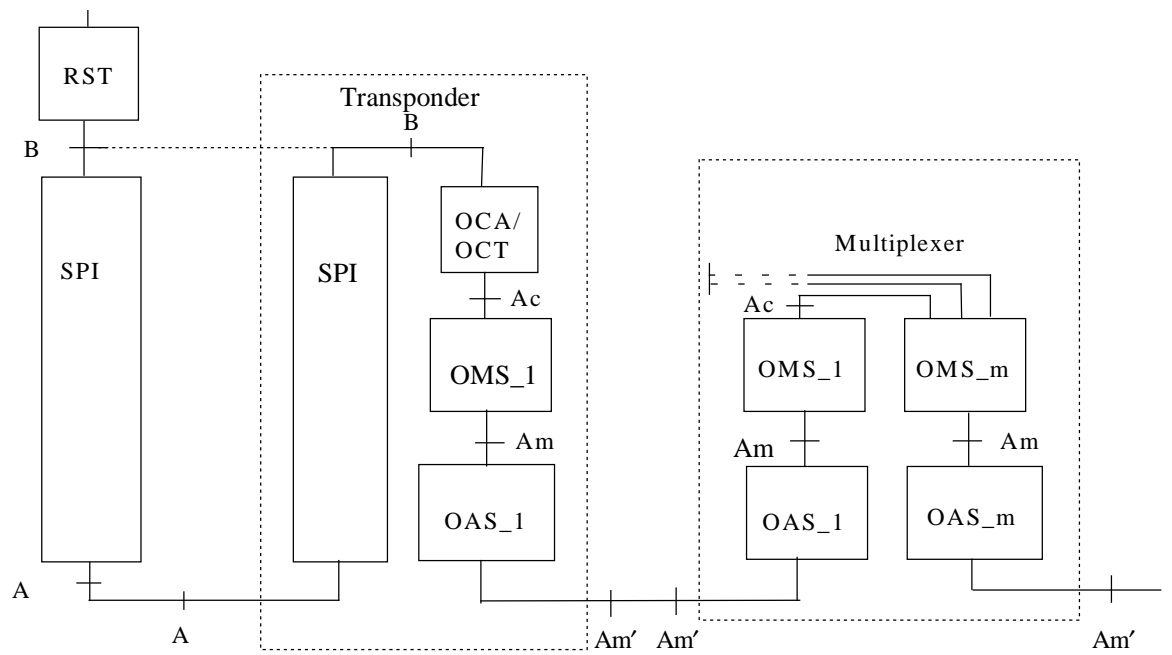
### Physical implementations of multichannel systems

#### I.1 Transponder implementations

Figure I.1a illustrates how the transponder configuration can be described using compound functions defined in clause 7. It is recognized that other implementations can be modelled using this technique.

The initial transmitted signal is associated with an SPI functional block as described within G.957/G.958 with an appropriate physical interface that conforms with Recommendations for existing SDH equipments. In this example the transponder is the group of functions that produces a conversion of the signal wavelength accompanied by the addition of a supervisory signal. Using the functional blocks described in clause 7, the transponder consists of an SPI block coupled to OCA/OCT, OMSA/OMST and OASA/OAST blocks (OMS\_1 and OAS\_1 respectively) to provide a suitable optical interface. The multiplexing unit is configured from OASA/OAST and OMSA/OMST (OAS\_1 and OMS\_1) functional blocks coupled OMSA/OMST and OASA/OAST (OMS\_m, OAS\_m) functional blocks.





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#### Functional blocks

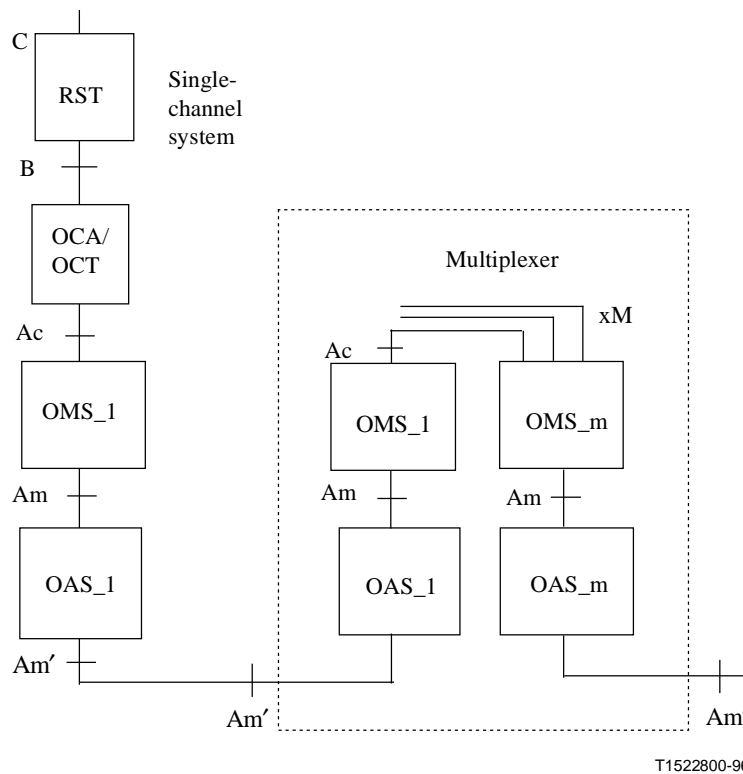
RST	Regenerator Section Termination
SPI	SDH Physical Interface
OCA/OCT	Optical Channel Adaptation/Termination
OMS_1	Single-channel OMSA/OMST function (Optical multiplex section adaptation/termination)
OMS_m	Multichannel OMSA/OMST function (Optical multiplex section adaptation/termination)
OAS_1	Single-channel OASA/OAST function (Optical amplifier section adaptation/termination)
OAS_m	Multichannel OASA/OAST function (Optical amplifier section adaptation/termination)

#### Reference points

Am', Am, Ac, B

**Figure I.1a/G.681 – Description of stand-alone transponder and multiplexer/amplifier configurations using compound functions defined in clause 7**

The dashed lines linking the reference points B and Ac indicate that the RST function can be mapped directly to the OCA/OCT compound function in the transponder and the OCA/OCT function in the transponder can be mapped directly to the OMSA/OMST (OMS\_m) compound function within the multiplex. This would result in the same functional description as outlined in clause 9.

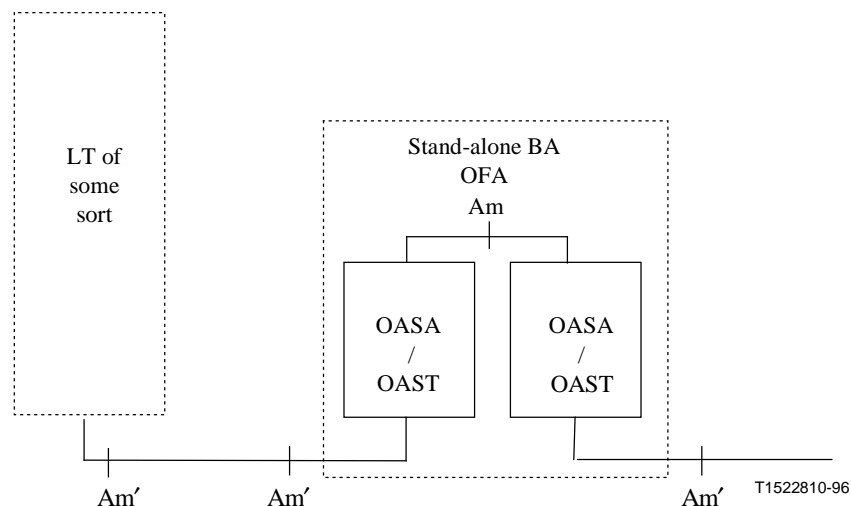


**Figure I.1b/G.681 – Mapping a stand-alone single-channel system into a multichannel system**

Similarly, Figure I.1b illustrates how the compound functions (functional blocks) can describe how a single-channel system can be mapped into a multichannel system.

## I.2 Stand-alone Booster Amplifier (BA) and Pre-Amplifier (PA)

Figure I.2 illustrates how a stand-alone booster optical amplifier configuration can be described using the compound functions (functional blocks) defined in clause 7. The line terminal is configured using any of the options shown in Figure 7-1. A stand-alone optical amplifier (e.g. BA, LA, or PA) is configured from two OASA/OAST compound functions. This stand-alone optical amplifier configuration yields not only for a BA, but also for a LA or PA optical amplifier in single-channel and multichannel system.



**Figure I.2/G.681 – Description of stand-alone optical amplifier configuration using the compound functions (functional blocks) defined in clause 7**

A symmetrical configuration applies at the receiver side with a pre-amplifier instead of the booster amplifier.

## APPENDIX II

### Realizations of new functions

#### II.1 Optical Amplification (OA) function

The OA function as OASA/OAST compound function is introduced into Recommendation G.681, single-channel and multichannel systems for the line termination (LT), the regenerator (REG) and for the optical non-regenerative repeater (nrREP) in single-channel and multichannel optical interoffice line systems up to STM-64 bit rate.

Physical realizations of the OA function in SDH equipments or systems up to the STM-64 level can be:

- physically integrated together with the E/O or O/E function as optically amplified;
- transmitter (OAT) or as Optically Amplified Receiver (OAR), respectively; and
- implemented in a specific stand-alone equipment (booster amplifier, pre-amplifier and line amplifier).

Optical amplifier characteristics, especially those of Optical Fibre Amplifiers (OFAs), are defined in Recommendations G.661, G.662 and G.663.

Optical amplifiers are implemented as Optical Fibre Amplifiers (OFAs) and as Semi-conductor Optical Amplifiers (SOAs). Proposed OFAs are the Erbium-doped fibre amplifier (EDFA) or the Erbium-doped fluoride fibre amplifier (EDFFA) for the 1550 nm wavelength region and the praseodymium-doped fluoride-fibre amplifier (PDFFA) for the 1310 nm fibre window. Also a SOA for the 1310 nm window is in discussion. These optical amplifiers can be a Booster Amplifier (BA) on the transmitter side and a Pre-Amplifier (PA) on the receiver side of a LT or REG as well as a Line Amplifier (LA) for instance as implementation of an optical non-regenerative repeater (nrREP).

The introduction of the OA function into LT, REG and nrREP functional groups will lead to new interoffice line system structures:

- LT(OA)/nrREP(OA)/LT(OA); and
- LT(OA)/nrREP(OA)/REG(OA)/nrREP(OA)/LT(OA).

## **II.2 Dispersion Accommodation (DA) function**

Interoffice line systems, regenerator sections and optical amplifier (non-regenerative repeater) sections require for a higher bit rate (e.g. STM-64) and a greater line length or repeater span (e.g. 80, 120 or 160 km) not only Optical Amplifiers (OA), but also a certain fibre dispersion accommodation (DA) technique on the transmitter and receiver side of a line termination (LT) or of an optical/electrical/optical regenerator (REG), as well as on the input and output side of a non-regenerative repeater (nrREP), to overcome fibre dispersion limitation.

The generic DA function allows different implementations of DA techniques. Identified have been linear fibre Dispersion Accommodation (DA) techniques like:

- Dispersion Supported Transmission (DST) method applying optical FSK/ASK signal conversion along the fibre;
- linear pre-chirping technique in laser diode or external modulator;
- Passive Dispersion Compensator (PDC),

and non-linear fibre Dispersion Accommodation (DA) techniques utilizing non-linear fibre-optic effects like:

- Self-Phase Modulation (SPM),

alone or in connection with:

- external AM or PM modulators (e.g. electro-absorption EA modulator or electro-optical mach-zehnder MZ modulator).

Other DA techniques, like:

- multilevel (e.g. duobinary) modulation; and
- mid-system spectral inversion (MSI) by four-wave-mixing (FWM),

are not specifically considered within the scope of this Recommendation.

## **APPENDIX III**

### **Example of functional modelling for single-channel and multichannel systems**

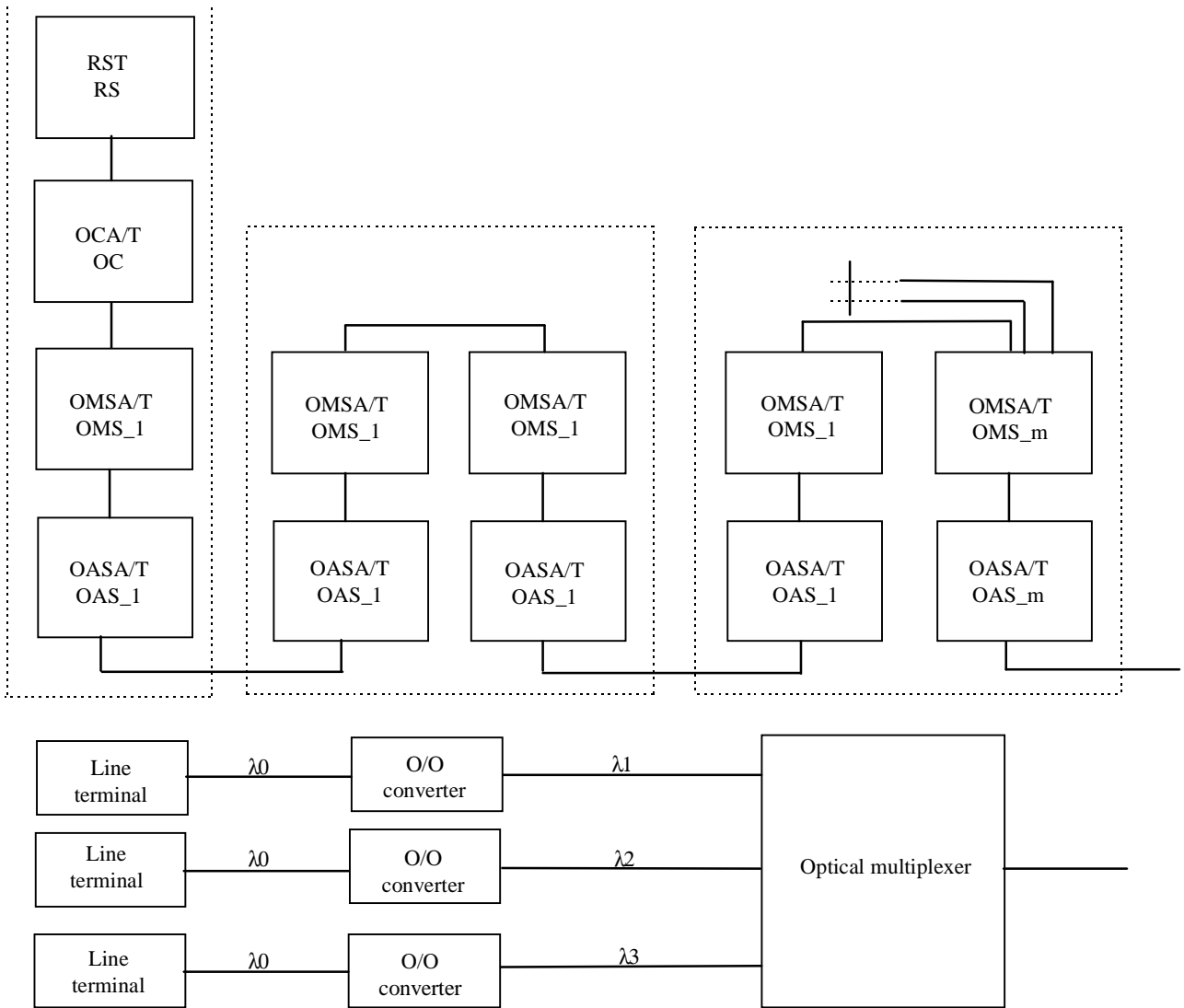
Some examples for the mapping of functional architectures on implementations are shown in the following subclauses.

#### **III.1 Example 1: Stand-alone equipment**

See Figure III.1.

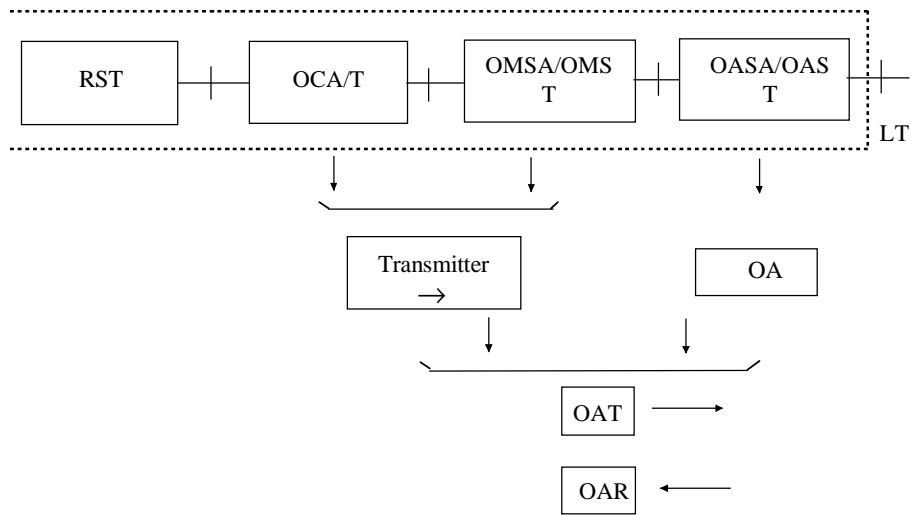
#### **III.2 Example 2: Mapping of functional blocks of a line terminal in a single-channel system on OAT and OAR implementations**

See Figure III.2.



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**Figure III.1/G.681 – Stand-alone equipment with O/O transponders**



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**Figure III.2/G.681 – Mapping of functional blocks of an LT in a single-channel system on OAT and OAR implementations**

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