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

Transmission media characteristics – Characteristics of optical components and subsystems

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Optical safety procedures and requirements for optical transport systems

ITU-T Recommendation G.664

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ITU-T Recommendation G.664

Optical safety procedures and requirements for optical transport systems

Summary

This Recommendation provides guidelines and requirements for techniques to enable optically safe working conditions (for the human eye and skin and for avoiding ignition) on optical interfaces of the Optical Transport Network, in particular, for systems employing high-power Raman amplification techniques, for equipment in restricted and controlled locations.

Because of revisions of relevant IEC requirements, the ALS procedure, defined in a previous version of this Recommendation for SDH systems, is no longer necessary and has therefore been moved to an informative appendix. Furthermore, this Recommendation provides new guidelines on APR procedures for systems employing high-power Raman amplification techniques.

Source

ITU-T Recommendation G.664 was revised by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 16 March 2003.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T 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 World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

ITU-T Recommendation G.664

Optical safety procedures and requirements for optical transport systems

1 Scope

This Recommendation provides guidelines and requirements for techniques to enable optically safe working conditions (for the human eye and skin and for avoiding ignition) on optical interfaces of the Optical Transport Network, including conventional SDH systems, for equipment in both restricted and controlled locations.

The actual definition and specification of optically safe levels are considered outside the scope of this Recommendation (they are provided by IEC).

The main fields of application are conventional SDH line systems with and without optical amplifiers and systems designed for the Optical Transport Network. In particular, some specific considerations are given for systems employing high-power Raman amplification techniques.

The impact of bidirectional transmission as described in ITU-T Rec. G.692 has also been considered.

Because of desired backwards compatibility with no longer existing Recommendations on the subject of optical safety, this Recommendation provides some descriptions for safety procedures in the case of single- and multichannel SDH systems with and without line amplifiers. A clarification is given as to why procedures employing restart pulses for Automatic Laser Shutdown (ALS) and Automatic Power Shutdown (APSD), defined in a previous version of this Recommendation, are no longer appropriate or necessary for applications given in ITU-T Recs G.691, G.693 and G.957.

The definition of optical safety procedures for the Optical Access Network is regarded as being outside the scope of this Recommendation.

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; 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. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

– ITU-T Recommendation G.662 (1998), *Generic characteristics of optical fibre amplifier devices and subsystems*.

– ITU-T Recommendation G.691 (2000), *Optical interfaces for single channel STM-64, STM-256 and other SDH systems with optical amplifiers*.

– ITU-T Recommendation G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*.

– ITU-T Recommendation G.693 (2001), *Optical interfaces for intra-office systems*.

– ITU-T Recommendation G.783 (2000), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*.

– ITU-T Recommendation G.872 (2001), *Architecture of optical transport networks*.

– ITU-T Recommendation G.957 (1999), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.

– ITU-T Recommendation G.959.1 (2001), *Optical transport network physical layer interfaces*.

– IEC 60825-1 Edition 1.2 (2001), *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*.

– IEC 60825-2 Second Edition (2000), *Safety of laser products – Part 2: Safety of optical fibre communication systems*.

– IEC 60825-2 Corr.I1 (2001), *Safety of laser products – Part 2: Safety of optical fibre communication systems – Interpretation sheet 1*.

3 Terms and definitions

3.1 Definitions

This Recommendation defines the following terms:

3.1.1 automatic laser shutdown (ALS): A technique (procedure) to automatically shutdown the output power of laser transmitters and optical amplifiers to avoid exposure to hazardous levels.

3.1.2 automatic power reduction (APR): A technique (procedure) to automatically reduce the output power of optical amplifiers to avoid exposure to hazardous levels.

3.1.3 automatic power shutdown (APSD): A technique (procedure) to automatically shutdown the output power of optical amplifiers to avoid exposure to hazardous levels; within the context of this Recommendation the term APSD is equivalent to the term ALS.

3.1.4 main (optical) path: The fibre plant between the MPI-S, S or S' point of the transmitting equipment and the MPI-R, R or R' point of the receiving equipment.

3.1.5 main path interfaces: The interfaces to the fibre plant.

3.2 Terms defined in other Recommendations

This Recommendation uses the following terms defined within other ITU-T Recommendations:

Loss of Signal (LOS)	ITU-T Rec. G.783
LOS overhead (LOS-O)	ITU-T Rec. G.798
LOS payload (LOS-P)	ITU-T Rec. G.798
Optical Multiplex Section (OMS)	ITU-T Rec. G.872
Optical Supervisory Channel (OSC)	ITU-T Rec. G.692
Optical Transmission Section (OTS)	ITU-T Rec. G.872

4 Abbreviations

This Recommendation uses the following abbreviations:

AEL	Accessible Emission Limit
ALS	Automatic Laser Shutdown
APR	Automatic Power Reduction
APSD	Automatic Power ShutDown
BA	Booster Amplifier

dLOS	Loss of Signal defect
IaDI	Intra-Domain Interface
LA	Line Amplifier
LOS	Loss Of Signal
LOS-O	LOS overhead
LOS-P	LOS payload
MPE	Maximum Permissible Exposure
MPI	Main Path Interface
MPI-R	Receive Main Path Interface reference point
MPI-S	Source Main Path Interface reference point
OAR	Optically Amplified Receiver
OAT	Optically Amplified Transmitter
OMS	Optical Multiplex Section
OSC	Optical Supervisory Channel
OTN	Optical Transport Network
OTS	Optical Transmission Section
PA	Pre-Amplifier
SDH	Synchronous Digital Hierarchy
WDM	Wavelength Division Multiplexing

5 General optical safety considerations

5.1 Safety considerations for avoiding damage to the human eye and skin

IEC 60825-2 provides a clarification of the difference between Laser Class and Hazard Level. The text below is taken from IEC 60825-2.

"**Class**: The word "Class" refers to a scheme by which, based on emission levels, a product or internal emitter can be grouped with respect to its safety. These levels are described in the Accessible Emission Limit Tables in IEC 60825-1. Classes range from Class 1, which is safe under reasonably foreseeable conditions, to Class 4, which is potentially the most hazardous case. In IEC 60825-1, the classification of products is based on normal operating conditions."

"**Hazard Level**: "Hazard Level" is a term in this standard which refers to the potential hazard from laser emissions at any location in an end-to-end fibre optic communication system that may be accessible during use or maintenance or in the event of a failure or fibre disconnection. The assessment of the hazard level uses the Class Accessible Emission Limit tables described in the IEC 60825-1."

"A whole optical fibre communication system will not be classified in the same way as required by IEC 60825-1. This is because, under intended operation, the optical radiation is totally enclosed, and it can be argued that a rigorous interpretation of IEC 60825-1 would give a Class 1 allocation to all systems, which may not reflect the potential hazard accurately."

"Based upon this statement, a complete optical fibre communications system can be regarded as a Class 1 laser product because, under normal conditions, the emissions are completely enclosed (like a laser printer) and no light should be emitting outside the enclosure. It is not until the fibre breaks, or an optical connector is unplugged, that someone might be exposed to a potentially hazardous light level if the internal emitters are of high enough power".

"Therefore, for each optical output port the Hazard Level must be assessed. The Hazard Level limits are dependent on the "dominant" wavelength range, taking into consideration that IEC 60825-1 defines different limits for different wavelength ranges Details can be found in IEC 60825-1. Furthermore, this standard allows the use of Automatic Power Reduction (APR) techniques to achieve a lower (less hazardous) Hazard Level based on the normal power in the fibre and speed of automatic power reduction".

In this Recommendation, Automatic Laser Shutdown (ALS) techniques (in the case of SDH systems) which were originally designed for the same purpose, i.e., to provide safe working environments, are also described in Appendix III.

NOTE 1 – Over the past years the term Automatic Power Shutdown (APSD) has also been used for systems with optical amplifiers. Because the term ALS has been in use much longer, in this Recommendation the term ALS will be used, noting that in this context the term APSD is intended to be equivalent to the term ALS.

It should furthermore be noted that, for the hazard level assessment, only those power levels should be considered which might occur under reasonably foreseeable conditions. IEC 60825-2 provides some description and guidance to define the meaning of "reasonably foreseeable".

For the purposes of this Recommendation, it is assumed that OTN equipment in general (including SDH equipment) will only be deployed in Controlled and Restricted locations. In IEC 60825-2 it is defined that the Hazard Level of equipment shall not exceed 1M in Restricted Locations and 3B in Controlled Locations. Additional requirements for Controlled Locations, which are outside the scope of this Recommendation, can be found in IEC 60825-2.

NOTE 2 – In IEC 60825-1, a Class 1M has been defined instead of 3A. In IEC 60825-2 a Hazard Level 1M is, however, not yet defined. In order to make both IEC documents consistent, an Interpretation Sheet has been agreed by IEC (IEC 60825-2 Corr.I1 (2001)) in which the Hazard Level 1M is introduced, replacing Hazard Level 3A. In particular, in the 1550 nm window, the 3A exposure limit was a fixed limit, in contrast to the 1M level, which is expressed by a formula and, as such, determined by several factors specified by IEC 60825-1 (e.g., exposure time, wavelength, fibre mode field diameter, measurement diameter and measurement distance). For the applications covered by this Recommendation, the Hazard Level 1M limit is generally higher than the previous Hazard Level 3A limit due to divergence of the beam from the optical fibre into free space. In this Recommendation, general reference is made to the new Hazard Level 1M instead of the previous Hazard Level 3A. In situations where the Hazard Level assessment is still 3A, it is suggested to use the guidelines applicable to Hazard Level 1M.

In systems which have an operational power in the fibre exceeding the potentially hazardous levels 1M or 3B in the case of Restricted or Controlled locations respectively, an APR or ALS capability shall be used to reliably reduce the operational power to a level below the safety level applicable for the type of location. More detailed requirements are defined in clause 6.

Furthermore IEC 60825-2 provides guidelines on the reliability of APR procedures.

5.2 Safety considerations to avoid ignition

Awaiting publication of IEC documents giving details on the topic of safety to avoid ignition, this clause is for further study.

6 Procedures and guidelines

6.1 General

For eye safety considerations, according to IEC 60825-1 and IEC 60825-2, it may be necessary to provide for a capability for Automatic (optical) Power Reduction (APR) in the case of loss of optical power within one section of the main optical path. For example, this loss of power can be caused by cable break, equipment failure, connector unplugging, etc. To facilitate an easy restoration of the system after reconnection of the link, an automatic (or manual) restart is considered in this Recommendation.

In a previous version of this Recommendation, regularly transmitted (restart) pulses were used to facilitate the restoration of the system. The use of pulses was a very convenient means for establishing restart in transversely compatible procedures. As clarified in Appendix III, the use of restart pulses with full operational power is, however, no longer considered appropriate because of revised IEC safety requirements. Because alternative methods suitable for inclusion in generic restart procedures have not yet been established by ITU-T, it is recommended to specify transversely compatible interfaces with optical power levels at Hazard Level 1M (or 3B in the case of Controlled Locations) or lower. In this case, APR procedures are not necessary as clarified in 5.1. In the case of system architectures employing an OSC, further possibilities exist to establish restart, and some examples are shown in Appendix I.

As clarified under clause 5, it is not necessary to provide a power reduction procedure for systems of Hazard Levels 1 and 1M according to IEC 60825-2. This is, furthermore, not necessary for systems with Hazard Level 3B in Controlled Locations. Currently, all optical power levels specified in ITU-T Recs G.691, G.693, G.957 and G.959.1 are Hazard Level 1M or lower. In particular, the levels in ITU-T Recs G.693 and G.957 are of Hazard Level 1, thus, considered completely safe. During the discussions on the first version of ITU-T Rec. G.957, APR was regarded necessary to maintain sufficient optical safety. Consequently, a shutdown procedure (called ALS) was defined. Because this procedure (which is no longer regarded necessary as stated above) has been widely deployed in SDH terminal equipment over the past years, it has been captured in Appendix III for historical purposes.

6.2 APR procedures

In this clause, basic requirements and guidelines are given for Automatic Power Reduction (APR) and restart procedures for systems where power levels above Hazard Level 1M in restricted and 3B in controlled locations are unavoidable (including OTN applications).

In particular, Distributed Raman amplification systems will need specific care to ensure optically safe working conditions, because high pump powers (power levels above +30 dBm are not uncommon) may be injected into optical fibre cables. Therefore, APR procedures are required in order to avoid hazards from laser radiation to human eye or skin and potential additional hazards such as temperature increase (or even fire) caused by locally increased absorption due to connector pollution or damage. For the same reason, very tight fibre bends also need to be avoided.

Raman- based systems differ from conventional optically amplified systems due to the possible presence of pump lasers at the "receiving" side of a link, launching high optical powers backward into the link. In order to ensure that the power levels emitting from broken or open fibre connections are at safe levels, it is necessary to reduce the power not only on the main optical signal sources but also on all pump-lasers employed, including the backward pumping lasers. Because the operating wavelength of the Raman pumps is usually different from the actual data signal, separate assessments at the various wavelengths used (thus both at pump laser wavelength and at main signal wavelength) need to be made.

In common with the other cases described in this Recommendation, APR techniques are necessary in the case that the sum of operational power (main optical signal) and pump-laser output power of the optical interfaces exceeds the applicable Hazard Levels defined in IEC 60825-2. The total power is the sum of the power in any one direction from all optical channels, the power from all pump-lasers and the power from Optical Supervisory Channels (OSC), if used.

The time within which the power reduction has to be achieved depends on the actual operational power level. In other words, the higher the power level, the shorter the shutdown time. Requirements for shutdown times can be calculated from IEC 60825-1.

After power reduction, the remaining total power level, i.e., the sum of the power from all optical channels, the power from pump-lasers in the case of Raman amplification and the power from an Optical Supervisory Channel (OSC), must be within Hazard Level 1M, noting that reduction of the total power to within Hazard Level 1 or even complete shutdown is not excluded.

NOTE 1 – For backwards compatibility, it is allowed to use the ALS-procedure described under clause III.3 (a modification of the ALS-procedure shown in Figure III.1 with respect to timing requirements) for already installed SDH multichannel systems with line amplifiers which have operational output powers of Hazard Level 3B (in the case of restricted locations). In this case, with reference to Figure III.5, depending on the specific implementation, "Tx" can be either any SDH transmitter in combination with a suitable adaptation of the MUX/OA equipment or the MUX/OA equipment. Furthermore "Rx" can be either the corresponding SDH receiver in combination with a suitable adaptation of the OA/DEMUX equipment or the OA/DEMUX equipment.

A generic APR description for OTN applications is shown in Figure 1. For systems employing an OSC (with or without Raman amplification), some example procedures for applying power reduction and restart are given in Appendix I. A more specific description for the case of systems employing Raman amplification without OSC is given in Appendix II.

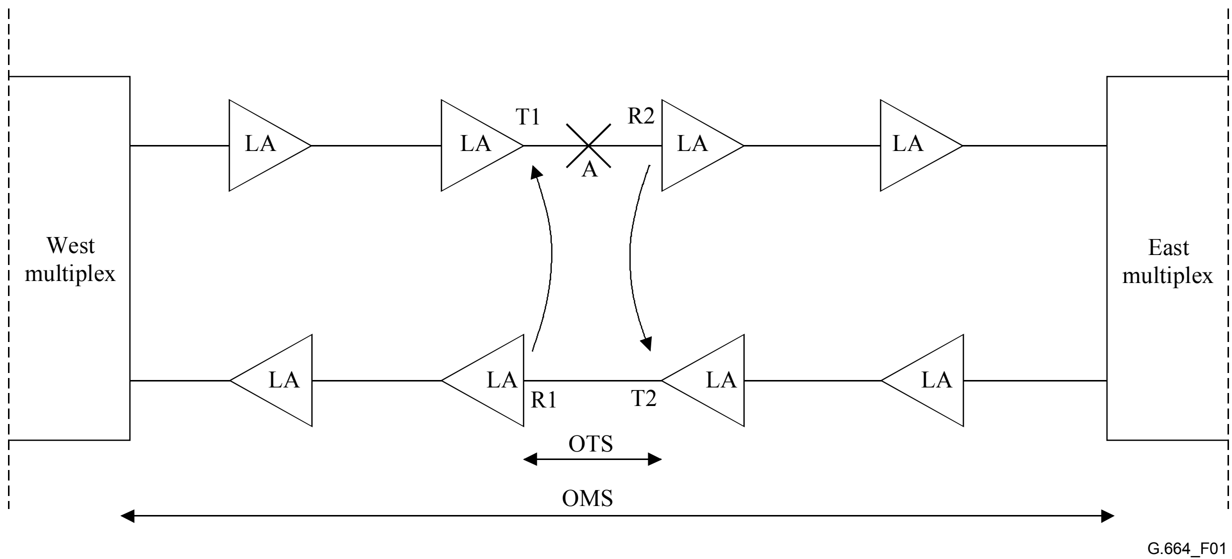


Figure 1/G.664 – Description of APR capability in the case of cable break

In the case that a cable break happens at point A of Figure 1, the available LOS defect indicator at receiving interface R_2 is used to reduce the output power of the transmitting interface T_2 which is the adjacent source in the opposite direction. This is detected in the receiving interface R_1 which, in its turn, reduces the output power of the transmitting interface T_1. The principle of detecting a power reduction at R_1 is for further study. In the case of OTN applications, LOS-O (LOS overhead) and LOS-P (LOS payload) could be used. Definitions of LOS-O and LOS-P are given in ITU-T Rec. G.798.

NOTE 2 – In this generic description the power on both the impacted link and the counter-propagating link within an OTS is reduced. In clause I.3, an example procedure is given where only the power on the impacted link is reduced.

The power reduction to Hazard Level 1M for restricted locations on all optical outputs within the impacted OTS shall be carried out within a certain time (with a maximum of 3 s) from the moment the continuity in the OTS is interrupted. The specific shutdown time is dependent on the actual operational optical power and can be calculated from the Maximum Permissible Exposure (MPE) specification in IEC 60825-1.

NOTE 3 – Secondary actions on other amplifiers in the impacted OMS section, including those potentially active on equipment (e.g., single-channel equipment) outside the OMS, are not excluded but a corresponding specification is regarded outside the scope of this Recommendation. These secondary actions shall not interfere with the safety procedures on the impacted OTS.

When the connection in the OTS has been repaired, either an automatic or a manual restart is necessary to restore transmission within the OTS. A restart shall not be initiated within 100 s from the moment the connection interruption occurred or from the finish of a previous (unsuccessful) restart action, unless connectivity is guaranteed. During and after the restart action, the optical power within the impacted OTS shall not exceed Hazard Level 1M until connectivity is guaranteed.

NOTE 4 – In the case that a restart pulse is chosen to re-establish a connection, its allowed power level depends on its duration.

The specification of a restart procedure, suitable to support operation on transversely compatible optical interfaces, is for further study. The above-mentioned APR procedures shall not result in the generation of downstream consequential alarms. In other words, alarms will only be notified by the affected OTS.

NOTE 5 – Bidirectional systems have to meet the same optical safety requirements and will use the same principles as unidirectional systems. The precise specification of these procedures are for further study.

Appendix I

Examples of APR architectures for systems (including those based upon Raman amplification) deploying an OSC

I.1 Introduction

The ALS procedure, defined in Appendix III.2, was originally defined in the 1988-1990 timeframe. An essential part of this ALS procedure is the frequent emission of a short (2 s) pulse, operating at full optical transmitter power, to restart the transmitters at both sides of the shutdown link. Under the IEC rules valid at that time, a system deploying optical interfaces compliant to ITU-T Rec. G.957 became safe when using the above-mentioned ALS procedure.

Since then, IEC 60825-1 has undergone several modifications and also optical amplifier technology, with increasing levels of output power, have become available. In particular, systems deploying Raman Amplifiers are operating at optical power levels substantially above the Hazard Level 1M limit.

If a frequently emitted pulse is to be used to restart a shutdown system, it either has to be very short or needs to have a reduced optical power level (compared to full operational power) in order to guarantee the safety of the system. Neither option, however, ensures restart of the system, because the short restart pulse might not be long enough to trigger a restart, or the power at the receiver might be too low to be detected.

Therefore, alternative ways to perform a restart have been considered. One could be the use of an Optical Supervisory Channel (OSC), when present in the system, to verify link connectivity. Because an OSC is usually operating at a safe optical power level (Hazard Level 1 or 1M), it can be kept "alive" on the fibre after the power has been reduced to a safe level. Restoration of OSC communication indicates full restoration of the link connectivity, after which the system can be brought back to its full operational power. In this way, it is ensured that the full operational power is only present in a fully enclosed configuration guaranteeing optical safety.

NOTE – The drawback of using the OSC is the fact that when it fails, automatic restart will not occur. This will, however, not impact the safety of the system. In this case, a manual restart could be considered to restore the full operational power at least until the OSC has been repaired.

Currently, the OSC is not required to be present on any transversely compatible link. On the other hand, an OSC is often present in IaDI system configurations, which are of proprietary nature. Therefore, in this appendix, several examples of principles of APR procedures are shown using the OSC to restart a system shutdown after an optical fibre break.

I.2 Description of APR procedure using co-propagating OSC

In Figure I.1 a multi-channel configuration is shown, where, in the upper link besides "traffic", an OSC, called OSC-WE, is also travelling from the West Multiplex to the East Multiplex and, in the lower link an OSC, called OSC-EW, is travelling from the East Multiplex to the West Multiplex. Within the context of this example, this configuration is referred to as a co-propagating configuration.

In the case that a cable break occurs at point A in the OTS indicated in Figure I.1, at receiving interface R2 both LOS-P (LOS payload) and LOS-O (LOS Overhead) will occur. Then, in line with the APR procedure described in 6.2, the optical power associated with the payload at transmitting interface T2 should be reduced sufficiently to meet the appropriate Hazard Level. In the case that backward pumped Raman amplifiers are used, the power inserted backwards into the upper link from receiving interface R2 should be reduced as well. At the same time, the OSC-EW should send a signal towards receiving interface R1 to indicate that, at transmitting interface T1, the payload optical power should be reduced accordingly. The payload powers at both T1 and T2 should be reduced within a certain time, depending on the operational power within the fibre. Details are provided by IEC 60825-1. It should be noted that, at receiving interface R1, LOS-P will also occur, but not LOS-O and, therefore (if present), the power pumped backwards by Raman amplifiers into the lower link at Receiving interface R1 does not have to be reduced.

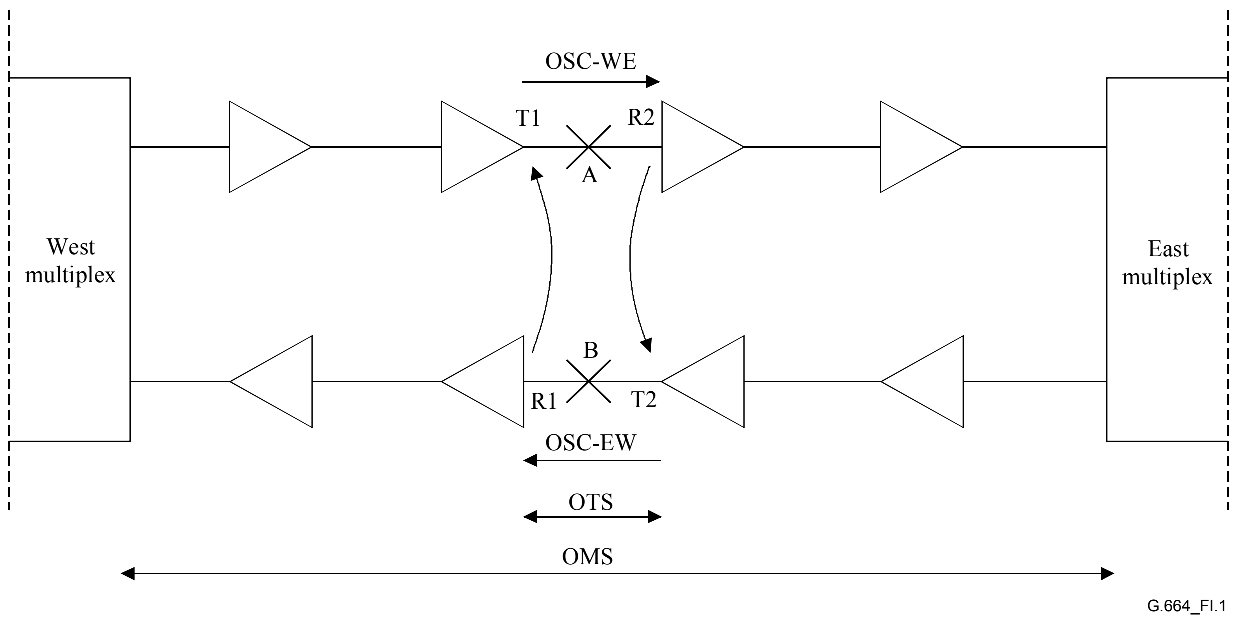


Figure I.1/G.664 – Description of APR capability in the case of cable break in a configuration with co-propagating OSC

As soon as the fibre cable is repaired at point A, LOS-O will disappear at receiving interface R2, and full OSC communication will be restored. Now, full connectivity is guaranteed. The payload power at transmitting interface T2, and the backward pumping (when present) at receiver interface R2, can be immediately restored while OSC-EW sends a signal to R1 that the payload power at transmitting interface T1 can be restored as well.

In the case that the cable is broken in both directions (at both points A and B), at both receiving interfaces R1 and R2, LOS-P and LOS-O will occur, triggering immediate reduction of payload power at both T1 and T2 and backward pumped power at both R1 and R2. In all cases, the optical power associated with the OSC will be maintained.

Order of actions/events:

1) Fibre break at point A;
2) LOS-O AND LOS-P at R2;
3) Reduced traffic associated power at T2 AND reduced backward pumped power at R2 AND OSC-EW signalling of fibre break A towards R1;
4) LOS-P at R1 AND R1 receiving message by OSC-EW, initiating reduction of traffic power at T1;
5) Link power reduced to safe level;
6) Repair of break at point A;
7) Clearing of LOS-O at R2, indicating full restoration of both WE and EW OSC links, thus confirming link connectivity;
8) Restore backward pumped power at R2 AND forward power at T2 AND OSC-EW signalling of repair of fibre break to West Multiplex;
9) LOS-P clearing at R1 AND R1 receiving repair message by OSC-EW;
10) Restoring forward power at T1;
11) Clearing of LOS-P at R2;
12) ink operation completely restored.

I.3 Description of APR procedure using counter-propagating OSC

In Figure I.2 a multi-channel configuration is shown where, in the upper link in addition to "traffic", an OSC called OSC-EW, is present on the link. Contrary to the configuration described in I.2, this OSC is travelling in the opposite direction from the East Multiplex to the West Multiplex. In the lower link, an OSC called OSC-WE, is travelling from the West Multiplex to the East Multiplex, also in a direction opposite to the traffic. Within the context of this example, this configuration is referred to as a counter-propagating configuration.

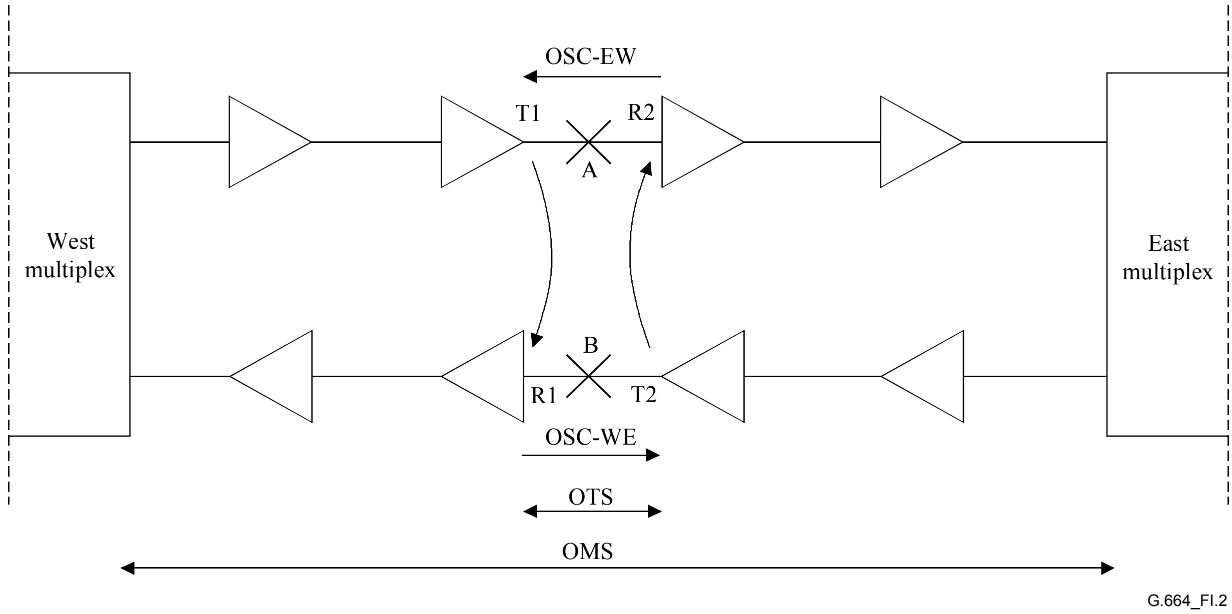


Figure I.2/G.664 – Description of APR capability in the case of cable break in a configuration with counter-propagating OSC

In the case that a cable break occurs at point A in the OTS indicated in Figure I.2, at receiving interface R2, LOS-P (LOS payload) and at transmitting interface T1 LOS-O (LOS overhead) will occur. Then, immediately the optical power, associated with the payload at transmitting interface T1 and the backward pumped power at R2 (when present), should be reduced sufficiently to meet the appropriate Hazard Level. Then the upper link is safe and there is no necessity to shutdown the lower link, because each link can be separately managed.

The payload powers at both T1 and R2 should be reduced within a certain time, depending on the operational power within the fibre. Details are provided by IEC 60825-1.

As soon as the fibre cable is repaired, LOS-O will disappear at transmitting interface T1, and full OSC communication will be restored on the upper link. Now full connectivity is guaranteed, which will be communicated from West to East multiplex by OSC-WE on the lower link. The payload power at transmitting interface T1, and the backward pumping (when present) at receiver interface R2, can be immediately restored.

Order of actions/events:

1) Fibre break at point A;
2) LOS-O at T1 AND LOS-P at R2;
3) Reduced traffic associated power at T1 AND reduced backward pumped power at R2;
4) Link power reduced to safe level;
5) Repair of break at point A;
6) Clearing of LOS-O at T1, indicating full restoration of EW OSC link, thus confirming link connectivity;
7) Restore forward power at T1 AND OSC-WE signalling of repair of fibre break to East multiplex;
8) Restore backward power at R2;
9) LOS-P clearing at R2;
10) Link operation completely restored.

Appendix II

Considerations on optical safety mechanisms for systems employing Raman amplification

Figure II.1 shows a configuration with both forward and backward pump lasers on a span of a (potentially multi-span) system deploying distributed Raman amplification. T1 and T2 represent the transmitting interface on this section, whereas R1 and R2 represent the receiving interface.

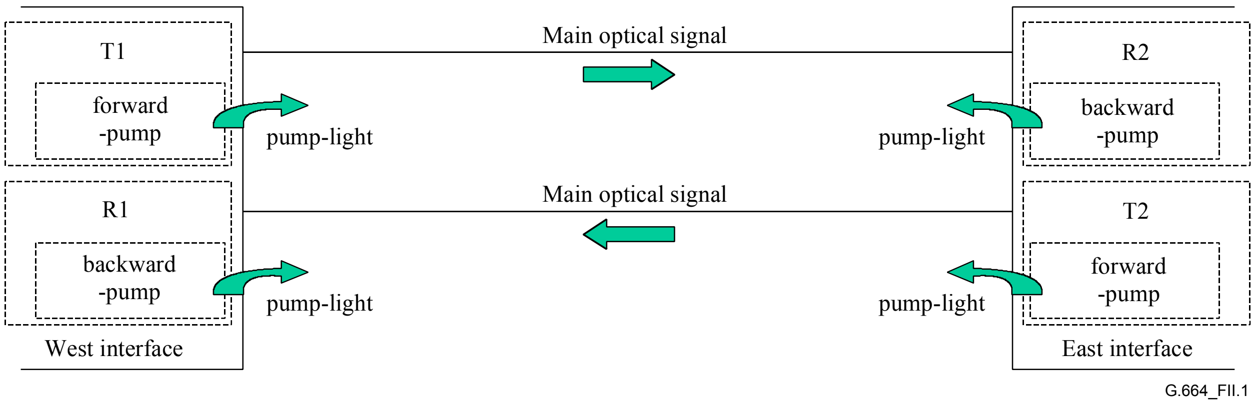


Figure II.1/G.664 – Configuration with forward and backward pump lasers in a section within multi-span transmission system employing distributed Raman amplification

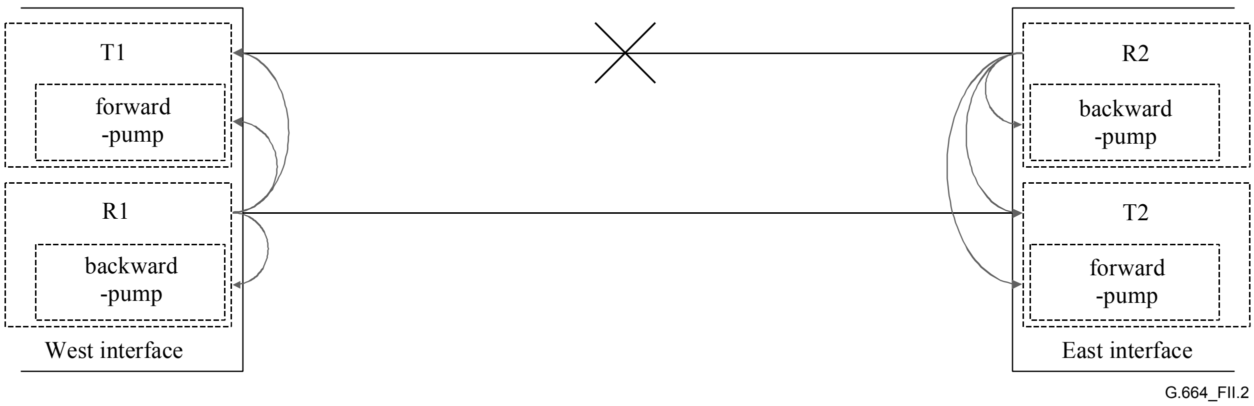


Figure II.2/G.664 – Possible actions in the case of a cable break

If a cable break happens as shown in Figure II.2, several actions need to be taken to ensure safe working conditions on the impacted link (in this case the upper link). Depending on the implementation of the architecture, of which the choice of OSC architecture may be playing an important role, either the power on only the impacted link, or additionally, the power on the reverse (lower in this case) link, needs to be reduced. In either case, both the forward (pumps and signal) and backward (pump) powers have to be reduced. In the case that an OSC is used, some considerations to perform APR and associated restart are given in Appendix I. In the case that no OSC is used, both links need to be shutdown (also the uninterrupted link) to ensure appropriate power reduction on the impacted link. In the example shown in Figure II.2, LOS will be detected at R2, which should be used to reduce the backward pumped power at R2 AND the forward power at T2. The forward power at T2 should be reduced sufficiently to trigger LOS at R1, which should be used to reduce the backward pumped power at R1 AND the forward power at T1.

Restart methods for configurations without OSC are for further study because the use of restart pulses is possibly hazardous as clarified in Appendix I. Otherwise, a manual restart can be used upon a confirmation that the link has been repaired.

NOTE – Care has to be taken that the possible presence of back reflected stimulated Raman amplified emission does not prevent the correct functioning of the LOS detectors.

Appendix III

Description of ALS/APSD procedures for single-channel point-to-point SDH systems

III.1 Introduction

In the first version of this Recommendation, the ALS procedure described in this appendix was part of the main body. Because of changes over time (since 1984) in the IEC 60825-1 and -2 documents, the ALS procedure no longer provides the optical safety as originally intended. In particular, the use of a repetitive pulse to restart the system is considered no longer appropriate for reasons given below. Furthermore, the optical power levels specified in ITU-T Rec. G.957 all are within the Hazard Level 1 category (fully safe) and those in ITU-T Rec. G.691 are all within Hazard Level 1M, as well as previous Hazard Level 3A (safe without viewing aids).

Because the ALS procedure has been widely deployed in SDH terminal equipment over the past years, it is captured in clause III.2 for historical purposes. Furthermore, a modified ALS procedure in the case of line amplifiers, is described in clause III.3. In this case, longer restart pulses are used, which makes the procedure even less appropriate.

The ALS procedure was originally defined in 1989 using a version of IEC 60825 from 1984. At that time, the optical power levels defined in ITU-T Rec. G.957 for both 1310 nm and 1550 nm windows were regarded above Hazard Level 1.

Since that time, IEC 60825-1 has undergone various modifications. The latest official version is Edition 1.2 (2001-08).

In particular, for the case of a 2.25 second restart pulse, the AELs (Accessible Emission Limits) have been modified in the exposure time range of interest (0.35 to 10s).

It can be calculated from the formula given in IEC 60825-1 that, for a 1550 nm system using ALS and stating Hazard Level 1, the maximum optical power during a 2.25 second restart pulse may "only" be 1.7 dB above the Hazard Level 1 limit for continuous power. If the restart pulse power (which may be equal to full operational power) goes above this value, then the system will exceed Hazard Level 1 e.g., it may become Hazard Level 1M instead. This means that, in this case, using the ALS procedure only reduces the Hazard Level in a very limited power range of 0 to 1.7 dB above the Hazard Level 1 limit of continuous power.

As an example: an SDH system using a booster amplifier with output power of +16 dBm (Hazard Level 1M or previously 3A), will still be 1M when using ALS. Thus the Hazard Level will not be lower when using ALS, in this case.

Another more specific example is for application codes U-16.2 and V-64.2b in ITU-T Rec. G.691, where the transmitter output power range is specified as +12 to +15 dBm. This is Hazard Level 1M with AND without ALS.

However, in the case of single-channel systems with high operational power levels (up to the Class 3B limit), using the ALS procedure can result in a reduced Hazard Level of 1M (provided the requirements in IEC 60825-2 on shutdown and restart are met).

III.2 Single-channel point-to-point SDH without line amplifiers

In this clause, an Automatic Laser Shutdown and restart (ALS) procedure for single-channel SDH systems is described which was originally designed to support optical safety requirements on transversely compatible SDH optical interfaces. Accommodation of this procedure, in the case of the additional presence of optical line amplifiers, is described in clause III.3.

NOTE 1 – As mentioned in clause III.1, a lower Hazard Level is generally not achieved because of the full operational power within a restart pulse. The exact Hazard Level, when using ALS, depends on the maximum power exiting the transmitter, the transmitter wavelength and some other parameters.

This ALS procedure consists of 2 parts, a shutdown and a restart part. "Complete" shutdown is used to trigger LOS in the relevant receivers. In particular, the definition of the restart part is critical in the case of transversely compatible interfaces (two different equipment vendors at the ends of the link). In the ALS procedure, a regularly transmitted, short restart pulse at full operational optical power is used to check whether the link has been repaired. Full operational power is required to clear LOS defects in the relevant receivers.

NOTE 2 – The ALS procedure specified in this clause, in particular the associated time constants, is designed to operate correctly only if no additional equipment is present between MPI-S and MPI-R (see Figure III.2).

In its most general sense, an SDH single channel system can consist of 2 terminals (East and West) and a chain of several regenerators, as shown in Figure III.1. The optical interfaces between these terminals and regenerators are supposed to be compliant with ITU-T Rec. G.957. Furthermore, optical boosters and preamplifiers might be present to enhance the power budgets on these interfaces.

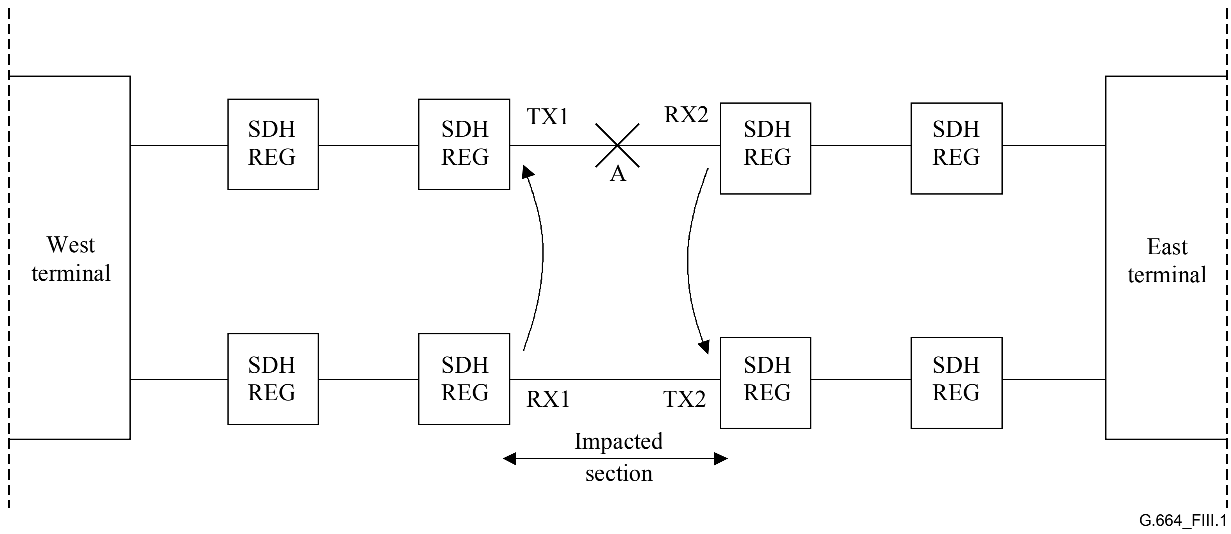


Figure III.1/G.664 – Clarification of ALS operation in the case of a cable break in a chain of SDH regenerators

The reference configuration for a single section from this configuration is shown in Figure III.2.

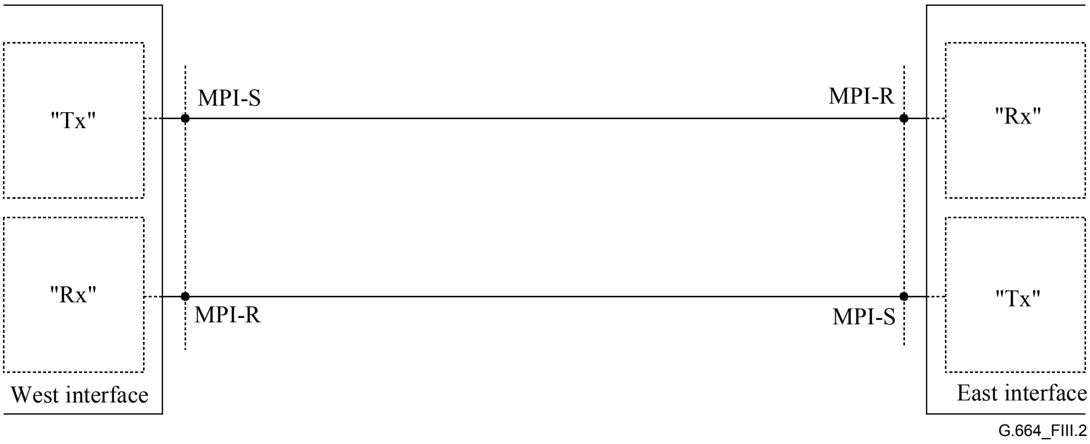


Figure III.2/G.664 – Reference configuration for description of ALS capability

In Figure III.2, "Tx" can be either a transmitter according to ITU-T Rec. G.957 (specified at reference point S) or it may include optical amplification to increase the output power (i.e., OAT or BA in combination with suitable adaptation of equipment according to ITU-T Rec. G.957). Furthermore, "Rx" can be either a receiver according to ITU-T Rec. G.957 (specified at reference point R) or it may include optical preamplification (i.e., OAR or PA used in combination with a suitable adaptation of equipment according to ITU-T Rec. G.957). The "West" and "East" Interfaces may be part of terminal equipment or of electrical regenerators.

In the case that a cable break happens at point A of Figure III.1, the consecutive Loss of Signal defect (dLOS) at "conventional" receiver RX_2 is used to shutdown the output of "conventional" transmitter TX_2, which is the adjacent transmitter in the opposite direction. This in turn leads to dLOS in "conventional" receiver RX_1, which in its turn shuts down "conventional" transmitter TX_1. After shutdown the output power of the transmitter shall be sufficiently low to generate dLOS at the receiver side. The definition of LOS is given in ITU-T Rec. G.783. In all cases, only the impacted section may be shutdown, which is clarified in Figure III.1.

After at least 500 ms of continuous presence of the LOS defect, the actual shutdown command will be activated which shall result in reduction of the optical output power at MPI-S within 800 ms from the moment loss of optical signal occurs at MPI-R.

NOTE 3 – The complete shutdown of the "conventional" transmitters is not required by IEC 60825-2, but is necessary in this case, because otherwise LOS might not be detected in the "conventional" receiver. The remaining output power of the involved optical amplifiers after shutdown of the "conventional" transmitters shall be within Hazard Level 1M for equipment in restricted locations, noting that this does not exclude reduction to within Hazard Level 1 (including the possibility of complete shutdown).

It is assumed that the optical boosters operate in a master/slave configuration, i.e., when the input signal vanishes, the output should be shut down, and when the input signal returns, the output power should be restored. It will not be necessary to shutdown the output of the preamplifier in the case that it is within Hazard Level 1 or 1M under reasonable foreseeable conditions as clarified in IEC 60825-2.

Figure III.3 shows a conceptual diagram of the automatic laser shutdown and restart procedure, for which it should be noted that this figure is not intended to be a state diagram. A clarification of the associated shutdown timing requirements is shown in Figure III.4.

NOTE 4 – If automatic laser shutdown is implemented, it should not impair fault sectionalization capability in the case of loss of signal at the transmitter or the receiver due to causes other than a cable break.

When the connection in the cable has been repaired, either an automatic or a manual restart according to Figure III.3, at TX_1 or TX_2, is necessary to restore transmission. The principle for the restart of a shutdown system is the use of a restart pulse, which shall be within Hazard Level 1M (not excluding Hazard Level 1) to minimize risk of exposure to hazardous power levels.

NOTE 5 – It is not implied by this text that both an automatic and a manual restart be implemented simultaneously.

NOTE 6 – In Figure III.3 the minimum delay between the restart pulses is specified to be 100 s, but in order to have backwards compatibility with no longer existing Recommendations, a minimum delay of 60 s can be used, if the optical power within the restart pulse is 3 dB lower than allowed for the 100 s minimum delay time. IEC 60825 requires that within a 100 s period the total energy of all pulses has to be accounted for to calculate the Hazard Level.

The activation response time of the "transmitter"/"receiver" combination (as shown in Figure III.1), measured from "receiver" input (point MPI-R) to transmitter output (point MPI-S) should be less than 0.85 s. This response time of 0.85 s refers to the time difference between the moment light enters the "receiver" at point MPI-R and the moment the "transmitter" starts light emitting at point MPI-S in the case that the "transmitter" is in the shutdown condition. The optical amplifiers shall restart sufficiently slow (within the above-mentioned activation response time) to avoid, as much as possible, optical surges.

The maximum deactivation time of booster and preamplifiers shall be 100 ms. A booster and preamplifier shall have a maximum activation time of 100 ms and 300 ms respectively.

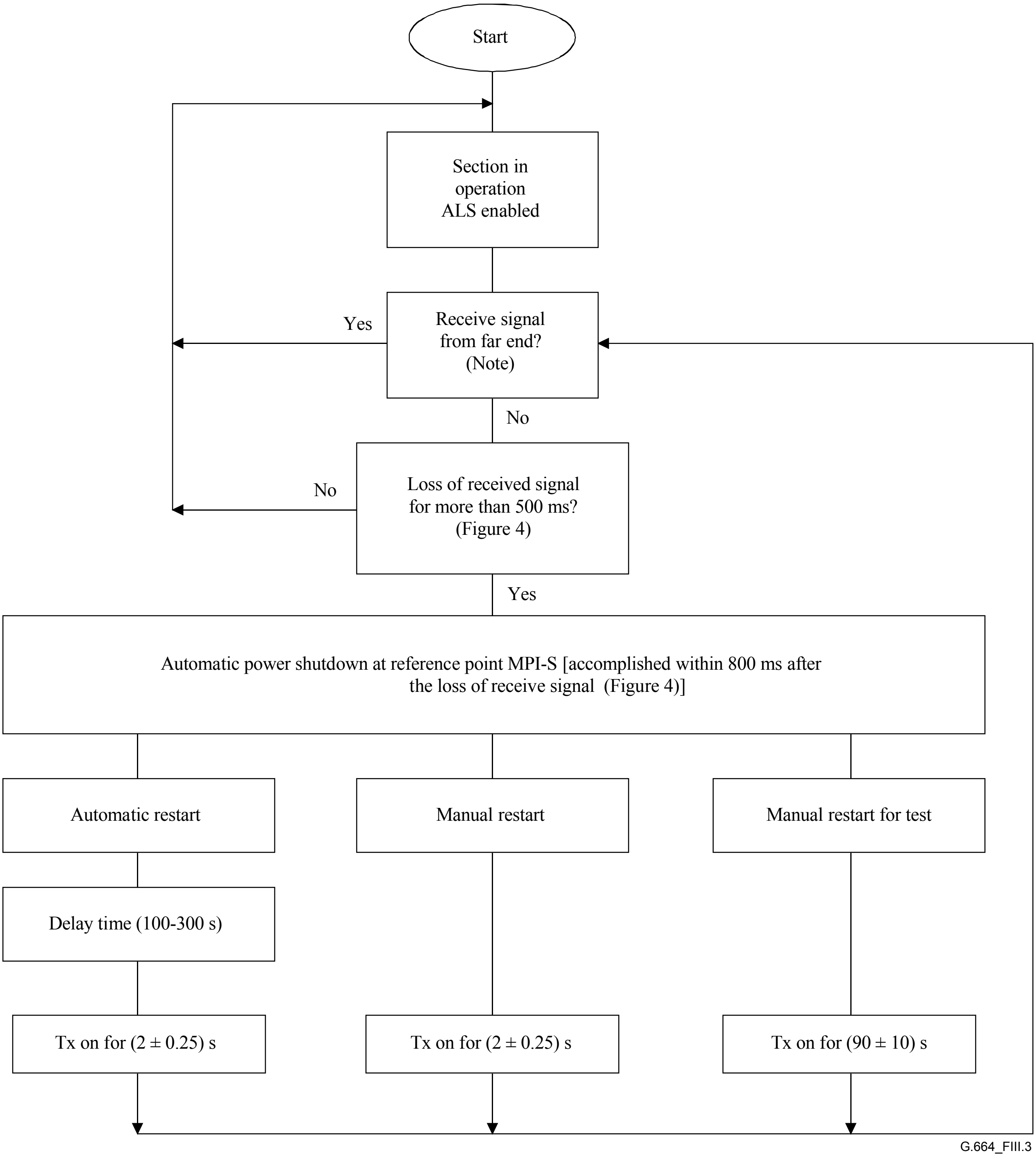
The various time constants are summarized in Table III.1.

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

NOTE 7 – During "manual restart for test" specific care must be taken to assure connectivity to avoid exposure to Hazardous optical levels, particularly in the case of Hazard Level 3B for equipment in restricted locations. Furthermore, to avoid accidental overexposure, it is recommended to use a sufficient delay, e.g., 100 s, between individual manual restart pulses.

"Manual restart" or "Manual restart for test" can only be activated when the laser is shut down.

In the case that protection switching in the electrical domain (e.g., MSP or MSSPRING) is implemented, a working channel receiver should shut down a working channel transmitter. Similarly, a protection channel receiver should shut down a protection channel transmitter.



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

Figure III.3/G.664 – Automatic laser shutdown and restart concept including optional test procedure

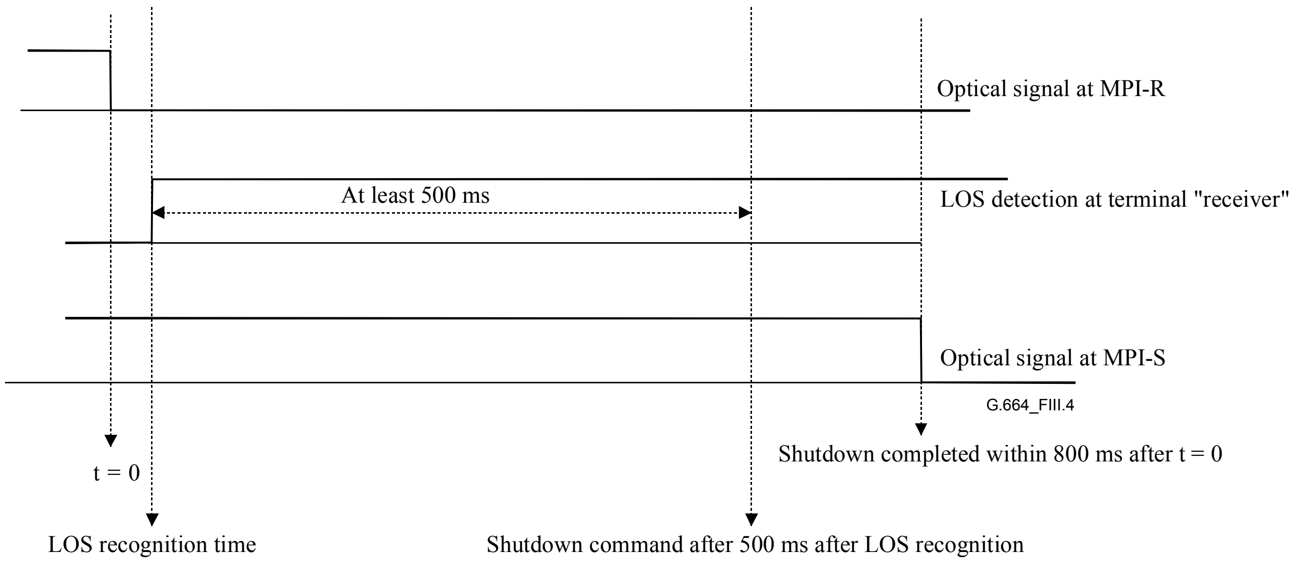


Figure III.4/G.664 – Clarification of shutdown timing requirements

Table III.1/G.664 – Time constants for automatic shutdown

Time constant	Reference points	Value	Note
Terminal response activation time	MPI-R to MPI-S	850 ms max.	
Terminal deactivation time	MPI-R to MPI-S	(500-800) ms	1
BA deactivation time	R' to MPI-S	100 ms max	
BA activation time	R' to MPI-S	100 ms max	2
PA deactivation time	MPI-R to S'	100 ms max	2
PA activation time	MPI-R to S'	300 ms max	2
Pulse length for manual and automatic restart	N/A	(1.75-2.25) s	
Pulse repetition time for automatic restart	N/A	(100-300) s	
NOTE 1 – The LOS condition applies even in the presence of ASE. NOTE 2 – Reference points S' and R' are specified in ITU-T Rec. G.662.			

III.3 Single-channel point-to-point SDH with line amplifiers

In some specific cases of single-channel point-to-point SDH systems, optical line amplifiers are inserted between conventional SDH terminals and regenerators (in addition to the insertion of boosters and preamplifiers) in order to further increase the physical distance between these terminals and regenerators. The reference configuration for this application is shown in Figure III.5. Also, in this case, the line amplifiers should act in a master/slave configuration, as already clarified in clause III.2.

Because of backwards compatibility with no longer existing Recommendations, the techniques described in this clause are allowed to enable safer working conditions on SDH systems with optical line amplifiers with operational output powers of Hazard Level 3B in the case of restricted locations.

When a cable break occurs at some point between MPI-S and MPI-R (see Figure III.5) not only the impacted section will be shut down, but all sections between MPI-S and MPI-R. The line amplifiers do have their specific activation and deactivation response times (e.g., a maximum activation time of 300 ms and deactivation time of 100 ms). Therefore, the shutdown and restart time constants, as specified under 6.2 are not sufficiently long to ensure proper functioning of the ALS procedure.

In order to avoid exposure to hazardous optical power levels, all amplifiers (boosters and line amplifiers) shall have sufficiently short deactivation times to accommodate shutdown of all amplifiers between MPI-S and MPI-R within 3 s from the moment the actual connection interruption occurs.

NOTE 1 – depending on the actual operational power the 3 s shutdown time (defined in the past) might not be fast enough. A check against IEC 60825-1 is recommended.

In order to allow automatic restart of SDH systems with line amplifiers, which are in shutdown condition, it may be necessary to increase the restart pulse length (defined in clause III.2) beyond the maximum of 2.25 s (to e.g., 9 ± 0.5 s), the actual value depending on the number of line amplifiers present. The definition of the revised restart pulse length, depending upon the actual number and output power of inserted line amplifiers, is considered outside the scope of this Recommendation. This restart pulse shall be of Hazard Level 1M in the case of restricted locations.

NOTE 2 – The actual power level to ensure Hazard Level 1M depends on the length of the restart pulse, i.e., shorter restart pulses can have a higher power level than longer pulses.

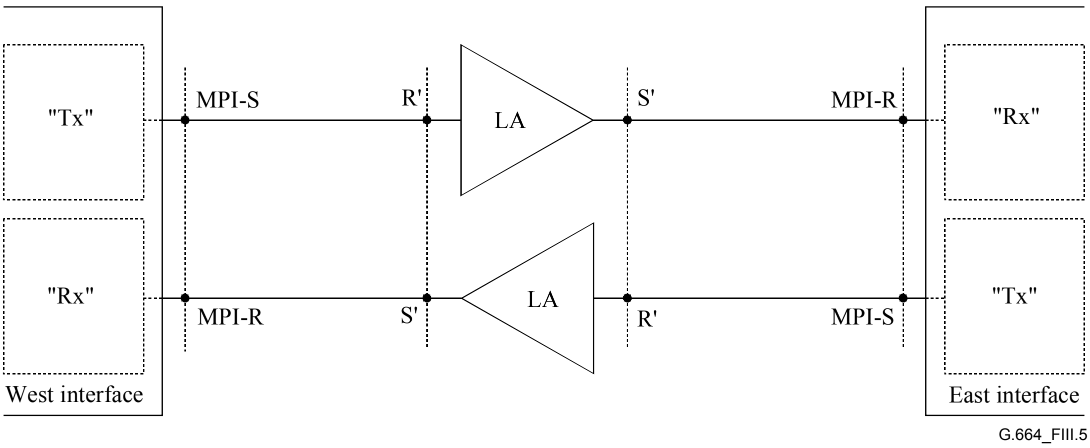


Figure III.5/G.664 – Reference configuration for description of ALS capability in the case that line amplifiers are present

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