International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.973.1
(11/2009)

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

Digital sections and digital line system – Optical fibre submarine cable systems

Longitudinally compatible DWDM applications for repeaterless optical fibre submarine cable systems

Recommendation ITU-T G.973.1

ITU-T

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	G.100–G.199
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	G.200–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	G.300–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	G.400–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	G.450–G.499
TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS	G.600–G.699
DIGITAL TERMINAL EQUIPMENTS	G.700–G.799
DIGITAL NETWORKS	G.800–G.899
DIGITAL SECTIONS AND DIGITAL LINE SYSTEM	G.900–G.999
General	G.900–G.909
Parameters for optical fibre cable systems	G.910–G.919
Digital sections at hierarchical bit rates based on a bit rate of 2048 kbit/s	G.920–G.929
Digital line transmission systems on cable at non-hierarchical bit rates	G.930–G.939
Digital line systems provided by FDM transmission bearers	G.940–G.949
Digital line systems	G.950–G.959
Digital section and digital transmission systems for customer access to ISDN	G.960–G.969
Optical fibre submarine cable systems	**G.970–G.979**
Optical line systems for local and access networks	G.980–G.989
Access networks	G.990–G.999
MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS	G.1000–G.1999
TRANSMISSION MEDIA CHARACTERISTICS	G.6000–G.6999
DATA OVER TRANSPORT – GENERIC ASPECTS	G.7000–G.7999
PACKET OVER TRANSPORT ASPECTS	G.8000–G.8999
ACCESS NETWORKS	G.9000–G.9999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T G.973.1

Longitudinally compatible DWDM applications for repeaterless optical fibre submarine cable systems

Summary

Recommendation ITU-T G.973.1 provides physical layer specifications for dense wavelength division multiplexing (DWDM) applications for repeaterless optical fibre submarine cable systems. Longitudinally compatible applications for DWDM applications for repeaterless optical fibre submarine cable systems are described for point-to-point, multichannel line systems without remotely pumped optical amplifiers. The primary purpose is to enable multiple vendors to design DWDM transmission equipment for submarine fibre links that are compliant with this Recommendation.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.973.1	2009-11-13	15

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). 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.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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 not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

CONTENTS

Recommendation ITU-T G.973.1

Longitudinally compatible DWDM applications for repeaterless optical fibre submarine cable systems

1 Scope

This Recommendation provides physical layer specifications for dense wavelength division multiplexing (DWDM) applications in point-to-point repeaterless optical fibre submarine cable systems. The goal is to enable longitudinally compatible applications.

The primary purpose is to enable multiple vendors to provide transmission equipment for submarine fibre links that are compliant with this Recommendation.

This Recommendation includes a generic reference model for the physical layer applications. The specifications take into account parameters such as maximum attenuation, fibre types, wavelength ranges, maximum chromatic dispersion, minimum local chromatic dispersion coefficient, maximum differential group delay, and minimum effective area.

This Recommendation focuses on repeaterless optical fibre submarine cable systems without remotely pumped optical amplifiers.

This Recommendation presumes that the optical tributary signals transported within optical channels are digital.

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 G.650.2] Recommendation ITU-T G.650.2 (2007), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

[ITU-T G.652] Recommendation ITU-T G.652 (2009), *Characteristics of a single-mode optical fibre and cable*.

[ITU-T G.653] Recommendation ITU-T G.653 (2006), *Characteristics of a dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.654] Recommendation ITU-T G.654 (2006), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.

[ITU-T G.655] Recommendation ITU-T G.655 (2009), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.656] Recommendation ITU-T G.656 (2006), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.959.1] Recommendation ITU-T G.959.1 (2009), *Optical transport network physical layer interfaces*.

[ITU-T G.978] Recommendation ITU-T G.978 (2006), *Characteristics of optical fibre submarine cables*.

3 Terms and definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 The following term is defined in [ITU-T G.650.2]:

– polarization mode dispersion (PMD)

3.1.2 The following term is defined in [b-ITU-T G.696.1]:

– client class

3.1.3 The following term is defined in [b-ITU-T G.709]:

– optical transport hierarchy (OTH)

3.1.4 The following term is defined in [b-ITU-T G.780]:

– synchronous digital hierarchy (SDH)

3.1.5 The following terms are defined in [b-ITU-T G.972]:

– dense wavelength division multiplexing (DWDM)
– dense wavelength division multiplexing system (DWDMS)
– wavelength division multiplexing (WDM)

3.1.6 The following terms are defined in [ITU-T G.959.1]:

– multichannel receive main path interface reference point (MPI-R_M)
– multichannel source main path interface reference point (MPI-S_M)

3.1.7 The following term is defined in [b-ITU-T G-Sup.40]:

– dispersion compensating single-mode fibre (DCF)

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

A_{eff}	Effective area
CSF	Cut-off Shifted single-mode Fibre
DCF	Dispersion Compensating single-mode Fibre
DGD	Differential Group Delay
DSF	Dispersion Shifted single-mode Fibre
DWDM	Dense Wavelength Division Multiplexing
DWDMS	Dense Wavelength Division Multiplexing System
FWM	Four-Wave Mixing
LEF	Large Effective area single-mode Fibre
MPI	Main Path Interface
MUX	Multiplexer
NDF	Negative Dispersion single-mode Fibre
NRZ	Non-Return to Zero
NZDSF	Non-Zero Dispersion Shifted single-mode Fibre
OA	Optical Amplifier

OTH	Optical Transport Hierarchy
PMD	Polarization Mode Dispersion
RZ	Return to Zero
SDH	Synchronous Digital Hierarchy
TTE	Terminal Transmission Equipment
WDMS	Wavelength Division Multiplexing System
WNZDF	Wideband Non-Zero Dispersion single-mode Fibre

5 Conventions

This clause is intentionally left blank.

6 Classification of optical interfaces

6.1 Applications

This Recommendation addresses longitudinally compatible DWDM application in point-to-point repeaterless optical fibre submarine cable system.

6.2 Reference configurations

For the purpose of this Recommendation, the relevant reference points applicable to the DWDM application for point-to-point repeaterless optical fibre submarine cable systems are shown in Figure 6-1.

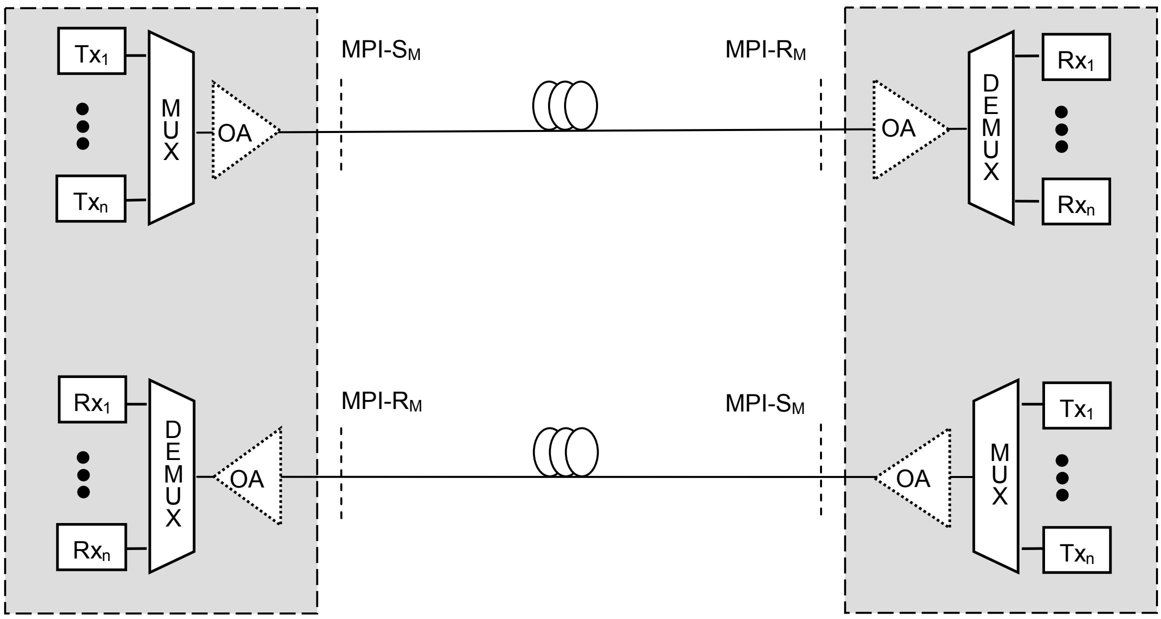

Figure 6-1 – Reference configuration for DWDM system

The reference points MPI-S_M and MPI-R_M in Figure 6-1 are defined as follows, using the same nomenclature as in [ITU-T G.959.1]:

– MPI-S_M is a (multichannel) reference point on the optical fibre just after the optical network element transport interface output optical connector;

– MPI-R_M is a (multichannel) reference point on the optical fibre just before the optical network element transport interface input optical connector.

7 Single-span longitudinal compatibility

The applications covered by this Recommendation are single-span longitudinally compatible. It is defined as follows.

The systems are defined to be "longitudinally compatible" when both ends of an optical section are terminated by equipment from the same manufacturer. Systems from different vendors can be installed on the various optical fibres of the cable. In this case only the cable characteristics (attenuation, dispersion, DGD) are specified. A single-span longitudinally compatible system is illustrated in Figure 7-1.

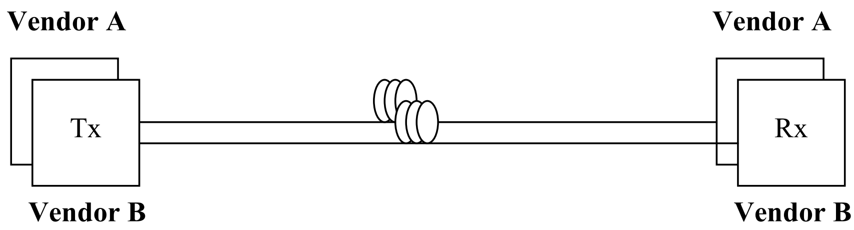

Figure 7-1 – Single-span longitudinal compatibility

NOTE – For multi-span systems, longitudinal compatibility is so far impossible to achieve because all fibre pairs make use of the same repeaters. It means that each amplifier module of each fibre is located into the same repeater housing which is supplied by one single vendor. The same applies for the other equipment of the wet plant (e.g., equalizers, branching units).

8 Parameters

8.1 Maximum attenuation

The maximum attenuation from MPI-S_M to MPI-R_M is specified for an operating wavelength region, which include loss caused by splices, connectors, optical attenuators and other passive optical devices (if used) as well as fibre loss.

The maximum attenuation coefficient of each G.652, G.653, G.654, G.655 and G.656 fibre is specified in the corresponding ITU-T Recommendations. In these Recommendations, the maximum attenuation coefficients at 1550 nm of cabled fibres are specified in the 0.22 to 0.4 dB/km range. It should be noted that a submarine transmission system sometimes requires smaller attenuation value.

The typical maximum attenuation value is for further study.

8.2 Fibre types

In submarine systems, several types of optical fibres are used to construct an optical path. These include the following:

- single-mode fibres defined in ITU-T Recommendations:
  - non-dispersion shifted single-mode fibre (SMF) defined in [ITU-T G.652];
  - dispersion shifted single-mode fibre (DSF) defined in [ITU-T G.653];
  - cut-off shifted single-mode fibre (CSF) defined in [ITU-T G.654];
  - non-zero dispersion-shifted single-mode fibre (NZDSF) defined in [ITU-T G.655];
  - wideband non-zero dispersion single-mode fibre (WNZDF) defined in [ITU-T G.656];

- positive dispersion single-mode fibre (PDF);
- negative dispersion single-mode-fibre (NDF);
- large effective area single-mode fibre (LEF);
- dispersion compensating single-mode fibre (DCF).

Depending on the system specifications, various combinations of these fibre types may be used to ensure that the system performs correctly. Further information about each type of fibre can be found in [ITU-T G.978].

8.3 Wavelength ranges

The operating wavelength range consists of one or more of the wavelength bands, as defined in [b-ITU-T G-Sup.41]. See Table 8-1.

Table 8-1 – Wavelength ranges

S	Descriptor	Range (nm)
O	Original	1260 to 1360
E	Extended	1360 to 1460
S	Short wavelength	1460 to 1530
C	Conventional	1530 to 1565
L	Long wavelength	1565 to 1625

8.4 Maximum chromatic dispersion

This parameter defines the maximum value of the optical path chromatic dispersion from MPI-S_M to MPI-R_M in the operating wavelength region. The chromatic dispersion of optical path must be held within certain limits to ensure acceptable system operation, which is expressed in ps/nm. Chromatic dispersion can be calculated as the product of the chromatic dispersion coefficient of each fibre (ps/nm·km) and its length (km). It is noted that, for submarine systems, the optical path could consist of several types of fibres with different chromatic dispersion coefficients.

The chromatic dispersion coefficient of each G.652, G.653, G.654, G.655 and G.656 fibre is specified in the corresponding ITU-T Recommendations.

Further information regarding chromatic dispersion impairment can be found in [b-ITU-T G-Sup.39].

8.5 Minimum local chromatic dispersion coefficient

The chromatic dispersion value of an optical path must be held at an acceptable system tolerance value. On the other hand, for DWDM systems, the local dispersion coefficient of the transmission fibre must have a minimum value to avoid the impairment caused by non-linear effects such as four-wave mixing (FWM) and cross-phase modulation (XPM). These non-linear effects in a fibre are strong when the chromatic dispersion coefficient at the operating wavelength region is close to zero and they induce degradation in the transmission performance. The impairment caused by non-linear effects depends on many aspects of system design such as the channel spacing, power level and path length. In general, DWDM systems with narrow channel spacing, high power level and long path length are more likely to suffer from these effects. In such systems, it is especially required to take particular care over the minimum value of the local chromatic dispersion coefficient to prevent the occurrence of non-linear effects.

Further information regarding non-linear effects can be found in [b-ITU-T G.663], and [b-ITU-T G-Sup.39].

8.6 Maximum differential group delay

The maximum differential group delay (DGD) applies to the whole link between a transmitter (shown as "T_X" connected to a MUX in Figure 6-1) and the corresponding receiver ("R_X" connected to the DEMUX in Figure 6-1).

The equation below can be used to calculate the maximum DGD of a link (containing multiple components and fibre sections) with a defined probability of being exceeded.

$$DGD\max_{link} = \left[DGD\max_F^2 + S^2 \sum_i PMD_{Ci}^2 \right]^{1/2}$$

where:

$DGD\max_{link}$: is the maximum link DGD (ps);

$DGD\max_F$: is the maximum concatenated optical fibre cable DGD (ps);

S: is Maxwell adjustment factor (see Table 8-2);

PMD_{Ci}: is PMD value of the ith component (ps).

This equation assumes that the statistics of the instantaneous DGD are approximated by a Maxwell distribution, with the probability of the instantaneous DGD exceeding $DGD\max_{link}$ being controlled by the value of the Maxwell adjustment factor taken from Table 8-2.

Table 8-2 – S values and probabilities

Ratio of max. to mean (S)	Probability of exceeding max.	Ratio of max. to mean (S)	Probability of exceeding max.
3	4.2×10^{-5}	4	7.4×10^{-9}
3.2	9.2×10^{-6}	4.2	9.6×10^{-10}
3.4	1.8×10^{-6}	4.4	1.1×10^{-10}
3.6	3.2×10^{-7}	4.6	1.2×10^{-11}
3.8	5.1×10^{-8}		

Further details can be found in [ITU-T G.650.2] and in [b-ITU-T G.691]. The value of $DGD\max_F$ (the maximum DGD due to the fibre part) can either be measured or, alternatively, an upper limit can be calculated for a given fibre length using the PMD_Q coefficient in the corresponding fibre Recommendation.

The DGD limits for the entire link are given in Table 8-3 for NRZ systems and in Table 8-4 for RZ systems.

Table 8-3 – Maximum link differential group delay for NRZ

Client class	Units	Value
2.5G	ps	120
10G	ps	30
40G	ps	7.5

Table 8-4 – Maximum link differential group delay for RZ

Client class	Units	Value
2.5G	ps	ffs
10G	ps	ffs
40G	ps	ffs

8.7 Minimum effective area

Effective area is a parameter that is closely related to optical fibre non-linear effects and will affect the transmission quality of optical fibre systems. In submarine systems, large effective area single-mode fibre (LEF) could be used to reduce such non-linear effects. When adopting LEF, the minimum effective area of the fibre should be specified.

The method for measuring the effective area A_{eff} in a single-mode fibre is described in [ITU-T G.650.2].

9 Characteristics and performance of the system

9.1 System reliability performance

The reliability of the submarine portion of an optical fibre submarine cable system is generally characterized by:

– The expected number of repairs requiring intervention by a cableship and due to system component (e.g., splices, transitions, etc.) failures during the system design life:

  The usual requirement for the reliability of a repeaterless system is less than one failure requiring cableship intervention during the system design life.

– The system design life:

  The period of time over which the optical fibre submarine cable system is designed to be operational in conformance with its performance specification. Usually, the system design life is a period of 25 years starting at the provisional acceptance date of the system, i.e., the date following installation when the system is claimed to be compliant with the performance specifications.

9.2 System capacity upgrading

It may be advantageous to increase the transmission capacity by increasing the signal bit rate and/or the number of transmission channels (WDMS or DWDMS). Such upgrading can be beneficial because the reuse of cables can be achieved cost-effectively over the equipment's long life, typically 25 years.

Bit-rate upgradeability demands that systems be constructed with cables optimized for the higher bit rate, while the lower bit-rate TTE may be initially used. Even after upgrading, the bit rate of TTE output must comply with SDH or OTH specifications to ensure compatibility with standard terrestrial equipment.

Upgradeability also demands that the initially installed cable be capable of carrying the maximum number of channels expected in the future. Upgrading by increasing signal bit rate or by adding more channels is much different from many viewpoints of system design including the post-amplifier output power, pre-amplifier input power, power budget, signal-to-noise ratio, fibre chromatic dispersion, and fibre non-linearities. It is therefore recommended that the systems be designed properly considering the possibility of future upgrades.

10 Characteristics and performance of the submarine cable

The recommended characteristics and performance of the submarine cable are given in [ITU-T G.978].

11 Optical safety considerations

While this Recommendation relates to the fibre infrastructure and does not specify the characteristics of the optical transmission systems operating over it, such systems may well operate at relatively high optical power levels. Information on optical safety considerations can be found in [b-ITU-T G.664], [b-IEC 60825-1], and [b-IEC 60825-2].

Bibliography

[b-ITU-T G.663] Recommendation ITU-T G.663 (2000), *Application related aspects of optical amplifier devices and subsystems*.

[b-ITU-T G.664] Recommendation ITU-T G.664 (2006), *Optical safety procedures and requirements for optical transport systems*.

[b-ITU-T G.691] Recommendation ITU-T G.691 (2006), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers*.

[b-ITU-T G.696.1] Recommendation ITU-T G.696.1 (2005), *Longitudinally compatible intra-domain DWDM applications*.

[b-ITU-T G.707] Recommendation ITU-T G.707/Y.1322 (2007), *Network node interface for the synchronous digital hierarchy (SDH)*.

[b-ITU-T G.709] Recommendation ITU-T G.709/Y.1331 (2003), *Interfaces for the Optical Transport Network (OTN)*.

[b-ITU-T G.780] Recommendation ITU-T G.780/Y.1351 (2008), *Terms and definitions for synchronous digital hierarchy (SDH) networks*.

[b-ITU-T G.972] Recommendation ITU-T G.972 (2008), *Definition of terms relevant to optical fibre submarine cable systems*.

[b-ITU-T G.973] Recommendation ITU-T G.973 (2007), *Characteristics of repeaterless optical fibre submarine cable systems*.

[b-ITU-T G-Sup.39] ITU-T G-series Recommendations – Supplement 39 (2008), *Optical system design and engineering considerations*.

[b-ITU-T G-Sup.40] ITU-T G-series Recommendations – Supplement 40 (2006), *Optical fibre and cable Recommendations and standards guideline*.

[b-ITU-T G-Sup.41] ITU-T G-series Recommendations – Supplement 41 (2007), *Design guidelines for optical fibre submarine cable systems*.

[b-IEC 60825-1] IEC 60825-1 (2007), *Safety of laser products – Part 1: Equipment classification and requirements*.

[b-IEC 60825-2] IEC 60825-2 (2007), *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	**Transmission systems and media, digital systems and networks**
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2010