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

Optical fibre and cable Recommendations and standards guideline

ITU-T G-series Recommendations – Supplement 40

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Supplement 40 to ITU-T G-series Recommendations

Optical fibre and cable Recommendations and standards guideline

Summary

Supplement 40 to the ITU-T G-series Recommendations provides information on the background and specifications used in the development of optical fibre and cable ITU-T Recommendations such as Recommendations ITU-T G.651.1, ITU-T G.652, ITU-T G.653, ITU-T G.654, ITU-T G.655, ITU-T G.656, ITU-T G.657 and L series Recommendations. It also contains information used in the development of test method Recommendations such as Recommendations ITU-T G.650.1, ITU-T G.650.2 and ITU-T G.650.3. Moreover, this Supplement maps ITU-T documents to optical fibre and cable standards developed under IEC.

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FOREWORD

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Optical fibre and cable Recommendations and standards guideline

1 Scope

This fibre guideline aims at providing a road map with regard to the specifications of various kinds of fibres and their test methods, as well as the most important fibre optics hardware which will be very useful for engineers reading the ITU-T Recommendations and other documents to design an optical fibre network. This guideline should also make it easier for readers to correlate the specifications found in the fibre, terrestrial system interface, components, submarine systems and physical infrastructure Recommendations currently being developed in ITU-T. Moreover, this guideline provides important information for system designs and optical fibre cable installations in relation to, for example, high power limitations and reliability, which is available to optical fibre cable installation suppliers and system designers. This guideline contains:

– Definitions of fibre parameters not specified in current ITU-T fibre Recommendations but which are very important for practical use.

– Features of existing optical fibre categories and their application areas.

– The relationship between fibre parameters and interface parameters.

– Optical fibre properties for operation and maintenance.

In the appendices, the following items are described for reference:

– Standardization criteria for optical fibres in ITU-T Study Group 15.

– Optical fibre cable structures and constructions.

– Fibre optics hardware and passive components mostly used in the construction of an optical network.

– Comparison of ITU-T Recommendations and IEC documents related to optical fibre specifications and test methods.

In particular, this guideline is prepared concisely by quoting document numbers so as to avoid any overlap with existing ITU-T Recommendations and Handbooks or IEC documents. This guideline would be a very useful desk book for engineers dealing with optical transmission systems.

2 References

[ITU-T G.650.1] Recommendation ITU-T G.650.1 (2018), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[ITU-T G.650.2] Recommendation ITU-T G.650.2 (2015), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

[ITU-T G.650.3] Recommendation ITU-T G.650.3 (2017), *Test methods for installed single-mode optical fibre cable links*.

[ITU-T G.651.1] Recommendation ITU-T G.651.1 (2018), *Characteristics of a 50/125 μm multimode graded index optical fibre cable for the optical access network.*

[ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable.*

[ITU-T G.653] Recommendation ITU-T G.653 (2010), *Characteristics of a dispersion-shifted single-mode optical fibre and cable*.

[ITU-T G.654] Recommendation ITU-T G.654 (2016), *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 (2010), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*.

[ITU-T G.663] Recommendation ITU-T G.663 (2016), *Application related aspects of optical amplifier devices and subsystems*.

[ITU-T G.664] Recommendation ITU-T G.664 (2014), *Optical safety procedures and requirements for optical transport systems*.

[ITU-T G.695] Recommendation ITU-T G.695 (2018), *Optical interfaces for coarse wavelength division multiplexing applications*.

[ITU-T G-Sup.39] ITU-T G-series Recommendations – Supplement 39 (2016), *Optical system design and engineering considerations*.

[ITU-T G-Sup.47] ITU-T G-series Recommendations – Supplement 47 (2012), *General aspects of optical fibre and cable*.

[ITU-T G-Sup.59] ITU-T G-series Recommendations – Supplement 59 (2018), *Guidance on optical fibre and cable reliability*.

[ITU-T L.105/L.87] Recommendation ITU-T L.105/L.87 (2010), *Optical fibre cables for drop applications*.

[ITU-T L.125/L.14] Recommendation ITU-T L.125/L.14 (1992), *Measurement method to determine the tensile performance of optical fibre cables under load*.

[ITU-T L.126/L.27] Recommendation ITU-T L.126/L.27 (1996), *Method for estimating the concentration of hydrogen in optical fibre cables*.

[ITU-T L.161/L.46] Recommendation ITU-T L.161/L.46 (2000), *Protection of telecommunication cables and plant from biological attack.*

[ITU-T L.256/L.45] Recommendation ITU-T L.256/L.45 (2000), *Minimizing the effect on the environment from the outside plant in telecommunication networks*.

[ITU-T L.300/L.25] Recommendation ITU-T L.300/L.25 (2015), *Optical fibre cable network maintenance*.

[ITU-T L.301/L.41] Recommendation ITU-T L.301/L.41 (2000), *Maintenance wavelength on fibres carrying signals*.

[ITU-T L.302/L.40] Recommendation ITU-T L.302/L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system.*

[ITU-T L.310] Recommendation ITU-T L.310 (2016), *Optical fibre maintenance criteria for access networks*.

[ITU-T L.312/L.68] Recommendation ITU-T L.312/L.68 (2007), *Optical fibre cable maintenance support, monitoring and testing system for optical fibre cable networks carrying high total optical power*.

[ITU-T L.313/L.66] Recommendation ITU-T L.313/L.66 (2007), *Optical fibre cable maintenance criteria for in-service fibre testing in access networks*.

[ITU-T L.340/L.74] Recommendation ITU-T L.320/L.74 (2008), *Maintenance of cable tunnels*.

[ITU-T L.361/L.64] Recommendation ITU-T L.361/L.64 (2012), *ID tag requirements for infrastructure and network elements management*.

[ITU-T L.400/L.12] Recommendation ITU-T L.400/L.12 (2008), *Optical fibre splices*.

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[IEC 60793-1-20] IEC 60793-1-20:2014, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*.

[IEC 60793-1-21] IEC 60793-1-21:2001, *Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry*.

[IEC 60793-1-22] IEC 60793-1-22:2001, *Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement*.

[IEC 60793-1-30] IEC 60793-1-30:2010, *Optical fibres – Part 1-30: Measurement methods and test procedures – Fibre proof test*.

[IEC 60793-1-31] IEC 60793-1-31:2010, *Optical fibres – Part 1-31: Measurement methods and test procedures – Tensile strength*.

[IEC 60793-1-32] IEC 60793-1-32:2018, *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability*.

[IEC 60793-1-33] IEC 60793-1-33:2017, *Optical fibres – Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility*.

[IEC 60793-1-34] IEC 60793-1-34:2006, *Optical fibres – Part 1-34: Measurement methods and test procedures – Fibre curl*.

[IEC 60793-1-40] IEC 60793-1-40:2001, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*.

[IEC 60793-1-41] IEC 60793-1-41:2010, *Optical fibres – Part 1-41: Measurement methods and test procedures – Bandwidth*.

[IEC 60793-1-42] IEC 60793-1-42:2013, *Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion*.

[IEC 60793-1-43] IEC 60793-1-43:2015, *Optical fibres – Part 1-43: Measurement methods and test procedures – Numerical aperture*.

[IEC 60793-1-44] IEC 60793-1-44:2011, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*.

[IEC 60793-1-45] IEC 60793-1-45:2017, *Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter*.

[IEC 60793-1-47] IEC 60793-1-47:2017, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*.

[IEC 60793-1-48] IEC 60793-1-48:2017, *Optical fibres – Part 1-48: Measurement methods and test procedures – Polarization mode dispersion*.

[IEC 60793-1-49] IEC 60793-1-49:2018, *Optical fibres – Part 1-49: Measurement methods and test procedures – Differential mode delay*.

[IEC 60793-1-50] IEC 60793-1-50:2014, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state)*.

[IEC 60793-1-51] IEC 60793-1-51:2014, *Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat*.

[IEC 60793-1-52] IEC 60793-1-52:2014, *Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature*.

[IEC 60793-1-53] IEC 60793-1-53:2014, *Optical fibres – Part 1-53: Measurement methods and test procedures – Water immersion*.

[IEC 60793-1-54] IEC 60793-1-54:2018, *Optical fibres – Part 1-54: Measurement methods and test procedures – Gamma irradiation*.

[IEC 60793-2-10] IEC 60793-2-10:2017, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*.

[IEC 60793-2-50] IEC 60793-2-50:2018, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*.

[IEC 60794.x] IEC 60794.x (in force), *Optical fibre cables*.

[IEC 60825-2] IEC 60825-2:2010, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*.

[IEC TR 61282-3] IEC TR 61282-3:2006, *Fibre optic communication system design guides – Part 3: Calculation of link polarization mode dispersion*.

[IEC TR 61282-7] IEC TR 61282-7:2003, *Fibre optic communication system design guides – Part 7: Statistical calculation of chromatic dispersion*.

[IEC TR 61292-4] IEC TR 61292-4:2013, *Optical amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers*.

[IEC TR 62000] IEC TR 62000:2010, *Single-mode fibre compatibility guidelines*.

[IEC TR 62048] IEC TR 62048:2014, *Optical fibres – Reliability – Power law theory*.

[IEC TR 62221] IEC TR 62221:2012, *Optical fibres – Measurement methods – Microbending sensitivity*.

[IEC TR 62283] IEC TR 62283:2010, *Optical fibres – Guidance for nuclear radiation tests*.

[IEC TR 62284] IEC TR 62284:2003, *Effective area measurements of single-mode optical fibres – Guidance*.

[IEC TR 62285] IEC TR 62285:2005, *Application guide for non-linear coefficient measuring methods*.

[IEC TR 62316] IEC TR 62316:2017, *Guidance for the interpretation of OTDR backscattering traces*.

[IEC TR 62324] IEC TR 62324:2007, *Single-mode optical fibres – Raman gain efficiency measurement using continuous wave method – Guidance*.

[IEC TR 62349] IEC TR 62349:2014, *Guidance for polarization crosstalk measurement of optical fibre*.

[IEC TR 62547] IEC TR 62547:2013, *Guidelines for the measurement of high-power damage sensitivity of single-mode fibres to bends – Guidance for the interpretation of results*.

[IEC TS 62033] IEC TS 62033:2000, *Attenuation uniformity in optical fibres*.

Furthermore, ITU-T L-series Recommendations and IEC documents concerning optical fibre cables and test methods are quoted in Appendix VI. The detailed information is omitted in this clause.

3 Definitions

For the purposes of this supplement, the definitions given in [ITU-T G.650.1] and [ITU-T G.650.2] are used.

4 Abbreviations and acronyms

This supplement uses the following abbreviations and acronyms:

ATM Alternative Test Method

DGD Differential Group Delay

PMD Polarization Mode Dispersion

PMD_Q statistical parameter for link PMD

RTM Reference Test Method

SBS Stimulated Brillouin Scattering

5 Conventions

None.

6 ITU-T G.65x-series Recommendations

Relationships among the various Recommendations and supplements pertaining to optical fibres and cables are shown in Figure 1.

Definitions and test methods of single-mode fibre and cable are described in ITU-T G.650.x series Recommendations. [ITU-T G.650.1] covers definitions and test methods for linear and deterministic parameters. Definitions and test methods for statistical and non-linear related parameters are described in [ITU-T G.650.2]. [ITU-T G.650.3] contains test methods relevant to an installed single-mode fibre cable link.

Characteristics of optical fibres and cables are specified in the ITU-T G.65x-series Recommendations. [ITU-T G.651.1] covers a 50/125 μm multimode fibre and cable for the optical access network. [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656] and [ITU-T G.657] specify the various types of single-mode fibre and cable.

NOTE – Test methods of multimode fibre were described in [ITU-T G.651], but [ITU-T G.651] was deleted in 2008. Test methods of multimode fibre are found in existing IEC documents. See also clause VI.2.

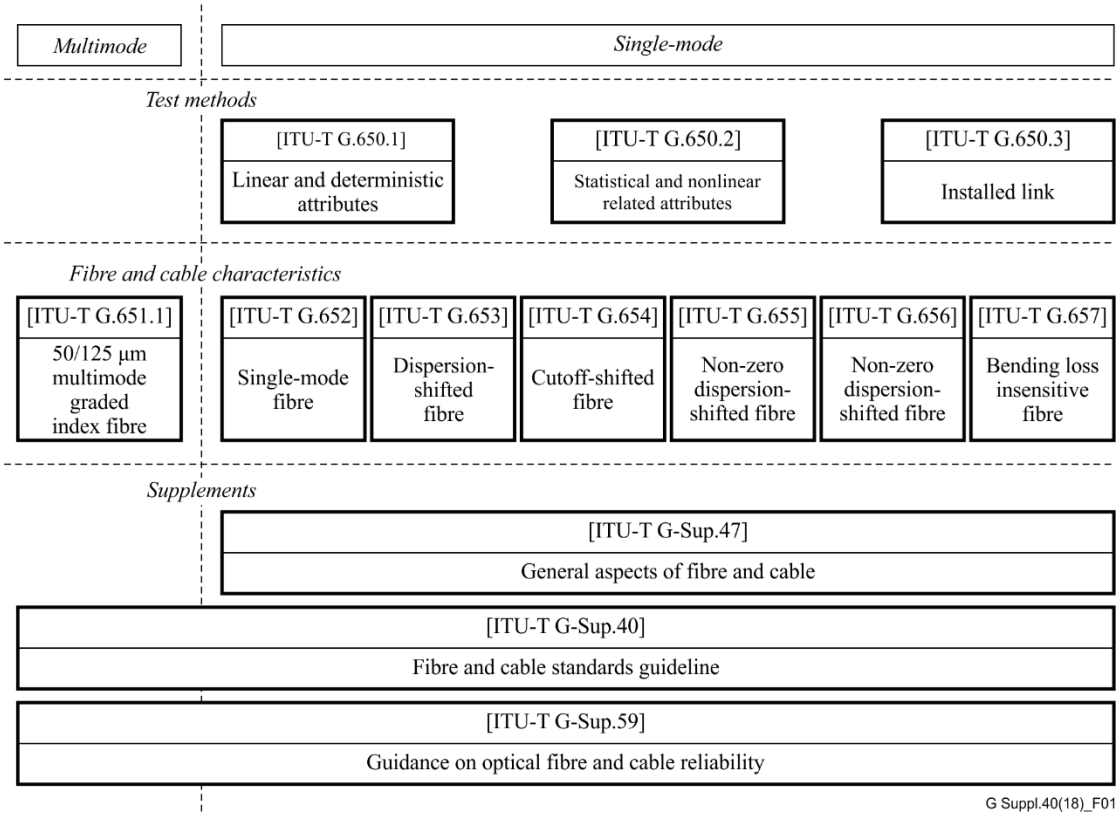

Figure 1 – Relationships amongst Recommendations and supplements related to optical fibres and cables

7 Features of existing optical fibre categories and their application areas

7.1 Attenuation properties

ITU-T G.65x series Recommendations specify the attenuation coefficient for a cabled fibre in order to ensure the interoperability of the optical cable fibre link. A tighter value may be requested for an uncabled fibre to account for additional attenuation in the cabling process.

Typical attenuation spectrum of ITU-T G.652 fibre with and without OH absorption loss is given in Appendix I of [ITU-T G.695]. Attenuation uniformity is given in [IEC TS 62033]. General information on an optical loss related to the fibre material is found in Appendix I of [ITU-T G-Sup.47].

7.2 Dispersion properties

The chromatic dispersion properties of ITU-T G.65x fibres are presented in respective Recommendations. The dispersion properties of [ITU-T G.652] and [ITU-T G.655] fibres are given in clause 10.3 of [ITU-T G-Sup.39]. Statistical calculation of chromatic dispersion is given in [IEC TR 61282-7]. Material dispersion characteristic is given in Appendix I of [ITU-T G-Sup.47].

7.3 Bending properties

The macrobending loss properties of ITU-T G.65x fibres are presented in the respective Recommendations. The macrobending loss property of [ITU-T G.657] fibre is shown in Tables 1 and 2 of [ITU-T G.657]. An effective bending radius of optical drop cable is described in clause 6.2.1 of [ITU-T L.105/L.87]. General aspects on the mechanical reliability of the fibre under bending condition is found in [IEC TR 62048].

8 Relationship between fibre parameters and interface parameters

8.1 Relationship between PMD and DGD

Relationship between PMD_Q and DGD_{max} is given in Appendix I of [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655] and [ITU-T G.656]. The definition of PMD_Q and the calculations of PMD_Q and DGD_{max} are given in Appendix IV of [ITU-T G.650.2]. Relationship between PMD and DGD is given in [IEC TR 61282-3].

8.2 Transmission limitation due to dispersion properties

"Worst-case" and "statistical" transmission limitation due to chromatic dispersion properties is given in clauses 9.2 and 10.3 of [ITU-T G-Sup.39], respectively.

"Worst-case" and "statistical" transmission limitation due to PMD is given in clauses 9.3 and 10.4 of [ITU-T G-Sup.39], respectively.

9 Unspecified fibre parameters and their test methods

The unspecified fibre parameters are defined in Appendix II of [ITU-T G.650.2] and Appendix II of [ITU-T G.663].

9.1 Non-linear coefficient

Information about non-linear coefficient is given in Appendix II of [ITU-T G.650.2] and [IEC TR 62285].

The characteristics of non-linear refractive index related to fibre material are described in Appendix I of [ITU-T G-Sup.47].

9.2 Effective area A_{eff}

Information on effective area is given in Appendix III of [ITU-T G.650.2] and [IEC TR 62284].

9.3 Stimulated Brillouin scattering (SBS) power rating

Information on SBS power rating is given in Appendix II of [ITU-T G.650.2] and Appendix II of [ITU-T G.663].

Fibre length dependence of SBS power rating is informed in clause 6.2 of [ITU-T G-Sup.47].

9.4 Raman gain coefficient

Information on Raman gain coefficient is given in Appendix II of [ITU-T G.663] and [IEC TR 62324].

The Raman gain coefficient related to fibre material is described in Appendix I of [ITU-T G-Sup.47].

9.5 Microbending loss

Measurement methods of microbending loss are given in [IEC TR 62221].

10 Optical fibre properties for operation and maintenance

See [IEC TR 62000].

NOTE – Mismatch of waveguide characteristics (MFD, scattering coefficient, etc.) at a splicing point may lead to apparent gain/loss in the OTDR trace. Detailed information on the interpretation of OTDR traces can be found in [IEC TR 62316].

10.1 Properties of cut-off wavelength under the deployment conditions

The length dependence of cut-off wavelength is given in clause 6.1 of [ITU-T G-Sup.47].

10.2 Properties of chromatic dispersion and PMD

General aspect on temperature dependence of chromatic dispersion is found in clause 5.1 of [ITU-T G-Sup.47].

General aspect on temperature dependence of PMD is found in clause 5.2 of [ITU-T G-Sup.47].

10.3 Splice loss

Information on splice loss is given in [ITU-T L.402/L.36] and [ITU-T L.400/L.12].

10.4 Input power limitation and safety aspects

[ITU-T G.664], [ITU-T L.312/68], [IEC TR 61292-4], [IEC 60825-2] and [IEC TR 62547] describe input power limitation and safety aspects.

10.5 Reliability of optical fibre cable

Reliability issues of optical fibre cable are given in [ITU-T L.125/L.14], [ITU-T L.256/L.45], [ITU-T L.161/L.46], [ITU-T G-Sup.59] and [IEC TR 62048].

10.6 Optical loss properties due to hydrogen

Information on optical loss properties due to hydrogen is given in [ITU-T L.126/L.27] and [IEC 60793-2-50].

10.7 Environmental test conditions for fibres

[IEC 60793-1-50], [IEC 60793-1-51], [IEC 60793-1-52], [IEC 60793-1-53] and [IEC 60793-1-54] describe the environmental test conditions for fibres.

10.8 Optical fibre cable network maintenance

[ITU-T L.300/L.25], [ITU-T L.431/L.29], [ITU-T L.302/L.40], [ITU-T L.301/L.41], [ITU-T L.310], [ITU-T L.361/L.64], [ITU-T L.313/L.66] and [ITU-T L.340/L.74] describe the optical fibre cable network maintenance.

Appendix I

Standardized criteria

I.1 Criteria for revising optical fibre Recommendations

A Recommendation covers a group of fibres which are approximately the same in both of the following respects:

1) Primary wavelength region of intended operation.

2) Chromatic dispersion value in the primary wavelength region of intended operation.

Within each Recommendation, the base category should be described in Table 1, while other categories may be described in subsequent tables, including at least two attribute types (fibre and cable) for each table. A third attribute type (links) remains under study.

The fibre Recommendation may include the main parameters of mode field diameter, cut-off wavelength, and chromatic dispersion. The values of these parameters must be broad enough to encompass all of the fibre categories in the Recommendation.

The base category (for which the Recommendation was originally created, and which serves as the default category) is described in Table 1. Minor changes in the parameter values of Table 1 may be made from time to time to keep Table 1 aligned with current industry practice.

Further categories, typically based on new fibre parameters, may be created, providing they distinguish implementation variations that support different transmission strategies. The categories shall be designated in the order of their adoption. Several examples, which differ in one or more parameter values, may be given to illustrate each category of fibre. It is expected that there will be a few fibre Recommendations, each containing at most a few categories, with a few examples within each category, all arrived at by consensus on the part of the experts. A brief descriptor must be provided for each category and example, as well as the history of the modification of specification values and revised dates.

I.2 Guideline for conducting measurement round robins in Question 5 of ITU-T Study Group 15 (Q.5/15)

a) **Objectives**: ITU-T Q.5/15 round robins should be carried out for completing the content of the test method or fibre parameters described in the ITU-T G.65x-series of Recommendations. For example, when determining the RTM and ATM for test methods of a parameter, or when a parameter value is specified in the Recommendation, the round robin is needed. This round robin activity is different from an academic one.

b) **Coordinators**: In principle, the editor of each Recommendation should coordinate the round robin activity. The responsible editor may appoint a substitute coordinator from ITU-T Q.5/15 members.

c) **Participants**: The round robin participants are fundamentally limited to only ITU-T members. Non ITU-T members may participate only when ITU-T Q.5/15 members accept the necessity of their participation.

d) **Round robin results handling**: Round robin results should be utilized for revising the Recommendation. The coordinator can present the round robin results only when all ITU-T Q.5/15 members, or all participants in the round robin, accept the necessity of disclosure of the round robin results.

Appendix II

Optical fibre cable structures

The following ITU-T Recommendations describe the optical fibre cable structures.

Recommendation ITU-T G.978, *Characteristics of optical fibre submarine cables.*

Recommendation ITU-T L.100/L.10, *Optical fibre cables for duct and tunnel application.*

Recommendation ITU-T L.102/L.26, *Optical fibre cables for aerial application.*

Recommendation ITU-T L.430/L.28, *External additional protection for marinized terrestrial cables.*

Recommendation ITU-T L.101/L.43, *Optical fibre cables for buried application.*

Recommendation ITU-T L.106/L.58, *Optical fibre cables: Special needs for access network.*

Recommendation ITU-T L.103, *Optical fibre cables for indoor applications.*

Recommendation ITU-T L.109, *Construction of optical/metallic hybrid cables.*

Recommendation ITU-T L.104/L.87, *Small count optical fibre cables for indoor applications.*

Recommendation ITU-T L.105/L.87, *Optical fibre cables for drop applications*.

The related information on optical fibre cable structure can also be found in [ITU-T TR-OFCS] and [ITU-T TR-LSTR-OTOP].

Appendix III

Fibre optics hardware and passive components

The following ITU-T Recommendations are related to fibre optics hardware and passive components.

Recommendation ITU-T G.671, *Transmission characteristics of optical components and subsystems*.

Recommendation ITU-T L.201/L.13, *Performance requirements for passive optical nodes: Sealed closures for outdoor environments*.

Recommendation ITU-T L.432/L.30, *Markers on marinized terrestrial cables*.

Recommendation ITU-T L.401/L.31, *Optical fibre attenuators.*

Recommendation ITU-T L.402/L.36, *Single mode fibre optic connectors*.

Recommendation ITU-T L.403/L.37, *Optical branching components (non-wavelength selective).*

Recommendation ITU-T L.404, *Field mountable single-mode optical fibre connectors.*

Recommendation ITU-T L.202/L.50, *Requirements for passive optical nodes: Optical distribution frames for central office environments.*

Recommendation ITU-T L.206, *Requirements for passive optical nodes – Outdoor optical cross-connect cabinets*.

Recommendation ITU-T L.200/L.51, *Passive node elements for fibre optic networks – General principles and definitions for characterization and performance evaluation.*

Recommendation ITU-T L.433/L.54, *Splice closure for marinized terrestrial cables (MTC).*

The related information on fibre optic hardware and passive components can also be found in [ITU-T TR-OFCS] and [ITU-T TR-LSTR-OTOP].

Appendix IV

Construction and installation practices

The construction issues are given in [ITU-T TR-OFCS] and [ITU-T TR-LSTR-OTOP], and in ITU-T Handbooks entitled "Marinized terrestrial cables". The following ITU-T Recommendations are related to construction and installation practices.

Recommendation ITU-T L.152/L.38, *Use of trenchless techniques for the construction of underground infrastructures for telecommunication cable installation.*

Recommendation ITU-T L.153/L.48, *Mini-trench installation technique*.

Recommendation ITU-T L.154/L.49, *Micro-trench installation technique.*

Recommendation ITU-T L.250/L.90, *Optical access network topologies for broadband services*.

Recommendation ITU-T L.158/L.56, *Installation of optical fibre cables along railways.*

Recommendation ITU-T L.156, *Air-assisted installation of optical fibre cables*.

Recommendation ITU-T L.157/L.61, *Optical fibre cable installation by floating technique*.

Recommendation ITU-T L.258/L.63, *Safety procedures for outdoor installations*.

Recommendation ITU-T L.159/L.77, *Installation of optical fibre cables inside sewer ducts.*

Recommendation ITU-T L.107/L.78, *Optical fibre cable construction for sewer duct applications*.

Recommendation ITU-T L.108, *Optical fibre cable elements for microduct blowing-installation application.*

Recommendation ITU-T L.155, *Low impact trenching technique for FTTx networks*.

Appendix V

Status of optical fibre and cable specifications in ITU-T and IEC

V.1 Fibre specifications

The status of optical fibre specifications in ITU-T and IEC is listed in Table V.1.

Table V.1 – Status of single-mode optical fibre specifications in ITU-T and IEC

Optical fibre specification			
ITU-T		**IEC**	
Fibre category	**Recommendation**	**Fibre category**	**Document**
Single-mode optical fibre	ITU-T G.652	B-652 (ex. B1.1/ex. B1.3) single-mode fibre	IEC 60793-2-50
Dispersion-shifted single-mode optical fibre	ITU-T G.653	B-653 (ex. B2) single-mode fibre	
Cut-off shifted single-mode optical fibre	ITU-T G.654	B-654 (ex. B1.2) single-mode fibre	
Non-zero dispersion shifted single-mode optical fibre	ITU-T G.655	B-655 (ex. B4) single-mode fibre	
Non-zero dispersion shifted single-mode optical fibre for wideband optical transport	ITU-T G.656	B-656 (ex. B5) single-mode fibre	
Bending loss insensitive single-mode optical fibre	ITU-T G.657	B-657 (ex. B6) single-mode fibre	

NOTE – New fibre designations, e.g., "B-652", have been agreed at the 2016 IEC SC86A meeting. The designation found in brackets "(e.g., Bx.x)" corresponds to the description found in [IEC 60793-2-50].

The status of multimode fibre specifications in ITU-T, IEC and ISO/IEC is listed in Table V.2.

Table V.2 – Status of multimode optical fibre specifications in ITU-T, IEC and ISO/IEC

Attribute		**ITU-T**	**ISO/IEC 11801-1**				
ITU-T Recommendation and ISO/IEC designation		G.651.1	OM1	OM2	OM3	OM4	OM5
Core diameter (μm)		50	62.5	50	50	50	50
ITU-T fibre type cross-reference				ITU-T G.651.1			
IEC fibre type cross reference [IEC 60793-2-10]		A1-OM2	A1-OM1	A1-OM2	A1-OM3	A1-OM4	A1-OM5
Minimum modal bandwidth-length product for overfilled launch (MHz, km)	850 nm	500	200	500	1500	3500	3500
	1300 nm	500	500	500	500	500	500

The relationship between multimode fibre specifications and IEEE system standards is listed in Table V.3

Table V. 3 – Relationship between multimode cabled fibre performances and IEEE 802.3 Ethernet system standards

Cabled fibre type	Core diameter (μm)	Minimum over filled launch bandwidth (MHz· km) @ 850/1300 nm	1000BASE-SR	10GBASE-SR	40GBASE-SR4 and 100GBASE-SR10	100GBASE-SR4 and 400GBASE-SR16	50GBASE-SR and 200GBASE-SR4
OM1	62.5	200/500	275 m	33 m			
OM2 (ITU-T G.651.1)	50	500/500	550 m	82 m			
OM3	50	1500/500		300 m	100 m	70 m	70 m
OM4	50	3500/500		400 m	150 m	100 m	100 m
OM5	50	3500/500		400 m	150 m	100 m	100 m

V.2 Fibre cable specifications

The status of [IEC 60794.x] regarding optical cables is shown in Figure V.1.

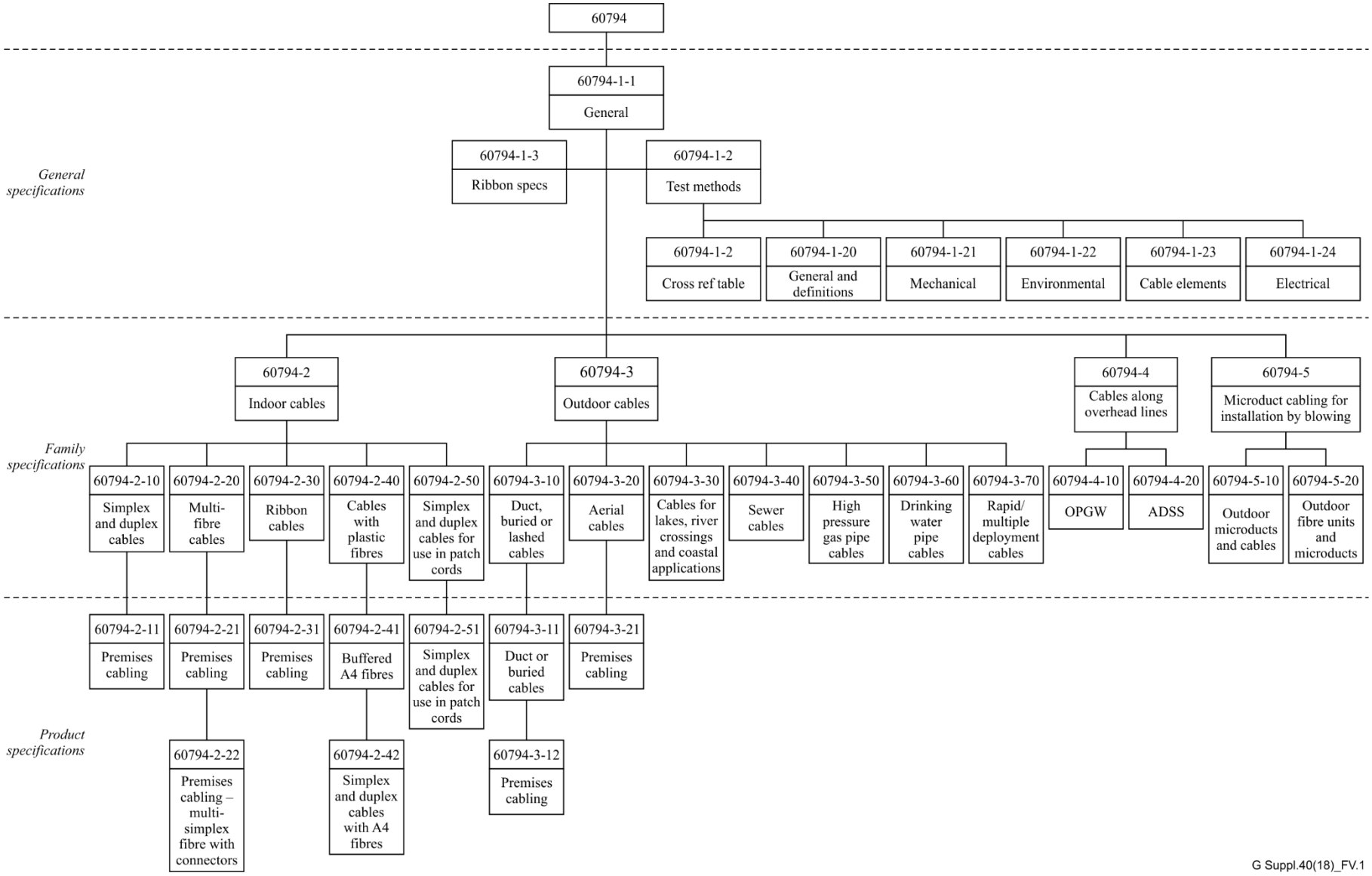

Figure V.1 – Status of [IEC 60794.x] regarding optical cables

Appendix VI

Comparison of ITU-T Recommendations and IEC documents concerning test methods

VI.1 Test methods for single-mode fibres

ITU-T Recs	Test methods		IEC documents	Test methods
[ITU-T G.650.1]			IEC 60793	
6.1	Test methods for the mode field diameter	⟺	[IEC 60793-1-45]	Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter
6.1.1	Reference test method: The far-field scan		Annex A	Far field scan
6.1.2	First alternative test method: The variable aperture technique		Annex B	Variable aperture
6.1.3	Second alternative test method: The near-field scan		Annex C	Near-field scan
6.1.4	Third alternative test method: Bidirectional backscatter difference		Annex D	Bidirectional backscatter difference
[ITU-T G.650.1]			IEC 60793	
6.2	Test methods for the cladding diameter, core concentricity error and cladding non-circularity	⟺	[IEC 60793-1-20]	Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry
6.2.1	Reference test method: The near-field image technique		Annex C	Near-field light (Gray-scale technique)
6.2.2	First alternative test method: The refracted near-field technique		Annex A	Refracted near-field
6.2.3	Second alternative test method: The side-view technique		None	
6.2.4	Third alternative test method: The transmitted near-field technique		Annex C	Near-field light (Single near-field scan technique)

ITU-T Recs	Test methods		IEC documents	Test methods
[ITU-T G.650.1]			IEC 60793	
6.3	Test methods for the cut-off wavelength	⟺	[IEC 60793-1-44]	Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength
6.3.1	Reference test method for the cut-off wavelength (λ_c) of the primary coated fibre		Annex C	Fibre cut-off wavelength λ_c
6.3.2	Reference test method for the cut-off wavelength (λ_{cc}) of the cabled fibre: The transmitted power technique		Annex B Annex A	Cabled cut-off wavelength, λ_{cc}, using cabled fibre Cabled cut-off wavelength, λ_{cc}, using uncabled fibre
[ITU-T G.650.1]			IEC 60793	
6.4	Test methods for the attenuation	⟺	[IEC 60793-1-40]	Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation
6.4.1	Reference test method: The cut-back technique		Annex A	Cut-back
6.4.2	First alternative test method: The backscattering technique		Annex C	Backscattering
6.4.3	Second alternative test method: The insertion loss technique		Annex B	Insertion loss
6.4.4	Third alternative test method: Spectral attenuation modelling		Annex D	Spectral attenuation modelling
[ITU-T G.650.1]			IEC 60793	
6.5	Test methods for the chromatic dispersion	⟺	[IEC 60793-1-42]	Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion
6.5.1	Reference test method: The phase-shift technique		Annex A	Phase shift (Annex C: Differential phase shift)
Appendix V	The interferometric technique (Informative)		None	
6.5.3	Alternative test method: The pulse delay technique		Annex B	Spectral group delay in time domain

ITU-T Recs	Test methods		IEC documents	Test methods
[ITU-T G.650.1]			IEC 60793	
6.6	Test methods for macrobend loss	⇔	[IEC 60793-1-47]	Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss
6.6.1	Reference test method: Fibre winding			Macrobending loss
None			Annex E	Parallel plate (2-point) macrobend loss approximation (Informative)
[ITU-T G.650.1]			IEC 60793	
6.6	Test methods for prooftesting	⇔	[IEC 60793-1-30]	Optical fibres – Part 1-30: Measurement methods and test procedures – Fibre prooftest
6.6.1	Reference test method: Longitudinal tension			Fibre prooftest
[ITU-T G.650.1]				
Appendix II	Test method for measuring chromatic dispersion uniformity based on the backscattering technique (Informative)	⇔	None	
[ITU-T G.650.1]				
Appendix IV	Test methods for measuring coherent MPI in short optical fibre cables (jumpers) (Informative)	⇔	None	
[ITU-T G.650.2]			IEC 60793	
6.1	Test methods for polarization mode dispersion	⇔	[IEC 60793-1-48]	Optical fibres – Part 1-48: Measurement methods and test procedures – Polarization mode dispersion
6.1.1	Reference test method: The Stokes parameter evaluation technique		Annex B	Stokes evaluation method Stokes parameter evaluation (SPE) Jones matrix eigenanalysis (JME) Poincare's sphere analysis (PSA)

ITU-T Recs	Test methods		IEC documents	Test methods
6.1.3	Second alternative test method: Interferometric method		Annex C	Interferometric method Interferometry (INTY) Traditional analysis (TINTY) General analysis (GINTY)
6.1.4	Third alternative test method: The fixed analyser technique		Annex A	Fixed analyser measurement method Fixed analyser (FA) Extrema counting (EC) Fourier transform (FT) Cosine Fourier transform (CFT)
[ITU-T G.650.2]			[IEC TR 62284]	
Appendix III	Test methods for effective area (A_{eff})	⟺	[IEC TR 62284]	Effective area measurements of single-mode optical fibres – Guidance
III.1	The far-field scan (FFS) technique		Annex A	Direct far-field method measurement specifics
III.2	The variable aperture (VA) technique		Annex B	Variable aperture in the far-field method measurement specifics
III.3	The near-field scan (NFS) technique		Annex C	Near-field method measurement specifics
[ITU-T G.650.3]				
Appendix III	Method for differentiating splice loss and macrobending loss in installed links (Informative)	⟺	None	
[ITU-T G.650.3]				
Appendix IV	Splice loss measurement using quasi-bidirectional technique (Informative)	⟺	None	

VI.2 Test methods for multimode fibres

ITU-T Recs	Test methods		IEC documents	Test methods
ITU-T G.651			IEC 60793	
6.1	Reference test method and alternative test method for geometrical and optical parameters measurements	⟺	[IEC 60793-1-20]	Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry
6.2	Reference test method for geometrical and alternative test method for numerical aperture: The refracted near-field technique		Annex A	Refracted near-field
6.3	Alternative test method for geometrical parameters: The near-field technique		Annex C	Near-field light distribution (Single near-field scan technique)
ITU-T G.651				
6.4	Reference test method for the numerical aperture: Far-field light distribution	⟺	[IEC 60793-1-43]	Optical fibres – Part 1-43: Measurement methods and test procedures – Numerical aperture
ITU-T G.651				
6.5	Reference test method and alternative test methods for attenuation measurements	⟺	[IEC 60793-1-40]	Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation
6.6	The reference test method: The cutback technique		Annex A	Cut-back
6.7	First alternative test method: The insertion loss technique		Annex B	Insertion loss
6.8	Second alternative test method: The backscattering technique		Annex C	Backscattering
ITU-T G.651				
6.9	Reference test method for baseband response measurements	⟺	[IEC 60793-1-41]	Optical fibres – Part 1-41: Measurement methods and test procedures – Bandwidth
6.10	Reference test method		Annex A	Impulse response
			Annex B	Frequency response

NOTE – Rec. ITU-T G.651 was deleted in 2008. Existing [ITU-T G.651.1] references the above IEC documents.

VI.3 Recommendation available only in ITU-T and not in IEC

[ITU-T G.650.3]	Test methods for installed single-mode optical fibre cable links

VI.4 Documents available only in IEC and not in ITU-T

[IEC 60793-1-21]	Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry
[IEC 60793-1-22]	Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement
[IEC 60793-1-31]	Optical fibres – Part 1-31: Measurement methods and test procedures – Tensile strength
[IEC 60793-1-32]	Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability
[IEC 60793-1-33]	Optical fibres – Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility
[IEC 60793-1-34]	Optical fibres – Part 1-34: Measurement methods and test procedures – Fibre curl
[IEC 60793-1-41]	Optical fibres – Part 1-41: Measurement methods and test procedures – Bandwidth
[IEC 60793-1-43]	Optical fibres – Part 1-43: Measurement methods and test procedures – Numerical aperture
[IEC 60793-1-49]	Optical fibres – Part 1-49: Measurement methods and test procedures – Differential mode delay
[IEC 60793-1-50]	Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state)
[IEC 60793-1-51]	Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat
[IEC 60793-1-52]	Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature
[IEC 60793-1-53]	Optical fibres – Part 1-53: Measurement methods and test procedures – Water immersion
[IEC 60793-1-54]	Optical fibres – Part 1-54: Measurement methods and test procedures – Gamma irradiation
[IEC 60794-1-21]	Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical tests methods
[IEC 60794-1-22]	Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental tests methods
[IEC 60794-1-23]	Optical fibre cables – Part 1-23: Generic specification – Basic optical cable test procedures – Cable elements tests methods
[IEC 60794-1-24]	Optical fibre cables – Part 1-24: Generic specification – Basic optical cable test procedures – Electrical tests methods
[IEC TR 62000]	Single-mode fibre compatibility guidelines
[IEC TR 62221]	Optical fibres – Measurement methods – Microbending sensitivity
[IEC TR 62283]	Optical fibres – Guidance for nuclear radiation tests
[IEC TR 62284]	Effective area measurements of single-mode optical fibres – Guidance
[IEC TR 62285]	Application guide for non-linear coefficient measuring methods
[IEC TR 62316]	Guidance for the integration of OTDR backscattering traces
[IEC TR 62324]	Single-mode optical fibres – Raman gain efficiency measurement using continuous wave method – Guidance
[IEC TR 62349]	Guidance for polarization crosstalk measurement of optical fibre
[IEC TS 62033]	Attenuation uniformity in optical fibres

Appendix VII

Examples of cable cut-off wavelength (λ_{cc}) measurement on cabled/uncabled single-mode fibres

VII.1 Introduction

This appendix describes examples of the cable cut-off wavelength (λ_{cc}) measurement on cabled/uncabled single-mode fibres on five types of fibre subcategories and two kinds of cable designs.

It should be noted that the following results are not applicable for arbitral fibre/cable designs, considering that the λ_{cc} value differs among fibre/cable products, and that the λ_{cc} values between uncabled and cabled fibre widely differ depending on the cabling process and cable design.

VII.2 Experiment design

In this appendix, the results using two types of optical fibre cables were summarized. The cross-sectional images of the cables are shown in Figure VII.1.

Cable A is a typical stranded loose tube outdoor cable. It consists of five buffer tubes, each with six fibres inside. Each tube includes ITU-T G.652.D/ G.654.E/G.655.D/G.657.A1/G.657.A2/G.657.B3 fibres.

Cable B is a typical indoor cable with four tight buffered fibres inside. It consists of two ITU-T G.652.D fibres and two ITU-T G.657.B3 fibres.

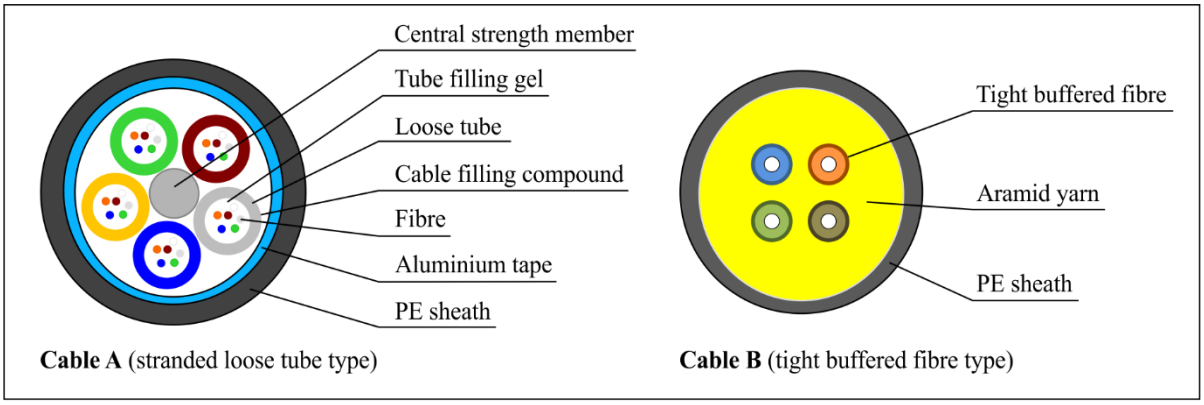

Figure VII.1 – Structure of cable samples: Cable A, 30-fibres stranded loose tube outdoor cable; Cable B, 4-fibres indoor cable

For each fibre type, one longer length (about 5 km) mother spool fibre should be selected. The mother spool fibre should be cut into several short length spools to ensure that the fibres under test in this experiment have better uniformity of cut-off wavelength.

During cabling, the bottom end and top end of each progress is recorded. It should be ensured that the measurements are based on the same end of the fibre/cable. The 22 meters cut-off wavelength should be tested as follows:

– First measurement: After the fibre has been cut from the mother spool, before cabling (22 m uncabled fibre);

– Second measurement: After cabling (22 m cabled fibre).

The experimental procedure is shown in Figure VII.2.

The test method is based on clause 6.3.2 of [ITU-T G.650.1], and the sample deployment conditions refer to Figures 11 and 12 of the same Recommendation. Multimode fibre reference has been used.

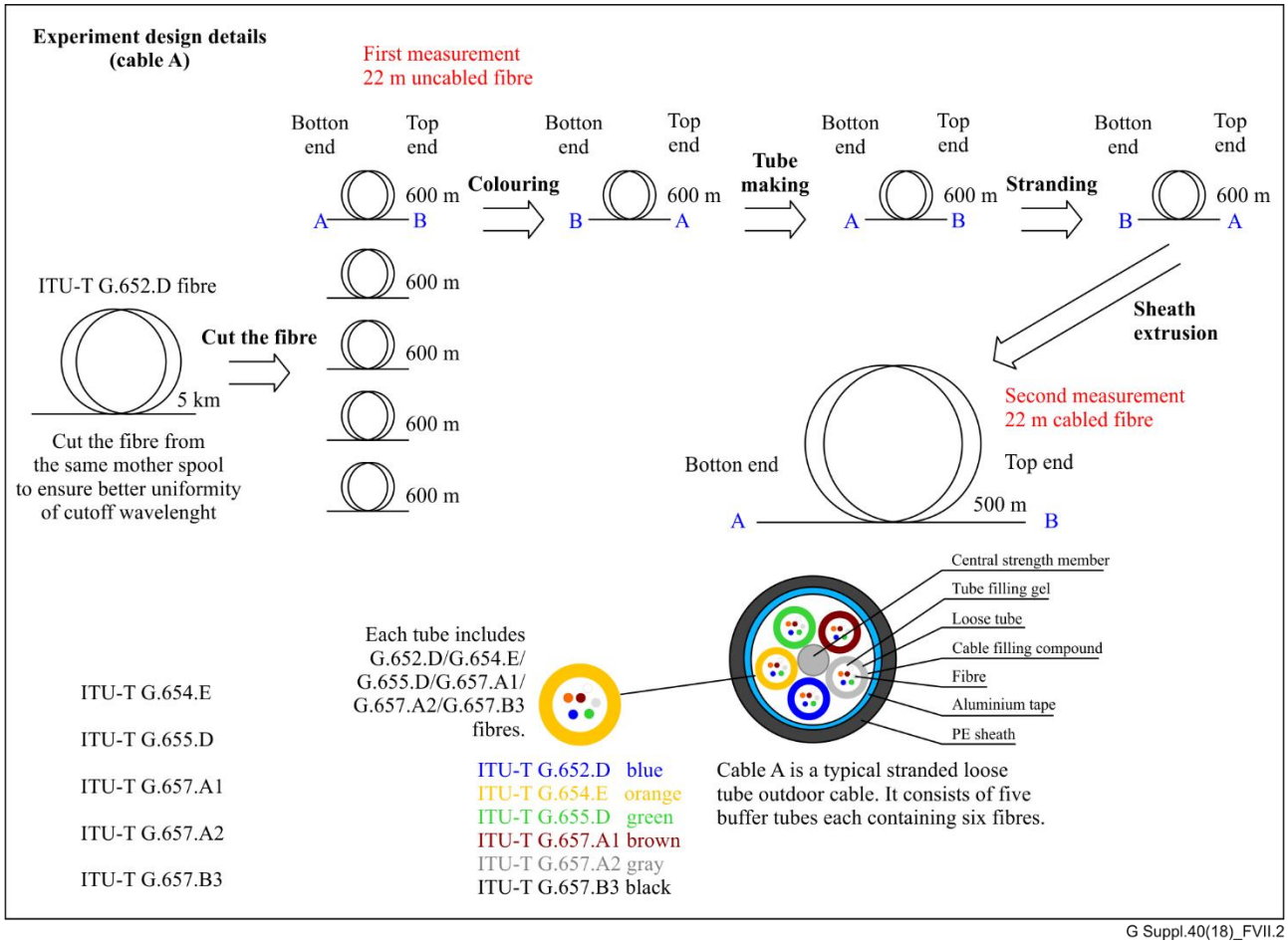

Figure VII.2 – Experiment design details of Cable A

VII.3 Measurement data and analysis

The measurement data are summarized in Table VII.1.

Table VII.1 – Test raw data of λ_{cc} on cabled/uncabled fibres (Cable A, stranded loose tube type)

Fibre type	Tube color	1st measurement	2nd measurement
		uncabled fibre nm	cabled fibre nm
ITU-T G.652.D	Blue	1156	1124
	Orange	1151	1129
	Green	1157	1125
	Brown	1158	1125
	Gray	1160	1127
	Average	**1156**	**1126**
ITU-T G.657.A1	Blue	1215	1181
	Orange	1213	1180

Table VII.1 – Test raw data of λ_{cc} on cabled/uncabled fibres (Cable A, stranded loose tube type)

Fibre type	Tube color	1st measurement	2nd measurement
		uncabled fibre nm	cabled fibre nm
	Green	1221	1183
	Brown	1217	1184
	Gray	1223	1188
	Average	**1218**	**1183**
ITU-T G.657.A2	Blue	1218	1194
	Orange	1222	1192
	Green	1225	1193
	Brown	1223	1193
	Gray	1219	1192
	Average	**1221**	**1193**
ITU-T G.657.B3	Blue	1217	1234
	Orange	1223	1235
	Green	1229	1236
	Brown	1229	1235
	Gray	1220	1234
	Average	**1224**	**1235**
ITU-T G.654.E	Blue	1407	1307
	Orange	1407	1305
	Green	1406	1304
	Brown	1417	1302
	Gray	1407	1304
	Average	**1409**	**1304**
ITU-T G.655.D	Blue	1296	1252
	Orange	1296	1237
	Green	1307	1244
	Brown	1299	1243
	Gray	1295	1252
	Average	**1298**	**1245**

Table VII.2 – Test raw data of λ_{cc} on cabled/uncabled fibres (Cable B, tight buffered fibre type)

Fibre type	Buffer color	λ_{cc} (uncabled fibre, nm)	λ_{cc} (cabled fibre, nm)
ITU-T G.652.D	Blue	1233	1221
	Orange	1239	1226
	Average	**1236**	**1224**
ITU-T G.657.B3	Green	1251	1250
	Brown	1241	1239
	Average	**1246**	**1245**

Table VII.3 – Test result average of λ_{cc} on cabled/uncabled fibres

Cable type	Fibre type	λ_{cc} (uncabled fibre, nm)	λ_{cc} (cabled fibre, nm)	λ_{cc} difference (nm)
Cable A	G.652.D	1156	1126	−30
	G.657.A1	1218	1183	−35
	G.657.A2	1221	1193	−28
	G.657.B3	1224	1235	11
	G.654.E	1409	1304	−105
	G.655.D	1298	1245	−53
Cable B	G.652.D	1236	1224	−12
	G.657.B3	1246	1245	−1

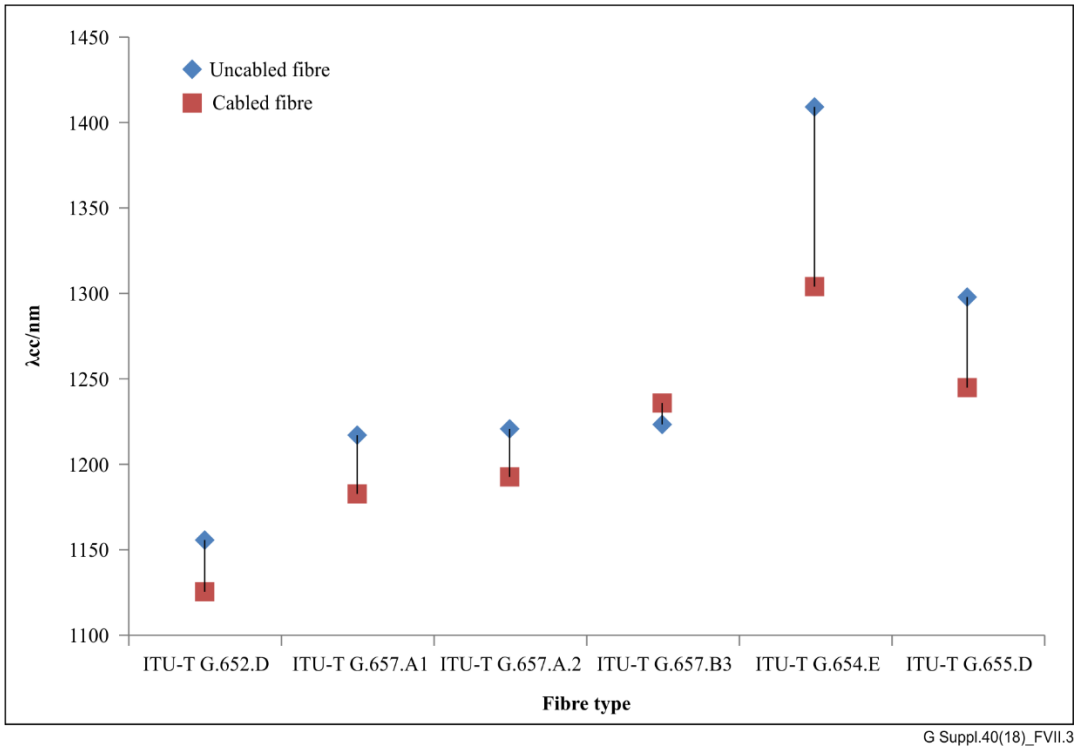

Figure VII.3 – Comparison of λ_{cc} on cabled/uncabled fibres (Cable A, stranded loose tube type)

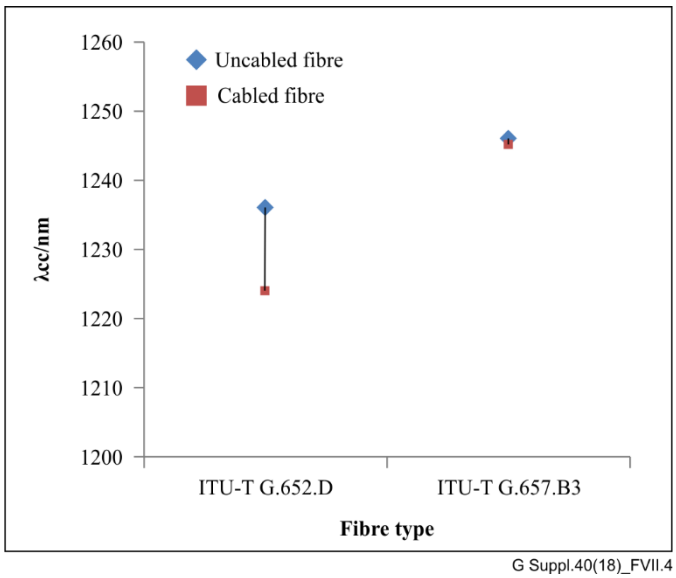

Figure VII.4 – Comparison of λ_{cc} on cabled/uncabled fibres (Cable B, tight buffered fibre type)

VII.4 Conclusion

According to the above experiment results, λ_{cc} measured with an uncabled fibre sample is generally longer than the one measured with a cabled fibre sample. The degree of the difference depends on the fibre type. For ITU-T G.657.B3 fibre sample, because of its excellent bending insensitive performance, λ_{cc} measured with an uncabled or cabled fibre sample could be very close.

This appendix presents measurement results on two cable types, with different fibre types from one fibre supplier. It should be noted that the differences between λ_{cc} measured with cabled/uncabled samples may vary on other combinations of fibre and cable designs.

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