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INTERNATIONAL STANDARD

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Standard for N times 64 kilobit per second optical fiber interfaces between teleprotection and multiplexer equipment

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Contents

STANDARD FOR N TIMES 64 KILOBIT PER SECOND OPTICAL FIBER INTERFACES BETWEEN TELEPROTECTION AND MULTIPLEXER EQUIPMENT

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The text of this standard is based on the following documents:

IEEE Std	FDIS	Report on voting
C37.94-2002	57/1258/FDIS	57/1290/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IEEE Standard for N Times 64 Kilobit Per Second Optical Fiber Interfaces Between Teleprotection and Multiplexer Equipment

Sponsor

Power System Relaying Committee
and
Power System Communications Committee
of the
IEEE Power Engineering Society

Approved 21 January 2003

American National Standards Institute

Approved 12 September 2002

IEEE-SA Standards Board

Abstract: An optical interface for use between teleprotection and digital multiplexer equipment that can operate at a data rate of N times 64 kilobit per second where N = 1, 2…12 is described. Requirements for both physical connection and the communications timing are also included.
Keywords: alarm indication signal, bit error rate, cyclic redundancy check, loss of frame, loss of signal, multimode optical fiber, multiplexer,remote defect indication, teleprotection, unit interval

IEEE Introduction

(This introduction is not part of IEEE C37.94-2002, IEEE Standard for N times 64 Kilobit per Second Optical Fiber Interfaces between Teleprotection and Multiplexer Equipment.)

Existing interface standards between teleprotection equipment and multiplexers are electrical only. These low-energy signal interfaces are susceptible to intra-substation electromagnetic interference (EMI). The use of dedicated optical fibers for the intra-substation communication links between teleprotection equipment and multiplexers eliminates the data corruption common to electrical connections.

Standard for N Times 64 Kilobit Per Second Optical Fiber Interfaces Between Teleprotection and Multiplexer Equipment

1. Overview

1.1 Scope

This standard describes the interconnection details for N, where N = 1, 2…12, times 64 kilobit per second connections of teleprotection equipment to digital multiplexers using optical fiber. Requirements for both physical connection and the communications timing are also included.

1.2 Purpose

The purpose of this standard is to allow the interconnection of different vendors' teleprotection equipment with different vendors' multiplexer equipment, without any restriction on the content of the N times 64 kilobit per second data using up to 2 km of 50 or 62.5 micrometer multimode optical fiber.

2. References

The following standard contains provisions, which through reference in this text constitute provisions of this standard. At the time of this publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this stardard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of the IEC and ISO maintain registers of currently valid International Standards.

IEC-60874-10-1 (1997-06) Connectors for optical fibres and cables– Part 10-1: Detail specification for fibre optic connector type BFOC/2.5 terminated to multimode fibre type A1.[1]

[1]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

3. Definitions and acronyms

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. *The IEEE Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition [B2] [2], should be used for terms not defined in this clause.

3.1.1 jitter: A term used to describe perturbations in the timing of data bit transitions when the frequency of the perturbations is greater than 10 Hz.

3.1.2 multimode optical fiber: An optical fiber that has a relatively large core, in which light bounces off the walls of the core. This results in multiple signal paths through the fiber, which limits the maximum signaling rate more and more as the fiber length increases.

3.1.3 multiplexer equipment: A device that allows the transmission of a number of different signals simultaneously over a single channel or transmission facility.

3.1.4 teleprotection equipment: Equipment that provides the interface between the protective relay and a communications circuit.

3.1.5 unit interval (UI): Time duration equal to the reciprocal of the bit rate.

3.1.6 wander: A term used to describe perturbations in the timing of data bit transitions when the frequency of the perturbations is less than 10 Hz.

3.2 Acronyms

BER	bit error rate
CRC	cyclic redundancy check
LOS	loss of signal
LOF	loss of frame
ppm	parts per million
RDI	remote defect indication

4. Frame structure

The frame structure is designed to allow the passage of information in packet format from the multiplexer to the teleprotection equipment and from the teleprotection to the multiplexer equipment. The format was chosen so:

a) The frame is a valid International Telecommunications Union (ITU-T) recommendation G.704 pattern from the standpoint of framing and data rate. However, the data structure is not a standard data format.
b) The bit pattern would have approximately equal ones and zeroes (for transmission through ac-coupled optical circuits).
c) The frame would have an easily detected bit pattern for frame synchronization.
d) The frame structure is identical in both directions. The frame is the same size and format regardless of the number of 64 kilobit per second timeslots being utilized.

[2]The numbers in brackets correspond to those in the bibliography in Annex C.

The frame is 256 bits and is repeated at a frame rate of 8000 Hz.

The resultant bit rate is 2048 kilobit per second.

The frame consists of three sections: the header, the overhead data, and the channel data arranged as shown in Figure 1.

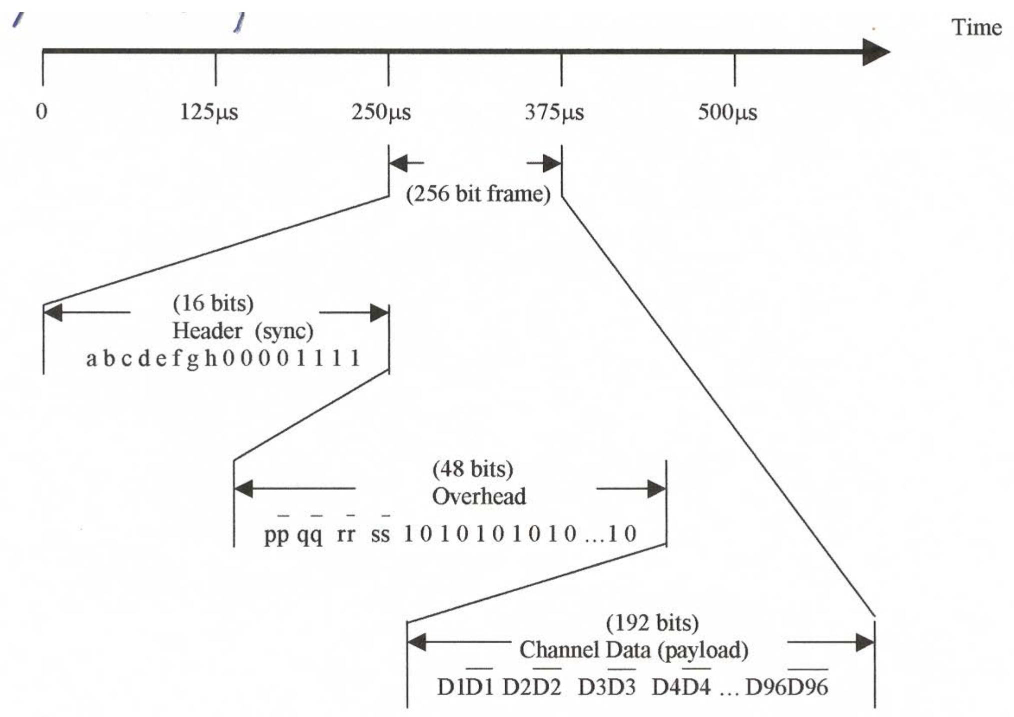

Figure 1—Frame structure

4.1 Header

The 16-bit header is a unique bit pattern to allow the receiver to synchronize to the 256-bit frame. The header is 16 bits with the following format.

a b c d e f g h 0 0 0 0 1 1 1 1

The first eight bits a, b, c, d, e, f, g, h form one of two patterns that alternate with every other frame. This is done to ensure compliance with ITU-T recommendation G.704.

The two patterns are:

Pattern 1: a b c d e f g h = 1 0 0 1 1 0 1 1
Pattern 2: a b c d e f g h = 1 1 y 1 1 1 1 1
y = Yellow Alarm bit
= 0 for normal;
= 1 if receiving bad signal (LOS declared)

The second eight bits are 0 0 0 0 1 1 1 1 in every frame
The receiver shall acquire frame sync by pattern matching to 1 1 0 0 0 0 1 1 1 1

4.2 Overhead data

This 48-bit section includes bits for providing information between the multiplexer and teleprotection equipment. Each data bit is followed by its complement (for 24 actual bits of information). The data currently assigned comprise:

Data bit	Definition
p,q,r,s	One or zero data that depend upon the value of N used, where N = 1 to 12. (p = most-significant-bit) e.g., 0,0,0,1 for N = 1 0,0,1,0 for N = 2 1,1,0,0, for N = 12

4.3 Channel data

This 192-bit section comprises 96 data bits, with each data bit followed by its complement.

The first N times 8 data bits carry the N times 64 kilobit per second (kbit/s) data.

The remaining 96 – (N times 8) data bits are set to 1.

4.4 Path frame alignment

Note that the standard does not require multiplexer equipment to provide end-to-end frame alignments; i.e., there is no requirement that a frame's first data bit D1 at the source site appears as a frame's first data bit D1 at the destination site.

5. Communication failure scenarios

5.1 Loss of signal (LOS)

It is important that a low-level signal (e.g., from a deteriorating optical fiber) does not result in garbled data for more than a few milliseconds.

The receiver shall declare LOS within 1 ms after receiving two or more errors in eight consecutive framing patterns.

The receiver shall clear LOS upon receiving eight consecutive correct framing patterns.

5.2 Signal failure actions

During LOS condition at its optical receive port, the teleprotection equipment shall:

Change the "Yellow" bit in the transmitted optical output frames from "0" to "1".

During LOS condition at its optical receive port, the multiplexer shall:

Replace the data bits over the higher order communications link with "All Ones," which is commonly referred to as Alarm Indication Signal or AIS.

Change the "Yellow" bit in the transmitted optical output frames from "0" to "1".

During the loss of the higher order communications link, the multiplexer shall:

Replace the data bits in the transmitted optical output frames with "All Ones."

5.3 Path "yellow" detection

The receiver shall declare Path "Yellow" (Far-end in alarm):

When three consecutive received frames have the "Yellow" bit = 1
AND the received signal is OK (no LOS).
(however the received data timing may be free-running, at ±100 ppm)

The receiver shall clear Path "Yellow":

When three consecutive received frames have the "Yellow" bit = 0
OR the received signal is bad (LOS).

5.4 Link failure response

Figure 2, Figure 3, and Figure 4 illustrate the signals generated in the three possible link failure modes. Dashes indicate resultant signals. X indicates failure locations.

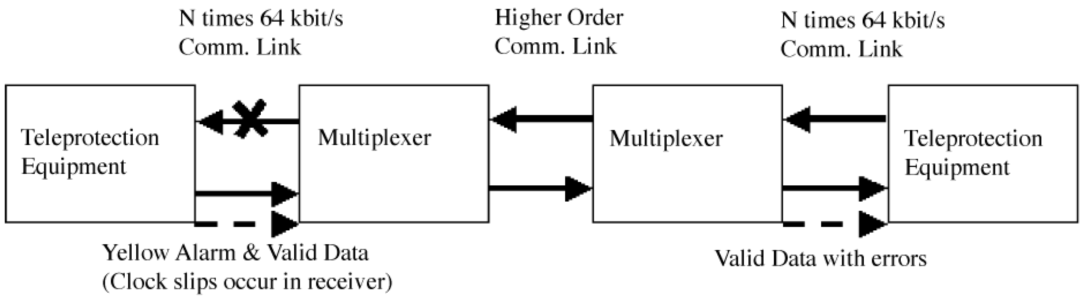

Figure 2—Multiplexer to teleprotection communication link failure

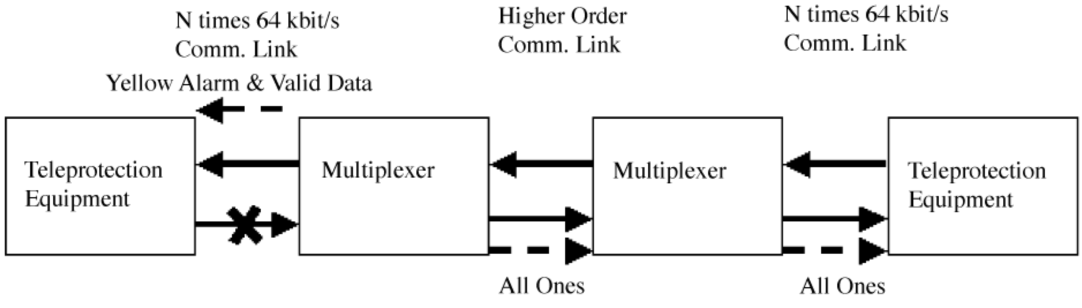

Figure 3—Teleprotection to multiplexer communication link failure

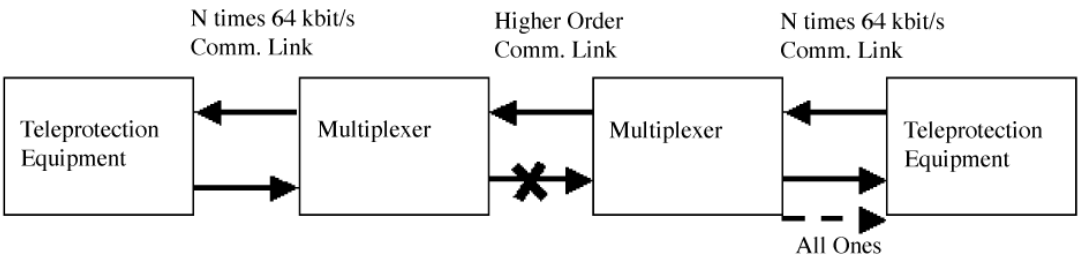

Figure 4—Higher order communication link failure

6. Clock timing

The optical signal comprises a binary (on-off) modulation with a 2048 kilobit per second bit stream with the following timing requirements.

6.1 Frequency

The frequency shall be 2048 kilobits per second ±100 ppm.

Each multiplexer end unit shall not use the signal from the teleprotection equipment for synchronization.

Each teleprotection equipment end unit shall use the signal from the multiplexer unit for synchronization; upon LOS, the unit shall free-run with the above tolerance.

Each multiplexer end unit shall be able to detect the overhead "yellow" bit correctly, even when the multiplexer end unit has lost synchronization (due to loss of optical input).

For clarification, the above requires that

a) The multiplexer unit normally receives data from the teleprotection equipment, at the same frequency as the multiplexer unit's outgoing data, but during the failure of the outgoing fiber, the multiplexer unit must accept incoming data up to ±100 ppm off frequency (detect framing, the overhead bits, and the data bits). It is acknowledged that being asynchronous to the multiplexer will cause bits to be lost, or filled (as in an asynchronous 64 kbit/s G.703 interface), but this is considered preferable to squelching the data.
b) The teleprotection equipment shall be able to receive signals with up to ±100 ppm frequency tolerance on its optical input, and use this for the frequency of its outgoing signal to the multiplexer. If its input is bad, or lost, the teleprotection equipment shall use an internal reference with ±100 ppm tolerance.

6.2 Jitter

For the multiplexer unit output, the jitter shall be within ±50 nanoseconds (±0.1 UI).

For the teleprotection equipment output, the jitter shall be within ±100 nanoseconds (±0.2 UI).
(This allows its clock recovery circuit to add ±50 nanoseconds to the jitter it receives.)

The multiplexer unit's receiver shall tolerate a jitter of ±100 nanoseconds.

For clarification, the above requires that if the data are observed on an oscilloscope triggered on either rising or falling transitions, the next transition should be at a minimum of 438 nanoseconds for the multiplexer unit output and a minimum of 388 to 438 nanoseconds for the teleprotection equipment output (depending on the jitter on its input data).

6.3 Wander

The multiplexer unit shall be able to operate with any roundtrip delay with a maximum wander of ±250 nanoseconds (±0.5 UI) peak-to-peak.

7. Optical transmitter output

7.1 Level

The mean optical power into 50 µm fiber shall be > –23.0 dBm and < –11.0 dBm.

The mean optical power into 62.5 µm fiber shall be > –19.0 dBm and < –11.0 dBm.

The data format is light "ON" for logic "1" bits.

The optical power for logic "0" bits shall be <10% of the level for logic "1" bits.

7.2 Wavelength

The center emission wavelength shall be 830 ±40 nm.

8. Optical receiver sensitivity

8.1 Operating range

The receiver shall operate error-free (BER <1E –9) for mean optical power between –32 dBm and –11 dBm.

9. Optical connectors

"BFOC/2.5" optical connectors shall be used.[3]

[3]The following information is given for the convenience of users of this standard and does not constitute an endorsement by the IEEE of these products. BFOC/2.5 is the correct generic term for the fiber optic connector commonly known as ST™. ST is a registered trademark of AT&T.

Annex A

(informative)

Fiber optics

A.1 Connectors

The optical connector specified is the BFOC/2.5 type, which is a bayonet style as shown in Figure A.1 with characteristics shown in Table A.1.

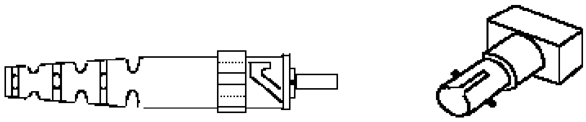

Figure A.1—Male and female BFOC/ 2.5 connector

Table A.1—BFOC/ 2.5 connector characteristics

Connector	BFOC/ 2.5
Typical loss	0.3 dB
Number of reconnects for <0.3 dB loss	1000
Temperature stability (-40 °C to 75 °C)	<0.3 dB increase
Axial load, nominal	35 lb

A.2 Fiber type

The optical fiber links between the teleprotection and multiplexer equipment shall be multimode glass fiber. Glass multimode optical fiber generally has an active core diameter of 50 or 62.5 µm compared to 9 µm of single-mode fibers. This allows easier coupling of optical fiber for intra-substation installations.

The following table shows typical specific actions for the attenuation.

Table A.2—Optical fiber characteristics

Optical fiber core size (micrometers)	Multimde fiber type	Typical attenuation at 790/820/850 nm (dB/km)	Max attenuation at 790/820/850 nm (dB/km)
50 µm	Graded- index	3.3/2.8/2.4	3.5/3.0/2.5
62.5 µm	Graded- index	3.5/3.1/2.7	4.0/3.4/3.0

A.3 Optical budget

From the optical power levels specified in 7.1 and 8.1, and using data from commonly available optical fiber (see A.2), the typical and worst-case link budgets for 2 km paths can be calculated with the following results in Table A.3.

Table A.3—Optical budget

Optical fiber core size	Optical budget (from 7.1, 8.1)	2 km fiber 820 nm typical attenuation	2 km fiber 790 nm maximum attenuation
50 µm	9.0 dB	5.6 dB (margin = 3.4 dB)	7.0 dB (margin = 2.0 dB)
62.5 µm	13.0 dB	6.2 dB (margin = 6.8 dB)	8.0 dB (margin = 5.0 dB)

NOTE—Connector losses (typically 0.3 dB per connector) have not been included here.

These figures show that 2 km is achievable for both 50 µm and 62.5 µm fibers.

Annex B

(informative)

Harmonization with other standards

B.1 Harmonization with IEC standards and ITU recommendations

B.1.1 Introduction

As far as could be determined by the working group, there was no suitable IEC standard, or work toward such a standard; however, there were some ITU recommendations that have been considered.

B.1.2 ITU G.704 recommendation for Frame Structure

ITU G.704 section 2.3 [B4] specifies a recommended frame structure for 2048 kbit/s interfaces.

Comments:

This document is compliant with G.704, specifically including the use of bit #3 in the non-frame-alignment section of the header for RDI or “Yellow” bit.

The “CRC-4” and “Synchronization Status Messages” options of G.704 are not mandatory and are not supported in this standard.

B.1.3 ITU G.706 recommendation for loss of frame (LOF)

ITU G.706 section 4.1.1 [B5] recommends “Frame alignment will be assumed to have been lost when three consecutive incorrect frame alignment signals have been received,” and it recommends a variety of algorithms for recovery.

Comments:

This IEEE standard uses only the one term “LOS” to denote Loss of Signal, whether due to a low or no received power level, or due to a bad data pattern caused by some electronic failure.

LOS is declared upon receiving two or more errors in eight consecutive framing patterns, and cleared upon receiving eight consecutive correct framing patterns.

These algorithms are simpler to implement, and clearer to understand, than those for LOF in G.706.

B.1.4 ITU G.775 recommendation for LOS

ITU G.775 section 4.2 [B6] specifies recommended algorithms for declaring “LOS” condition.

> LOS for 2048 kbit/s interfaces, is declared when the received signal power has dropped below a level “Q” for between 10 and 255 UI.

> LOS for 2048 kbit/s interfaces, is cleared when the received signal power has risen above a level "P" for between 10 and 255 UI.
>
> Table 1 specifies "Q" to be 35 dB below nominal.
>
> Figure 1 specifies "Q" to be the maximum expected cross-talk level.
>
> Table 1 specifies "P" to be 9 dB below nominal.
>
> Figure 1 specifies "P" to be 3 dB below [nominal + maximum cable loss].

The G.773 Appendix 1 also notes a prior LOS algorithm in use:

> An absence of signal transitions on the incoming signal for a period of 5 µm to 1 ms.

Comments:

This IEEE standard uses the absence of a correct framing pattern to declare LOS.

LOS is declared upon receiving two or more errors in eight consecutive framing patterns, and cleared upon receiving eight consecutive correct framing patterns.

These algorithms are simpler to implement, and clearer to understand, than those for LOS in G.775; they are also more appropriate in view of the more robust framing pattern used, and the failure mode of fiber versus copper cables.

B.1.5 ITU G.775 recommendation for RDI

ITU G.775 section 6.2 [B6] specifies recommended algorithms for RDI condition.

> An RDI defect at 2048 kbit/s path termination functions is detected when the incoming signal has the "Remote alarm indication" bit set to binary ONE ("1") for z consecutive double frame periods, where z = 2.5. z is not provisional.
>
> The RDI defect is cleared when the incoming signal has the "Remote alarm indication" bit set to binary ZERO ("0") for z consecutive double frame periods.

Comments:

This IEEE standard continues the use of a path "Yellow" terminology instead of the recently introduced term "RDI" to denote a far-end alarm status.

The algorithm specified complies with this G.775 recommendation.

Annex C

(informative)

Bibliography

[B1] Bean, David M., "Fiber Selection Guide for Premises Networks", WP 1160 issued 5-98, Corning White Paper.

[B2] IEEE 100™, The IEEE Athoritative Dictionary of IEEE Standards Terms, Seventh Edition.[4, 5]

[B3] IEC-60793-2-10 (2002-03) Optical fibres - Part 2-10: Product specifications–Sectional specification for category A1 multimode fibres.

[B4] International Telecommunications Union (ITU-T) recommendation G.704, Section 2.3, Recommendation for Frame Structure.[6]

[B5] International Telecommunications Union (ITU-T) recommendation G.706, Section 4.1.1, Recommendation for Loss of Frame.

[B6] International Telecommunications Union (ITU-T) recommendation G.775, Section 4.2, Recommendation for Loss of Signal and Section 6.2, Recommendation for Remote Defect Indication.

[B7] International Standards Organization/ International Electrotechnical Commission ISO/IEC 11801 1995+A1: 1999+A2: 1999(E) Edition 2.1 2000-01 Information Technology – Generic cabling for customer premises.

[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[5]The IEEE standards or products referred to in Annex B are trademarks belonging to the Institute of Electrical and Electronic Engineers, Inc.

[6]ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (http://www.itu.int/).

Annex D

(informative)

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