

RECOMMENDATION ITU-R BT.1367*

Serial digital fibre transmission system for signals Conforming to Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120

(Question ITU-R 42/6)

(1998)

The ITU Radiocommunication Assembly,

considering

- a) that the development of digital production facilities has resulted in the increasing use of serial digital interfaces;
- b) that a worldwide compatible digital approach will permit the development of equipment with many common features, permit operating economies and facilitate the international exchange of programmes;
- c) that to implement the above objectives, agreement has been reached on the fundamental encoding parameters of digital television for studios in the form of Recommendations ITU-R BT.601, ITU-R BT.799 and ITU-R BT.1120;
- d) that to implement the above objectives, agreement has been reached on the transmission of signals in their electrical serial digital form in the form of Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120;
- e) that in the practical implementation of Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120 it is desirable that interfaces be defined also in an optical interface form;
- f) that optical interfaces allow a higher noise immunity for the signals to be transmitted and the transmission of signals over greater distances than with electrical interfaces,

recommends

1 that where optical interfaces are required for conformity with Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120 they should be in accordance with the following description.

1 Scope

1.1 This Recommendation defines an optical fibre system for transmitting bit-serial digital signals. It is specifically intended for transmitting signals specified by Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120, (270 Mbit/s through 1.485 Gbit/s). For HDTV studio signal applications, only single-mode fibre is used as specified in Recommendation ITU-R BT.1120.

* Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2003 in accordance with Resolution ITU-R 44.

1.2 In this recommend “shall” denotes a mandatory provision of the Recommendation; “should” denotes a provision that is not mandatory; and “may” denotes features included at the option of the designer whose incorporation makes the system performance, cost, and/or convenience of installation more attractive to the user.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Recommendation:

- Recommendation ITU-R BT.656;
- Recommendation ITU-R BT.799;
- Recommendation ITU-R BT.1120;
- IEC 169-8 (1978), Part 8: R.F. Coaxial Connectors with Inner Diameter of Outer Conductor 6.5 mm with Bayonet Lock – Characteristic Impedance 50 Ohms (Type BNC) and Appendix A (1993), Information for Interface Dimensions of 75-Ohm Characteristic Impedance Connectors with Unspecified Reflection Factors;
- IEC 874-7 (1990), Part 7: Fibre Optic Connector Type SC/PC;
- ANSI/EIA/TIA-455-107-1989 (Factory Testing), Return Loss for Fibre Optic Components;
- ANSI/EIA/TIA-455-108-1989 (Field Testing), Return Loss for Fibre Optic Components;
- ANSI/EIA/TIA-492AAAA-1989, Detail Specifications for 62.5 um Core Diameter, 125 um Cladding Diameter, Class Ia Multimode, Graded-index Optical Waveguide Fibres;
- ANSI/EIA/TIA-492BAAA, Detail Specifications for Class IVa Dispersion-Unshifted Single-Mode Optical Waveguide Fibres used in Communication Systems;
- ANSI/EIA/TIA-604-3-1993, (FOCIS) Fibre Optic Connector Intermateability Standards.

3 Optical transmission system specifications

(See Appendix A for definition of fibre terms.)

3.1 Transmitter and receiver units physical packaging and connectors

The transmitter (Tx) and receiver (Rx) units may be packaged either as standalone assemblies, or as a part of other television equipment. Tx/Rx electrical domain interface connectors, if required, shall be 75-ohm type BNC female per IEC 169-8. Tx and Rx unit optical domain connectors and their mating input and output cable sections shall be type SC/PC as per IEC 847-7.

The Tx unit light source shall be connected to its type SC/PC output optical connector via a short pigtail of single-mode fibre specified in ANSI/EIA/TIA-492BAAA, if it is not physically installed and interconnected to that connector in a receptacle (see Appendix A.1.4). A multimode fibre

pigtail per specification ANSI/EIA/TIA-492AAAA is acceptable if the Tx unit is intended exclusively for multimode link applications. The Tx unit's label shall indicate which type of pigtail, if any, is installed.

The Rx unit optical receiver shall be connected to its type SC/PC input optical connector via a short length of multimode fibre specified in ANSI/EIA/TIA-492AAAA, if it is not physically installed and interconnected to that connector in a receptacle (see Appendix A.1.4).

3.2 Transmitter unit

The transmitter unit shall produce an intensity-varying optical output signal per Table 1 when modulated by an electrical signal conforming to Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120.

3.3 Receiver unit

The receiver unit shall output an electrical signal as per Recommendations ITU-R BT.656, ITU-R BT.799 and ITU-R BT.1120 when receiving an optical signal per Table 2.

3.4 Optical fibre circuit and connector specifications

3.4.1 Optical fibre type options

Either single-mode fibre or multimode fibre may be used to establish a point-to-point optical circuit between the transmitter and receiver and SC/PC optical connectors. A point-to-point circuit may consist of one or multiple serially interconnected sections of the selected type of optical fibre in cables, jumpers and/or patch cords, when assembled in accordance with ANSI/EIA/TIA-568-A (see Appendix A for definitions of terms). Mixing fibre types in the multiple sections of a point-to-point circuit is physically possible, but technically unacceptable.

NOTE – Only single-mode fibre is allowed for HDTV studio signals as specified ITU-R BT.1120.

3.4.1.1 Single-mode optical fibre shall comply with ANSI/EIA/TIA-492BAAA (class IVa dispersion-unshifted, 9/125 micron step index [SI] fibre), and have a maximum attenuation of 1.0 dB per kilometre at 1 310 nm.

3.4.1.2 Multimode optical fibre shall comply with ANSI/EIA/TIA-492AAAA (62.5/125 micron graded index [GI] fibre), and have a maximum attenuation of 1.5 dB per kilometre at 1 310 nm.

3.4.1.3 The system designer may elect to use already-installed 50/125 micron graded-index fibre circuits. This choice will result in a loss budget reduction of approximately 3 dB over values calculated for 62.5/125 micron fibre circuits.

TABLE 1

Optical transmitter output signal specifications

Transmission circuit fibre	Single mode (multimode optional)	multimode (62.5/125 μm) ¹
Light source type	Laser	Laser or LED ^{2,3}
Optical wavelength	1 310 nm \pm 40 nm	1 310 nm \pm 40 nm
Maximum spectral line width between half-power points	10 nm	30 nm
Maximum power output	-7.5 dBm	-7.5 dBm
Minimum power output	-12 dBm	-12 dBm
Extinction ratio	5:1 minimum, 30:1 maximum	5:1 minimum
Rise and fall times	see Note 4	see Note 4
Jitter	see Note 4	see Note 4
Maximum reflected power	4%	4%
Electrical/optical transfer function	Logic "1" maximum intensity Logic "0" minimum intensity	

NOTE 1 – See § 3.4.1.3 for optional multimode fibre type.

NOTE 2 – LEDs may not function reliably at bit rates higher than specified in ITU-R BT.656 / ITU-R BT.799.

NOTE 3 – Tx units intended solely for multimode transmission link applications shall be so marked.

NOTE 4 – Rise/fall times and jitter for the optical interconnect are specified in each electrical signal document.

TABLE 2

Optical receiver input signal specifications

Transmission circuit fibre	Single-mode	Multimode
Maximum input power	-7.5 dBm	-7.5 dBm
Minimum input power	-20 dBm	-20 dBm
Detector damage threshold	+1 dBm minimum	-4 dBm minimum
Jitter	see Note 1	see Note 1

NOTE 1 – Jitter for the optical interconnect is specified in each electrical signal document.

3.5 Optical connector specifications (excerpted from ANSI/EIA/TIA-586-A)

3.5.1 Type (see Appendix A for definition of terms)

Telecommunications industry SC/PC optical connectors, adapters and receptacles shall be used in cables, patch cords, and/or pigtails which interconnect Tx and Rx units to the multimode or single-mode fibres comprising the first and last segments of a multiple section transmission circuit. Use of other types of connectors, adapters, and receptacles at intervening connection points is the purview of the transmission circuit designer or installer.

NOTE – On Tx/Rx optical interface design, optical transmission link manufacturers may assert compliance with this Recommendation if jumpers or physical adapters are provided to interface other terminal equipment connectors to SC/PC connectors, adapters, or receptacles.

The dimensions of simplex SC/PC connectors and adapters, to include keys and keyways, shall meet IEC 874-7 specifications. Multimode and single-mode connectors and adapters shall have these same dimensions to permit intermating the two optical fibre types through adapters. The designer shall employ an obvious and consistent practice to visually differentiate the two types. As specified in ANSI/EIA/TIA-586-A, the multimode connector and adapter may be beige and the single-mode connector and adapter blue. Alternately, text markings on the equipment may be used to specify the type of fibre to be used in the transmission circuit.

3.5.2 Return loss

Type SC/PC connectors shall have optical return losses as follows, with measurements performed at $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$, in accordance with ANSI/EIA/TIA-455-107 (factory testing) and ANSI/EIA/TIA-455-108 (field testing);

Fibre type	Minimum return loss
62.5/125 micron multimode	20 dB
8-10/125 micron single-mode	26 dB

Appendix A

Definition of optical domain transmission media and connector terms

A.1 Optical fibre and cables assemblies

A.1.1 Cables contain one or more sheathing-encased individual optical fibres, arranged in a bundle or flat ribbon configuration. Fibre counts selected for high-density cables will be the designer's choice between the need for conduit space conservation and the need for convenient optical fibre cable management.

A.1.2 Jumpers, patch cords, and fibre circuit extenders are special-purpose optical fibre cables containing one or more fibres, each enclosed in a protective sheath.

A.1.3 Hybrid optical/copper cables are assemblies of one or more multimode and/or single-mode sheathed fibres, and two or more electrically-insulated copper wires or braids. They are fabricated for use in special applications such as interconnection of camera heads and base stations. Their specifications are to be defined in a separate Recommendation.

A.1.4 Pigtails are single fibres encased in a plastic material, but not including a protective sheath. They are fabricated for installation within terminal equipment to extend a fibre circuit from an interconnection panel receptacle to an optical device located within the equipment. They shall be terminated at the interconnection panel end in a type SC/PC connector. The other end termination shall be made as recommended in relevant telecommunications industries practices.

A.2 Type SC/PC optical connection components

Type SC/PC connectors, adapters, and receptacles have evolved from three decades of fibre optic connection device development in the global telecommunications industry. The SC family was designed and first installed in 1984, and is now the preferred or specified family for all new construction among virtually all standards-setting organizations worldwide.

A.2.1 Connectors are installed at both ends of all fibres in single, duplex, or multiple fibre patch cords, and sheath-protected multifibre cables. Connectors are also installed at one end of pigtails whose other end is physically affixed to optical Tx and Rx devices located within user equipment.

A.2.2 Adapters are installed in rack- and wall-mounted patch panels in telecommunications closets and equipment rooms to intermate connector-terminated fibres. They are the optical equivalent of double-sided BNC barrels or panel-mounted adapters used to interconnect tandem lengths of coaxial cable. Adapters provide mechanical means for precisely butting together projecting fibre connector ferrules. They are used to physically established circuits consisting of serially-connected lengths of multimode and single-mode cable fibres or pigtails.

Adapters also accommodate the intermating of a single-mode light source output pigtail to a multimode transmission circuit input, and the intermating of a single-mode transmission circuit output to a multimode optical receiver input pigtail. Telecommunications industry practice allows the use of single-mode pigtails in a Tx unit to interface multimode fibre circuits. In an Rx unit, multimode pigtails may be used to receive optical signals from single-mode fibre circuits.

A.2.3 Receptacles are installed in terminal equipment to provide the interface between internally installed optical Tx and Rx devices and premises (plant) cabling circuits. A receptacle may physically compromise half of an adapter, with light sources or photo diodes physically installed in the other half. Such receptacles may be physically mounted on Tx or Rx unit PC boards. When a multimode or single-mode E/O or O/E transducer is mounted on a printed circuit board which cannot be physically located at the interface panel, interconnection to the panel receptacle is established by a pigtail (see § 3.1).

Appendix B

Optical transmission circuit design and performance options

B.1 Tx and Rx unit selection criteria

The power budget of a fibre optic transmission link is the arithmetic difference between the Table 1 optical source minimum output power and the Table 2 optical receiver maximum input power. The minimum power budget required for transmission of a signal between source and destination

equipment is the fibre's attenuation at the 1310 nm transmission wavelength, plus the sum of the measured or specified losses at all splice points and in connectors which may be as high as 1 dB per splice or connection. The system designer is advised to include a 3 dB to 6 dB contingency loss in setting up the loss budget of a long multisection circuit.

Higher costs for single-mode Tx and Rx units needed to meet a specific loss budget may be offset by the use of lower cost multimode fibre throughout the circuit. However, the "minimum fibre bandwidth" of multimode fibres (expressed as a maximum "bandwidth-kilometre" value in the fibre specification) forces the use of single-mode fibre in any circuit which may eventually be required to transport 1.3 Gbit/s to 1.5 Gbit/s HDTV signals.

B.2 Multimode and single-mode fibre transmission characteristics

The distances over which digital signals can be transmitted on multimode and single-mode fibres without errors have "cliff effect" circuit length limits caused by "modal" and "chromatic" dispersion phenomena, respectively. Multimode fibres accept multiple input light rays (modes) from the light source at maximum angles of incidence defined by the "acceptance cone" (numerical aperture – NA) of the fibre. Propagation delays of the pulse-carrying rays reflected from boundary to boundary in the core increase with distance. The cliff effect distance of multimode fibre, calculated from its "bandwidth-kilometre" rating (see above), is that distance at which the signal is no longer recoverable, because the time of arrival of pulses transported by many rays masks signal transition points or overlaps pulses from adjacent signal unit intervals.

Even the most expensive semiconductor laser light source does not emit light at a single wavelength. The single ray transmitted down the 8 to 10 micron core experiences different propagation delay at each wavelength within the 10 nm maximum spectral line width output of the laser (Table 1). The cliff effect point of single-mode fibre, many kilometres further than for multimode fibre, is that distance at which the time of arrival of pulses transported at the spectral wavelength extremes mask signal transition points, or overlap pulses from adjacent signal unit intervals.

B.3 E/O transducer digital signal processing limitation

Designers should be aware that serial digital signals, specified by the referenced ITU-R Recommendations, can contain substantial low-frequency energy. Transducers used in signal transmission must therefore, employ appropriate coupling time constants, clamping, and power-control loops. Proper performance can be verified by test transmission of the SDI checkfield signals specified in SMPTE RP 178 "1996 – Serial Digital Interface Check field for 10-Bit 4:2:2 Component and 4 fsc Composite Digital Signals" for SDTV and SMPTE RP 198 "Bit-Serial Digital Check field for Use in High-Definition Interfaces" for HDTV.

Appendix C

Laser safety information

Visible and non-visible radiation from laser diodes and LEDs used in optical fibre communications systems is considered to be a safe application of laser technology. Light output is entirely confined to the core of the interconnected fibre, and does not leak through the cladding or outer sheath. If the pigtail of an active light source is disconnected, damage to the eye is remotely possible under the most unlikely possibility that a person would look directly into the fibre at close range for an extended period of time.

Publications of the IEC provide guidance on practices to be followed in working with optical fibre communications systems. They also contain information on labelling requirements for modules containing a laser/LED light source coupled to the outside via a pigtail or optical connector.
