Serial Shortwave Very Short Reach (VSR) OC-192 Interface for Multimode Fiber

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4 Document Revision History

Version 1.0 – Draft – Baseline text based on OIF2000.70.1 [1]
Version 1.1 – Draft – Link budget for standardized fiber added. Link budget, transmitter rise time and ER, and receiver sensitivity modified slightly.
Version 1.2 – Draft – Modified author list, minor typographical corrections.
Version 2.0 – Changes due to comments from straw ballot incorporated.
Version 2.1 – Minor errors corrected in Tables 2 & 3.
Version 2.2 – Reference application models added; link budget now allows for two complete patch panels (four additional connectors).

5 Project Summary

Note: This section is removed when the document is forwarded to the TC for vote. It is used to help maintain the progress of the document. It is expected that appropriate key content from this section is contained in the Introduction.

5.1 Working Group project(s)

5.2 Working Group(s)

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6 Introduction

This technical document describes a functional low-cost shortwave serial SONET/SDH OC-192 interface for very short reach (VSR) applications.

This VSR interface utilizes a single 850 nm vertical cavity surface-emitting laser (VCSEL) for the transmitter optical element, and a single PIN PD for the receiver. This implementation integrates the serdes function and complies with the OIF 99.102 serdes requirements.

The target performance of the VSR interface is to transmit a SONET/SDH OC-192 data stream over standard multimode fiber at distances of 85 meters. New high bandwidth fiber is supported at distances of 300 meters.

This document defines the optical interface parameters required for a shortwave serial link operating over multimode fiber.

6.1 Application

The application of the OC-192 VSR interface is to interconnect co-located equipment. Due to the short distances, an alternative that is less costly than current OC-192 SR solutions is desired. Examples of equipment that is often co-located and interconnected within a central office (CO) include:

1. Routers
2. Dense Wavelength Division Multiplexers (DWDM) terminals, and
3. SONET/SDH Add-drop multiplexers (ADMs).

Shown in Figures 1 and 2 below are the two reference application models supported by this VSR. Reference application 1 is a direct intra-office connection of up to 100 meters with no patch panels. Reference application 2 is an intra-office connection of up to 300m with two patch panels.

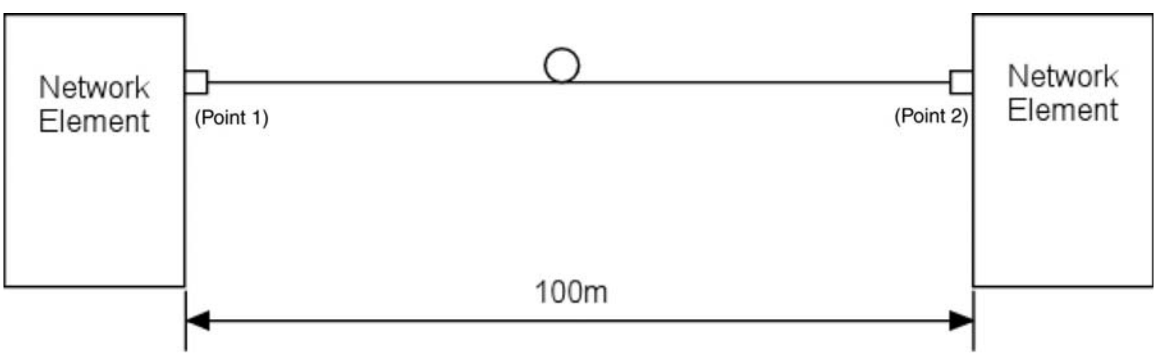

Figure 1. Reference application 1, intra-office, direct connection, 100m, no patch panels,

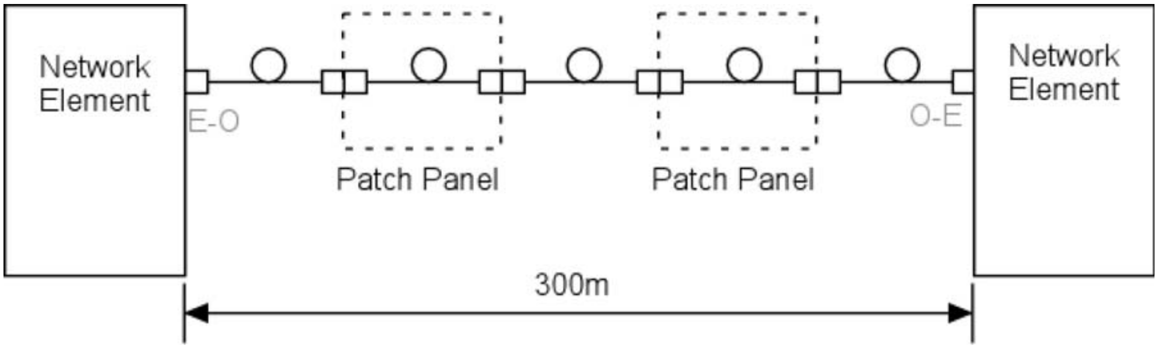

Figure 2. Reference application 2, intra-office, no PXC, 300m, with patch panels.

6.2 Functional Overview

The OC-192 VSR interface is a bi-directional interface. A functional block diagram (enclosed within the dotted line) is illustrated in Figure 3.

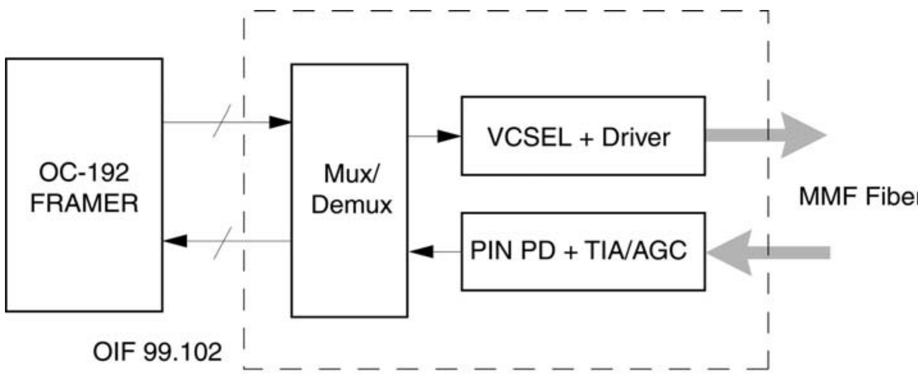

Figure 3. Functional block diagram of shortwave serial OC-192 VSR interface.

The transmit direction comprises an electrical multiplexer, laser driver, and shortwave 850nm VCSEL, whose output is coupled to a multimode fiber cable plant, operating over a distance up to 300 meters. The output of the multiplexer and VCSEL is a 9.95328 Gb/s SONET/SDH compliant data stream.

The receive direction comprises a PIN photodiode coupled to the MM fiber, whose output is amplified by a transimpedance amplifier followed by an optional post-amp stage. This signal is demultiplexed to a 16 bit wide data stream.

The framer-serdes electrical I/O interface shown in the transponder above is fully compliant with the OIF99.102.5 specification (at SERDES interface) [1]. The optical interface is described in detail in the following section.

7 Optical interface specifications

7.1 Optical interface requirements

Here we describe the optical specifications governing the receiver, transmitter and cable plant, as well as present the link budget. This link budget is based on the IEEE Gigabit Ethernet model and spreadsheet [3,4]. The output power of the transmitter meets new CDRH and IEC eye-safety standards, which means the receiver is compatible with transmitter power up to –1.3 dBm and distances up to 300m will be supported on new high-bandwidth multimode fiber.

7.1.1 Transmitter specification

The transmitter for the VSR link consists of a single directly-modulated 850 nm VCSEL. The transmitter will meet the specifications in table 1 below as well as the eye mask requirements listed in section 7.3.5.

Table 1: Transmitter specifications

Description	Value	Units
Type	Shortwave VCSEL	
Signaling speed	9.95328	GBd
Wavelength range	840 to 860	nm
Trise/Tfall (20-80%)	35	ps
RMS spectral width (max) (b)	0.35	nm
Avg. launch power (max)	see note (c)	dBm
Avg. launch power OMA (min)	360	uW
RIN OMA (max)	-125	dB/Hz
Encircled flux (min) (d)	85	%

(a) Relevant GbE model parameters: MN = 0.3 dB, MPN k factor 0.5

(b) Experimental evidence suggests larger values are supportable

(c) The lesser of class 1 eye safety limit or average receiver power (max), currently -1.3 dBm

(d) Measured in a 16 um radius in a 50 um fiber, as per TIA/EIA 455-203 (draft)

7.1.2 Receiver specification

The receiver consists of a single PIN photodiode and amplifier stages and will meet the specifications in table 2 below. The BER of the link will be 10^{-12} without forward error correction.

Table 2: Receiver specifications

Description	Value	Units
Type	PIN photodiode	
Signalling speed	9.95328	GBd
Wavelength range	840 to 860	nm
Avg. receive power (max)	-1.3	dBm
Receiver sensitivity (a)	57.0	uW
Return loss (min)	12	dB
Stressed receive sensitivity	160.0	uW

(a) BER 10-12 without FEC

(b) Relevant GbE model parameter: receiver BW 7.734 GHz

7.1.3 Link power budget and penalties

The link power budget presented in table 3 below is based on the latest IEEE Gigabit Ethernet spreadsheet [3,4] and shows the relevant parameters both for 85 meters of standard 500 MHz-km MMF and 300 meters of 2000 MHz-km MMF.

Table 3: Link power budget

Description	Value		Units
Fiber type (a)	50 um MMF	50 um MMF	
Fiber modal BW	500	2000	MHz-km
Link power budget	8.0		dB
Operating distance	85	300	m
Channel insertion loss	2.31	3.09	dB
Link power penalties	4.73	4.73	dB
Unallocated margin	0.96	0.18	dB
Maximum number of connectors	4		dB
Connector loss budget	2.0		dB

7.1.4 Jitter specification

The jitter specification for the VSR link is based on scaled GbE specifications. The compliance points for the jitter specification are illustrated above in Figure 1. Note that point 1 and point 4 in the VSR reference cabling model of figure 1 above are equivalent to TP2 and TP3 respectively in the GbE specification.

This VSR implementation will conform to the jitter specification in Table 4 below. Note that only values in the table in **bold** are normative. All other values are informative.

Table 4: Jitter budget

Compliance point	Total jitter (a) UI	Total jitter (a) ps	Deterministic jitter UI	Deterministic jitter ps
Point 1	**0.431**	**43**	0.200	20
Point 1 to point 4	*0.170*	*17*	*0.050*	*5*
Point 4	**0.510**	**51**	0.250	25

(a) Total jitter is the algebraic sum of deterministic and random jitter at that point

7.2 Optical fiber specification

This link is designed to work up to 85 meters over standardized multimode fiber with a modal bandwidth of 500 MHz-km. However, other types of MMF are also supported, including high-BW MMF, with the following modal bandwidths and distances as shown in Table 5 below.

Table 5: Supported fiber

Fiber type	Modal BW (MHz-km) *	Minimum range (meters)
50 um MMF	2000	300
50 um MMF	500	85
62.5 um MMF	160	25

** Launch conditions defined by TIA/EIA-455-203*

7.3 Measurement of the optical parameters

All measurements are to be made through a short patch cord of multimode fiber, 2-5 meters in length. Note that much of this suite of measurement techniques is closely based on the IEEE Standard 802.3, Section 38.6 [5].

7.3.1 Center wavelength and spectral width

The center wavelength and spectral width shall be measured as in ANSI/EIA/TIA-455-127-1991 under modulated conditions using a 9.95328 Gb/s PRBS data stream.

7.3.2 Optical power measurements

Optical power shall be measured as specified in ANSI/EIA-455-95-1986, with the transmitter sending a 9.95328 Gb/s PRBS data stream.

7.3.3 Extinction ratio measurements

Extinction ratio shall be measured using the methods of ANSI/TIA/EIA-526-4A-1997 under the worst-case reflection conditions, the transmitter modulated with a 995.328 MHz square wave.

7.3.4 Relative intensity noise measurements

RIN shall be measured according to the procedures of ANSI X3.230-1994 (FC-PH), Annex A [6], except that multimode fiber is to be substituted for single-mode fiber and no polarization rotator should be used. Note that RIN is referred to as RIN_{12} in the referenced document.

7.3.5 Eye mask test

The transmitter shall meet the STM-16 eye mask parameters specified in ITU-T Recommendation G.957 [7], section 6.2.5, and using a unit interval (UI) corresponding to 9.95328Gb/s.

7.3.6 Transmitter rise/fall characteristics

The rise and fall measurements shall be made on waveforms whose waveforms comply with the eye mask of section 7.3.5 above. If a filter is needed so that the waveform conforms to the mask, the rise or fall time of the filter shall be subtracted in quadrature from the measured value or rise or fall time, respectively, to arrive at the true response time. These rise and fall times are measured from the 20% and 80% excursions of the leading and falling edges respectively.

7.3.7 Stressed Receiver sensitivity measurement

The receiver shall be tested in accordance with IEEE Standard 802.3 [5], section 38.6.11, with the following modifications. The conformance test signal will be conditioned such that the duty cycle distortion (DCD) component of deterministic jitter (DJ) shall be no less than 10ps. The receiver bandwidth must be at least 20GHz and is coupled through a 14.93 GHz fourth-order Bessel-Thompson filter. The linearly-modulated laser source may be a VCSEL-based transmitter, provided the eye closure is as specified in section 38.6.11.

7.3.8 Jitter measurements

Measurements of jitter shall be done in accordance with the methods described in ANSI X3.230-1994 (FC-PH), Annex A, A.4.2 and A.4.3.

7.3.9 *Optical Modulation Amplitude (OMA)*

Optical modulation amplitude is tested in accordance with T11/00-020v4 dpANS – Fibre Channel - Physical Interface, Rev 6.6, Annex A.5

8 Summary

We have presented a shortwave serial physical layer implementation for the VSR application, operating over 85 meters of standard multimode fiber and 300 meters of new high bandwidth multimode fiber.

9 References

1. OIF2000.070.1 “VCSEL Serial VSR Proposal – Task Group Report,” Optical Internetworking Forum – Physical Link Layer Working Group, May 2000.
2. OIF1999.102.6 “SFI-4 Common electrical interface between frames and serializer/deserializer parts for STS-192/STM-64 interfaces,” Optical Internetworking Forum – Physical Link Layer Working Group, May 2000.
3. "The Gigabit Ethernet Optical Link Model", Chapter 9, Gigabit Ethernet Networking, D. Cunningham, W. Lane, Macmillan Technical Publishing, 1999. ISBN: 1-57870-062-0.
4. IEEE P802.3ae 10Gb/s Ethernet Task Force document http://www.ieee802.org/3/10G_study/public/email_attach/3pmd046.xls
5. IEEE 802.3 Information Technology, Part 3: "Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications"
6. ANSI X.230-1994 “Fibre Channel – Physical and Signaling Interface (FC-PH),” American National Standards Institute, 1994.
7. ITU-T G.957 (6/99) “Optical interfaces for equipments and systems relating to the synchronous digital hierarchy”

10 Appendix A: Glossary

11 Appendix B: Open Issues / current work items

12 Appendix C: List of companies belonging to OIF when document was approved

Accelerant Networks
Accelight Networks
Acorn Networks
AdventNet
Aerie Networks
Agilent Technologies
Agility Communications
Alcatel
Algety Telecom
Alidian Networks
All Optical Networks, Inc.

Allegro Networks
Altera
Alvesta Corporation
Amber Networks
AMCC
Amkor Technology
Ample Communications
Analog Devices
ANDO Corporation
AON Networks
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Applied Innovation
Aralight
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Axiowave Networks
Axsun Technologies
Bandwidth9
Bay Microsystems
Bellsouth Telecommunications
Big Bear Networks
Blaze Network Products
Bravida Corp
BrightLink Networks
Broadcom
BT
Cable & Wireless
Calient Networks
Calix Networks
Caspian Networks
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Computer & Communications Research Labs
Conexant
ConnectCom MicroSystems
Continuum Networks
Coriolis Networks
Corning Incorporated
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Entridia
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ETRI
Extreme Networks
Ezchip
Fast-Chip
FCI
Finisar Corporation
Force 10 Networks
Foundry Networks
Fujikura
Fujitsu
Fujitsu
Furukawa Electric Technologies
G2 Networks
Gazillion Bits
Gemfire
General Dynamics
Genoa
Glimmerglass Networks

Global Crossing North American Networks
Gore & Associates
Gotham Networks
Gtran
GTS Network Services
Helix AG
Hi/fn
Hitachi
Honeywell
Huawei Technologies
Hyperchip
IBM Corporation
Ilotron
Infineon Technologies
Information Management Systems
Informed Diagnostics Inc.
Innovance Networks
Inphi
Integral Access
Intel
Internet Machines
Iolon
IPOptical
Iris Labs
Ironbridge Networks
Jasmine Networks
JDS Uniphase
Jedai Broadband Networks
Jennic
Juniper Networks
KDD R&D Laboratories
KereniX
Kestrel Solutions
Korea Telecom
Kromos Technology
Lambda Crossing
LANCAST
Lara Networks, Inc.
Laurel Networks
Level 3 Communications
LightLogic
LSI Logic
Lucent Technologies
Luminous Networks
Luxcore
LuxN
LYNX - Photonic Networks
Mahi Networks
Maple Optical Systems

Marconi Communications
Mayan Networks
Memlink
Metro-OptiX
MicroOptical Devices
Mintera
Mitel Corporation
Mitsubishi Electric Corporation
Multilink Technology Corporation
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Nayna Networks
NEC
NEL America, Inc.
Net Insight
Net-Hopper Systems
NetPlane
Network Associates
Network Elements
Network Photonics
New Focus
NewPort Communications
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Nortel Networks
nSerial
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ON Semiconductor
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ONI Systems
Opthos
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Opticalwave Networks
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PicoLight
Pine Photonics Communications
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Point Reyes Networks
Princeton Networks
Procket Networks
Quake Technologies
Quantum Bridge
Redback Networks
Redfern Broadband Networks
Reversi Networks
RHK
Sandia National Laboratories
Santec Corporation
Scientific Atlanta
SDL
Seneca Networks
Siemens
Silicon Access
SITA Equant
Solidum Systems Corporation
Solinet Systems
Sorrento Networks
SpectraSwitch
Sphera Optical Networks
Spirent Communications
Sprint
Stratos Lightwave
Sumitomo Electric Industries
Sycamore Networks
Syntera Communications
T-Networks, Inc.
TDK Semiconductor
Tektronix
Telcordia Technologies
TELE-WORX
Tellabs
Tellium
Tenor Networks
TeraBeam Networks
TeraBurst Networks
TeraOp
Terawave Communications
Texas Instruments
Toshiba Corporation

Transparent Optical
TranSwitch Corporation
Trellis Photonics
TriQuint Semiconductor
Turin Networks
TyCom
US Conec
Valiant Networks
Vectron International
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Versanetworks
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